MERCURY PROJECT SOLUTIONS

Implications of a Dynamic Datum on the Cadastre

Final Report

v1.3 - 10 September 2018

Document Approval:

Project Manager	Executive Sponsor
Signed Date	Signed Date

Document Control

Version	Primary Author(s)	Description	Date Completed
0.1	Maurits van der Vlugt	Initial draft for internal discussion	12 June 2018
0.2	Maurits van der Vlugt	First complete draft for review	14 June 2018
1.0	Maurits van der Vlugt	Final draft for PMG	28 June 2018
1.2	Maurits van der Vlugt	Final report for approval	10 August 2018
1.3	Maurits van der Vlugt	Final approved version	10 September 2018

Document Location

/Users/Shared/Dropbox/Maurits MPS/CRCSI Dynamic Datum - MPS Working/Final report/CRCSI3.20 Final Report v1.3.docx

Distribution

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Executive Summary

Background

A cadastre is normally a parcel based, and up-to-date land information system containing a record of interests in land (e.g. rights, restrictions and responsibilities). A digital cadastre is a database of cadastral survey data relating to cadastral boundaries within a jurisdiction. The digital cadastre is also often referred to as the Digital Cadastral Database (DCDB).

Increasing user expectations regarding cadastral data accuracy, combined with improving accuracy of consumer-grade GNSS devices, put ubiquitous, sub-decimetre positioning capabilities in the hands of consumers. This leads to a paradigm shift in which Australia's tectonic plate movement of 7cm per year will play an increasing role in accurate positioning, especially in use cases where plate-fixed coordinates (e.g. cadastral maps related to GDA94) are combined with earth-fixed coordinates (e.g. those derived from GNSS).

To address this issue, Australia is scheduled to adopt a dynamic, time dependent datum (the Australian Terrestrial Reference Frame, or ATRF) by the end of the decade, and this will have implications for all people who use and rely upon accurate location information.

It will be increasingly important to understand that latitude and longitude coordinates do not define a unique location unless the related time stamp is also identified. At best, a coordinate without datum is ambiguous and may even be meaningless. In 2020, the dynamic datum will establish a different kind of location reference system that will continually model the movement of the Australian continent.

The new dynamic (ATRF) datum will bring with it the need to create and work with time-tagged coordinates. New processes and tools to collect, manage, integrate and disseminate spatial information will therefore be required. This is in addition to, and cannot be seen separate from, the implementation of the new static datum, GDA2020, which is currently under way.

This project postulates that if these issues can be resolved for the cadastre, the findings and outputs can be translated to the management of other layers of spatial information. The project focussed on NSW initially, and then expanded its investigation and findings through engagement points with other jurisdictions.

Objectives and Approach

The project objectives are:

1. Document how the cadastre in NSW will be affected by adoption of a dynamic datum.
2. Establish and prioritise what tasks need to be undertaken to transition the cadastre in NSW to the dynamic datum.
3. Identify what new procedures and tools will be required for the on-going management of the cadastre once the dynamic datum has been adopted.

The project addressed these objectives in three phases: Impact Assessment, Implementation Planning, and Maintenance and Coordination. Each of these phases combined desk study and extensive stakeholder engagement in a combination of online surveys & questionnaires, workshops, one-on-one interviews and project briefings and presentations. The first two phases delivered stand-alone reports and are summarised in this final report.

Impact Assessment

The consensus in the literature is that 'do nothing' is not an option. Increasing user expectations regarding cadastral accuracy, combined with this improved accuracy of consumer GNSS devices and a gap between coordinates from the GDA2020 and ATRF coordinate reference frameworks that will increase over time, all mean that while the impact of ATRF will be small initially, it will grow steadily from 2020 onwards.

Different user applications have different requirements regarding data accuracy, and different levels of business impact of reduced data accuracy. Therefore, different user domains will be impacted at different times. Identifying the sectors and domains that will be impacted most (and earliest) will be an important element in implementation planning.

There will be possible issues with downstream data products such as planning data, utilities or building footprints, which often coincide, or have a fixed relative spatial relationship with the cadastre. This impact will be highest where the DCDB accuracy is highest, i.e. in urban centres (sub decimetre).

A significant contingent of users with lower data accuracy requirements will not need the complexity of an ATRF. Others may require ATRF base-data while their software won't yet support ATRF to GDA2020 (other plate-fixed datum) transformations.

Highly variable levels of understanding of datum modernisation in general, and ATRF in particular, will, if unaddressed, prevent broad implementation. This could contribute to possible confusion in the marketplace about the why, when and how of ATRF implementation. Understanding the arguments for adoption for each user domain, and communicating these, will be critical.

There is a risk that ATRF adoption levels will be further reduced if users perceive the implementation to be separate from GDA2020 and involving significant extra disruption, cost and effort. Coordination of messaging and implementation will be crucial, to avoid the risk of reduced confidence in the (digital) cadastre, leading more users to decide to maintain their own cadastre, rather than use the NSW DCDB.

For any implementation to be successful, there will be an increased reliance on accurate and complete metadata to indicate the reference framework and epoch (timestamp) of any set of coordinates. Given the current practices in this regard, a significant behavioural change would be required to achieve the required levels of metadata completeness.

Ideally, coordinate transformation will occur at the point of supply to users (be they GIS specialists or mainstream consumers) and will need to be easy. To quote one interviewee: "If you don't make it easy for people to do the right thing, you're wasting money on datum modernisation". The community expectation is that in an ATRF implementation (or any datum modernisation for that matter), coordinate transformation 'just works'. Data sources and different datums are aligned 'on the fly', invisible to the end-user: software and applications 'just deal with it'.

A thorough understanding of the impact and mitigation strategies would be needed to prevent ATRF being perceived as a 'solution looking for a problem'.

Data custodians, providers and professional users will need education and awareness raising so that they become conscious of the issues and possibilities. Awareness raising is also required to alert relevant authorities to possible risks and negative impacts over time of a 'do nothing' approach, and the urgency of a sustained and coordinated approach to mitigate these.

Implementation Plan

The proposed roadmap for implementing ATRF for the NSW Cadastre shows the sequencing and dependencies of work packages, and distinguishes two key transition stages over a 4-year period:

1. Options Analysis and Business Case - this stage is primarily targeted towards preparation, specification and scoping of the transition, and securing any funding requirements.
   This stage will take approximately 18 months, until the GDA2020 epoch: 1 January 2020

2. Coordinated Implementation (from January 2020). There will be about a 2 to 3-year period before mainstream impact of ATRF coordinates.

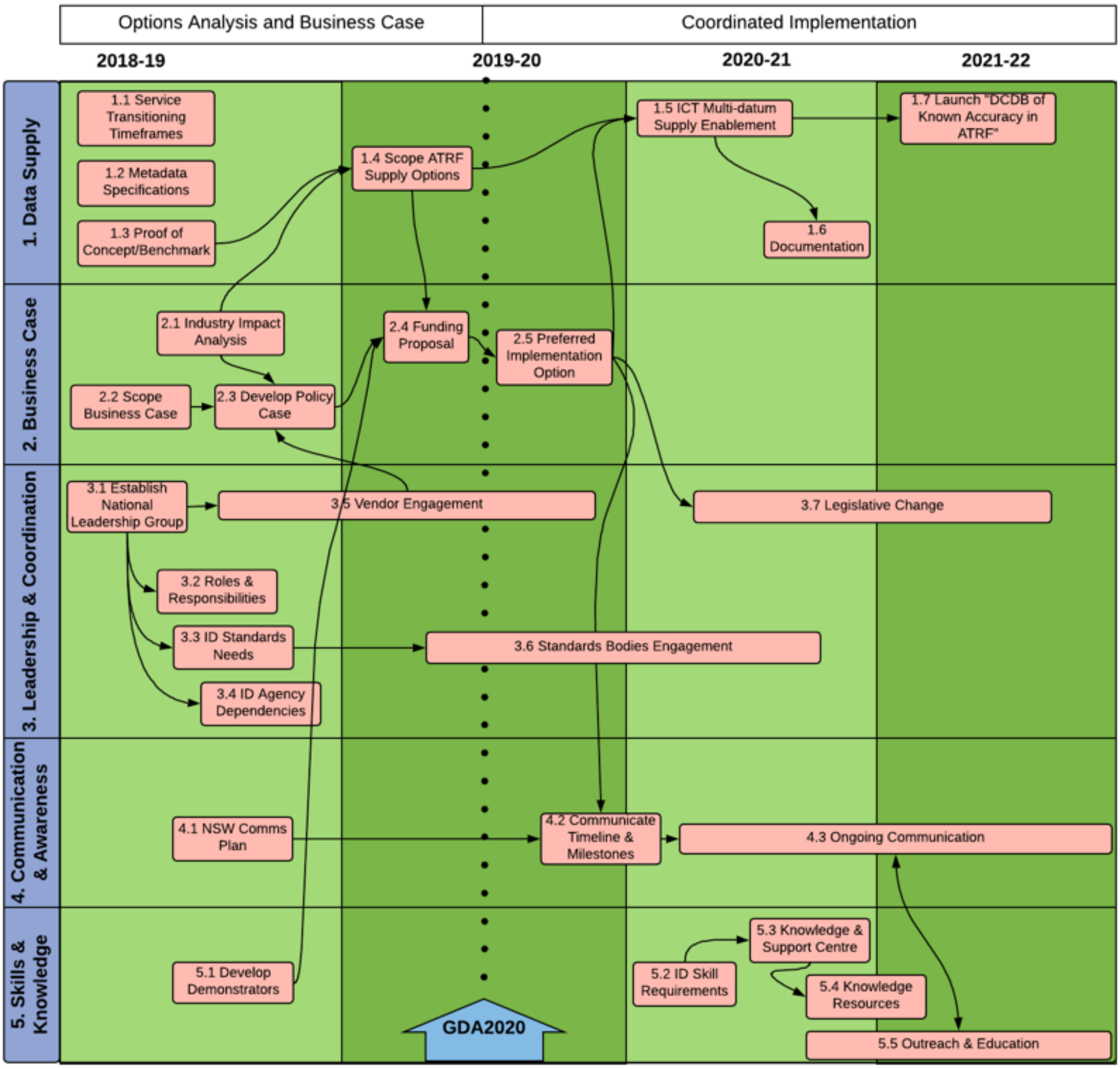

Figure 1 Proposed Transition Roadmap – within five Work Programs

The initial cost and effort estimates for NSW Spatial Services can go up to $650K per year in year 1 (mainly for developing the business case and skills & knowledge management), and year 3 (primarily for technology development), plus up to four full-time equivalent Spatial Services staff in year 4 (mainly for skills & knowledge management). In year 2, the cost and effort for NSW Spatial Services are limited, as most of the activities are nationally coordinated.

Maintenance and Coordination

The maintenance systems, processes, tools and services that will be required for implementation and enduring support of ATRF for the NSW cadastre specifically, and more generally nationally and for related (downstream) datasets as well, should include:

- DCDB maintenance can continue with a static datum (GDA2020);
- Supply DCDB coordinates ‘on-demand’ with transformation to other datums and projections, including GDA94 and ATRF;
- Upgrading the Survey Marks database to supply both GDA2020 and ATRF coordinates;
- Coordinate with other jurisdictions to ensure there is a national supply of shared resources such as transformation parameters, demonstrators, educational materials, as well as nationally coordinated influence on standards and technology development.

It is also critical to facilitate the relation with other, downstream datasets. Tools and services to maintain these relationships with integrity, in the context of a dynamic datum, include metadata services and implementation, online transformation services, COTS software as it becomes available, knowledge and educational services.

The main findings from the review of the NSW findings with other jurisdictions are:

- GDA2020 implementation is under way in all jurisdictions, albeit at different levels of progress. Most jurisdictions (including NSW) have not committed to dates from which they will deliver (cadastral) data in GDA2020, and some indicate their implementation is still subject to funding and legislative or market demands.
- No jurisdictions have started ATRF implementation planning in earnest, though most recognise the need to do so with the exception of GA’s Marine Cadastre and the ACT.
- The timing of ATRF implementation in the jurisdictions is yet to be determined, creating an opportunity for national harmonisation.
- There is a risk of a disconnect between GDA2020 and ATRF implementation: possibly leading to inconsistency, doubling up on effort, and potential alienation of end-users.
- While there are regulatory differences and disparities in the survey plan lodgement process between jurisdictions, these are not considered to have material impact on transforming DCDB management and delivery to ATRF.
- The consensus is that the findings for NSW are generally applicable across all Australian jurisdictions, and everyone is looking forward to an (inter-) nationally coordinated and consistent approach in which NSW, by virtue of its head start, can provide leadership.

Recommendations

In conclusion, we make several recommendations for ATRF implementation, for the NSW cadastre, and also for other jurisdictions and (foundation) datasets:

Recommendation 1: ‘Do nothing’ is not an option. Increasing user expectations regarding cadastral accuracy, combined with improved accuracy of consumer GNSS devices means that while the impact of ATRF will be small initially, it will grow steadily from 2020 onwards.

Recommendation 2: Any implementation must focus on the required change in human knowledge, behaviours and practices. It must be easy for people to ‘do the right thing’, and datum transformation should ‘just work’ for end-users.

Recommendation 3: Ensure a national, and where relevant, internationally coordinated implementation approach. This will support consistency between jurisdictions in e.g. synchronization of epoch snapshots, metadata standards and implementation approach, as well as the shared development of knowledge resources and tools.

Recommendation 4: ANZLIC and ICSM should maintain responsibility for national coordination, in collaboration with the Permanent Committees for the Cadastre and Geodesy (PCC and PCG), and clear accountabilities across the jurisdictions.

Recommendation 5: Utilise expertise and applied research capabilities available through FrontierSI in implementing specific national work packages, e.g. developing metadata specifications, demonstrators or knowledge resources; conducting industry impact analysis; and outreach and education.

Recommendation 6: Establish funded working groups with dedicated personnel at both jurisdictional and national levels, to drive consistent and sustainable implementation and maintenance over the long term.

Recommendation 7: As Australia is a first mover to implement a dynamic datum, it will need to assume a pro-active position in promoting the development of tools and standards on a global stage.

Recommendation 8: Capitalise on the 'blank canvas' opportunity. While no jurisdictions have started ATRF implementation planning, a nationally coordinated approach is more likely to succeed.

Recommendation 9: Specifically for NSW, maintain the momentum that flows from this impact assessment. Start execution of transition roadmap stage 1 (Options Analysis & Business Case) early in FY19, in parallel with GDA2020 implementation.

Recommendation 10: Integrate GDA2020 and ATRF implementation into a coordinated datum modernisation experience.

Recommendation 11: Conduct further industry impact analysis to identify early adopters and target them with both technical and educational support.

Recommendation 12: Make sure the ATRF (and GDA2020) implementation addresses not only data and technology aspects, but also standards, people and governance dimensions.

Recommendation 13: Upgrade NSW SCIMS (or equivalent) to enable delivery of coordinates in both static (GDA2020) and dynamic (ATRF) datums.

Recommendation 14: Maintain NSW DCDB coordinates in a static (GDA2020) datum. Enable 'on-demand' supply of DCDB coordinates in ATRF, at least for a transitional period.

Recommendation 15: NSW Spatial Services should conduct proof-of-concept demonstration trials to test the feasibility and computational complexity of on-demand ATRF delivery of the DCDB.

1 Introduction

1.1 Project Background and Objectives

This research project is jointly sponsored by the Intergovernmental Committee on Surveying and Mapping (ICSM), NSW Spatial Services, and the Cooperative Research Centre for Spatial Information (CRCSI). The CRCSI has engaged Mercury Project Solutions to conduct the research, in close collaboration with NSW Spatial Services.

A cadastre is normally a parcel based, and up-to-date land information system containing a record of interests in land (e.g. rights, restrictions and responsibilities). It usually includes a geometric description of land parcels linked to other records describing the nature of the interests, the ownership or control of those interests, and often the value of the parcel and its improvements. A digital cadastre is a database of cadastral survey data relating to cadastral boundaries within a jurisdiction. The Digital Cadastre is also often referred to as the Digital Cadastral Database (DCDB).

A datum is a coordinate-based reference system that allows locations on the Earth's surface to be uniquely identified. Every country has its own datum and officially Australia's current national datum is called the Geocentric Datum of Australia 2020 (GDA2020), which supersedes GDA94. Many of the latitude and longitude coordinates of features on NSW maps are based on GDA94 as defined by the NSW Surveying and Spatial Information Act. NSW links the GDA94 datum to GDA2020 through rigorous transformation.

Australia is scheduled to adopt a dynamic, time dependent datum (the Australian Terrestrial Reference Frame, or ATRF) by the end of the decade, and this will have implications for all people who use and rely upon accurate location information. It will be increasingly important to understand that latitude and longitude coordinates do not define a unique location unless the related time stamp is also identified. At best, a coordinate without datum is ambiguous and may even be meaningless. In 2020, the dynamic datum will establish a different kind of location reference system that will continually model the movement of the Australian continent.

The new datum will bring with it the need to create and work with time-tagged coordinates. New processes and tools to collect, manage, integrate and disseminate spatial information will therefore be required. The associated technical and procedural challenges represent a major barrier to the efficient and wholesale adoption of the new datum. The broader spatial sector has expressed concern about the potential cost of adopting a new datum and the lack of commercial off the shelf (COTS) software that can support a dynamic datum. There are also highly varying levels of understanding across industry regarding the technical elements of datum and reference system implementation (Stakeholder Requirements for Modernising Australia's Geocentric Datum – CRCSI July 2015).

The digital representation of the cadastre is inarguably one of the most critical layers of spatial information held and managed by any jurisdiction. Not only does it represent state-wide land assets of major economic importance, there are also large volumes of other spatial and non-spatial information that are directly linked to and affected by, changes to the cadastral fabric.

The DCDB's positional accuracy is being improved. Managing the cadastre in the context of this improving accuracy, and the impact of a new dynamic datum, poses a substantial and pressing priority not only for NSW, but for land agencies across Australia.

This project postulates that if these issues can be resolved for the cadastre, the findings and outputs can be translated to the management of other layers of spatial information. The project focussed on NSW initially, and expanded its investigation and findings through engagement points with other jurisdictions.

Information about Australia's datum modernisation, including a simple explainer animation, frequently asked questions, fact sheets and progress updates, is available on the ICSM website, www.icsm.gov.au.

1.1.1 Project Objectives

1. Document how the cadastre in NSW will be affected by adoption of a dynamic datum.
2. Establish and prioritise what tasks need to be undertaken to transition the cadastre in NSW to the dynamic datum.
3. Identify what new procedures and tools will be required for the on-going management of the cadastre once the dynamic datum has been adopted.

1.2 Related Document and Initiatives

This project does not stand in isolation. Several initiatives and research projects are currently underway that have relevance to this project.

- CRCSI project 3.19: "Functions & Benefits of the Spatial Cadastre" (April 2017- June 2018)

  This project explores the actual and potential uses of a more accurate spatial record of cadastral boundaries in Australia & New Zealand and the resulting benefits. Across all jurisdictions it will develop and apply a framework to assess the principal components of evidence for locating and representing cadastral boundaries that contribute to spatial accuracy; the functions that a more accurate spatial cadastre can contribute to; the dependencies of those functions on spatial accuracy; and qualitative identification of costs that can be avoided through enhanced spatial accuracy.

- CRCSI project "Upgrading the spatial accuracy of the digital cadastre – a pilot study" (March 2017 – Feb 2018)

  This project will explore the extent to which high-resolution airborne and space borne imagery, in cases complemented by LiDAR data, can be used to upgrade the spatial accuracy of the digital cadastre.

- CRCSI Program 3 – Spatial Knowledge Infrastructures (SKI) initiative

  The Cooperative Research Centre for Spatial Information (CRCSI) conceptualised a Spatial Knowledge Infrastructure (SKI) that moves the agenda from more traditional Spatial Data Infrastructure (SDI) concepts, to automatically creating, sharing, curating, delivering and using knowledge (and not just data and information) in support of the digital economy and the rise of spatially aware and equipped citizens. Just how the SKI will be delivered and why it is necessary, is explored in a white paper that sets out the research agenda required to make the transition from a SDI to SKI. The digital cadastre is used to case study the need for change and explain the necessary research and development required to streamline data supply, improve information value and increase knowledge utility.

- Cadastre NSW (Ongoing)

  Cadastre NSW is a Spatial Services program to address the key barriers to adoption of a single land cadastre in NSW. More specifically Cadastre NSW is addressing three key issues highlighted by all major stakeholder groups:

  - Proposed plan data is not consistently distributed
  - Users are uncertain about the cadastre's accuracy
  - Lack of a co-ordinated minimum NSW Cadastre

1.3 Acknowledgements

This research project would not have been possible without the generous support and contributions from many organisations and individuals. They are too many to mention and thank here. A quick look in Appendix 3 will show the extent of organisations and people who have selflessly contributed to this work.

However, a specific thank you goes out to:

- The project sponsors: ICSM, the CRC-SI, and NSW Spatial Services. We extend our thanks to the ICSM chair, Michael Giudici, and the PCC chair Russell Priebbenow; the CRC-SI's Phil Collier and NSW Spatial Services' Bruce Thompson, Wayne Patterson and Surveyor General Narelle Underwood for their leadership and support;
- The CRC-SI Project Management Group: Phil Collier, Kylie Armstrong and Zaffar Sadiq Mohammad Ghouse, David Mitchell, Stephanie Pradier, Darren Mottolini, and Ivana Ivanova;
- The Project Review Group, who faithfully attended our monthly meetings to review and guide progress, and provide valuable input: Narelle Underwood, Wayne Patterson, Adrian White, Melissa Daley, and Takis Ellis;
- The people throughout NSW Spatial Services and other jurisdictions who without fail took time out to contribute, brainstorm, be interviewed, complete surveys, or just listen. You know who you are;
- And a last, very special thank-you goes to Adrian White, Spatial Services project lead. Invariably positive, knowledgeable and professional, he somehow managed to keep finding time in his busy schedule to continue guiding this project in the right direction.

1.4 About this document

The structure of this document is as follows:

- Section 2 presents the scope and methodology of the project
- Section 3 summarises the findings of phase 1: "Impact Assessment" (full findings are available in a stand-alone report)
- Section 4 summarises the findings of phase 2: "Transition Tasks" (full findings are available in a stand-alone report)
- Section 5 presents the findings of phase 3: "Maintenance and Coordination" (originally titled "New Tools and Procedures")
- Section 6 contains the conclusions and recommendations
- The appendices cover additional detailed information and resources

2 Approach and Methodology

2.1 Project Scope and Timeline

The project ran from August 2017 to June 2018, and had three distinct phases:

1. Impact Assessment: August – October 2017
2. Implementation Planning: November 2017 – March 2018
3. Maintenance and Coordination: April 2018 – June 2018

Phase 1: Impact Assessment

Scope of works:

- Literature review of research into managing the dynamic cadastre
- Document the impact of a dynamic datum on managing and disseminating the cadastre in NSW
- Present findings to other jurisdictions in Australia and New Zealand with a view to extending the impact assessment where necessary
- Coordinate with related research projects to conduct interviews with other jurisdictions
- Prepare a report on Stage 1

Phase 2: Implementation Planning

Scope of works:

- Document the tasks (manual and automated) that need to be done in NSW to transition the digital cadastre from a static to a dynamic datum
- Identify the magnitude, nature, priority and resources required to complete each task
- Present findings to other jurisdictions with a view to extending the list of required tasks where necessary
- Coordinate with related research projects to undertake a workshop of initial results, feedback and response.
- Prepare a report on Stage 2

Phase 3: Maintenance and Coordination

Scope of works:

- Scope what tools and procedures will be needed to maintain and disseminate the cadastre in NSW once it has been transitioned to the new datum
- Establish a work plan and budget to develop, validate and implement these new tools and procedures
- Validate the outcomes with other jurisdictions with a view to refinements where necessary
- Prepare a report on Stage 3

2.1.1 Out of scope

The following aspects are specifically identified as out of scope:

- Non-linear transformations in the ATRF. For the purpose of the DCDB and related datasets, a pure linear transformation can be assumed and is considered sufficient;
- In the future (local) deformations may be needed, e.g. in case of a major earthquake. But these are considered out of scope for now.
- 3D (and 4D) coordinates

2.2 Engagement

2.2.1 Project Governance Structure

Figure 2 shows the Project Governance Structure.

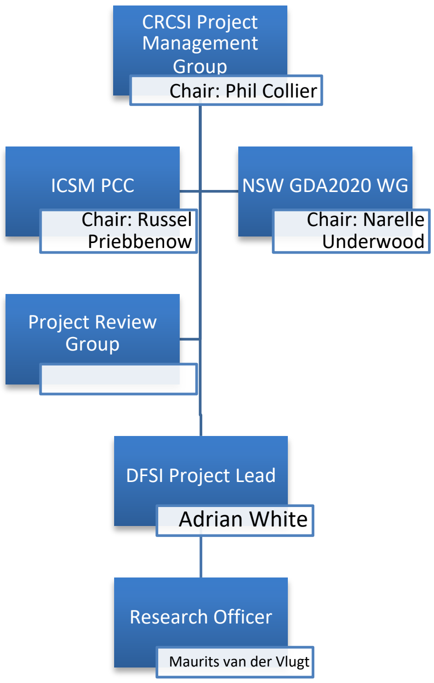

Figure 2 Project Governance Structure

The respective roles in the Project Governance Structure were:

- Project Management Group (PMG; project 3.20): nominated by the CRCSI and chaired by Phil Collier, the PMG oversees the project and approves project deliverables;
- ICSM Permanent Committee on the Cadastre (ICSM PCC). Chaired by Russell Priebbenow. Advisory and Review role;
- NSW GDA2020 Working Group. Chaired by the NSW Surveyor General (Narelle Underwood). Advisory and Review role;
- Project Review Group. To provide review & feed-back on the project progress on a regular basis. Using an 'Agile-like' review & planning approach, where next month's activities are discussed and prioritised. The Project Review Team has an advisory role and can make recommendations. Membership Wayne Patterson (Spatial Services), Narelle Underwood (NSW Surveyor General), Adrian White (Spatial Services), Melissa Daley (Sutherland Shire – local government user representative), Takis Ellis (Sydney Water – utilities user representative);

- DFSI Spatial Services Project Lead (Adrian White). Day-to-day project management and oversight;
- Research Officer (Maurits van der Vlugt). Responsible for project execution and delivery of the agreed scope & outcomes as agreed with Spatial Services.

2.2.2 Stakeholder Map

Figure 3 shows the identified stakeholders, classified by the level by which they are likely to be impacted by the project, and the level of influence they have, into four categories:

- Group 1: Key Players – from whom strong buy-in is required;
- Group 2: Engage – Active Engagement and Consultation is required;
- Group 3: Regular Consultation;
- Group 4: Maintain Interest and Keep Informed.

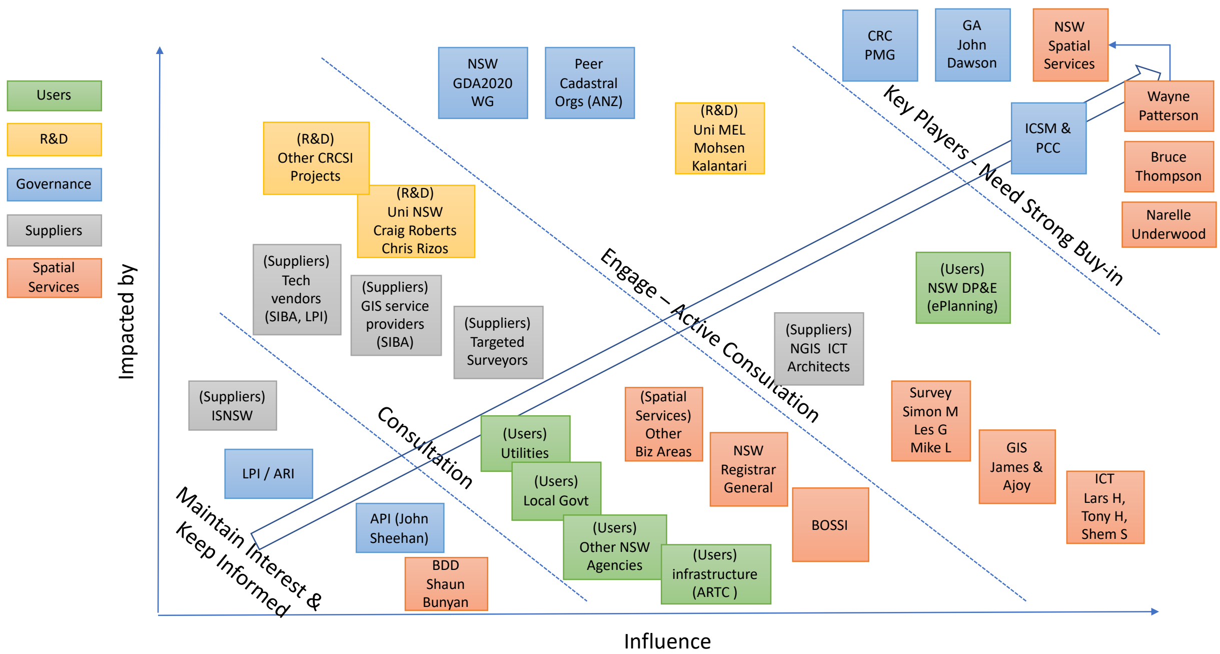

Figure 3 Stakeholder Map

Selected stakeholders were consulted in the respective project phases through a combination of online surveys & questionnaires, workshops, one-on-one interviews and project briefings and -presentations.

A full listing of stakeholders is available in Appendix 3.

2.3 Statement of Intent

The Statement of Intent is a one-page summary of the project's objectives, drivers, current- and future states and principles, approach and constraints to arrive at the future state. It serves as a high-level project plan to guide project execution and outcomes.

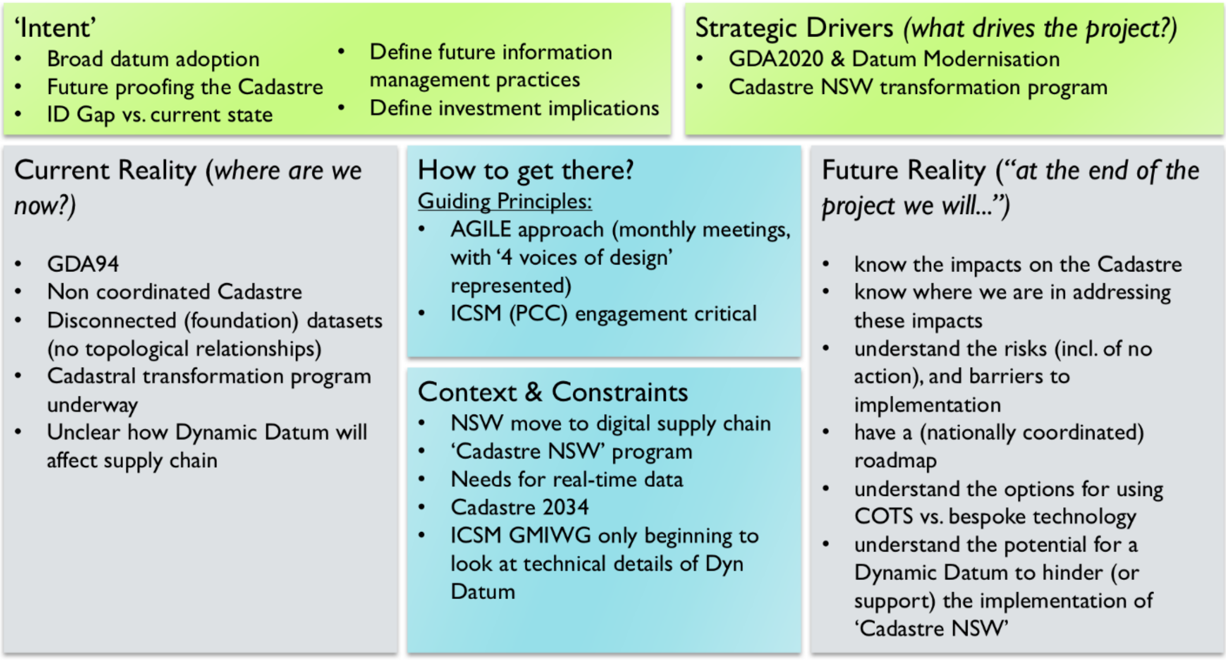

Figure 4 Statement of Intent

2.4 Research Questions

The project scope defines several research questions to be addressed. These are allocated to the respective project phases in the tables below.

Table 1 Research Questions for 3 phases

Phase 1 – Impact Assessment
• What legislative barriers exist and what changes might be necessary to support the cadastre in the context of a dynamic reference frame?
• How can the integrity of the cadastre be maintained in the context of a dynamic datum?
• What impact will a dynamic datum have on the legal definition and re-identification of property boundaries?
• What impact will a dynamic datum have on the cadastral data supply chain (e.g. plan preparation by surveyors, data validation, approvals by councils and others etc)?
• What differences exist between jurisdictions in terms of starting point, capability, technology etc?
• How are other spatial and a-spatial datasets linked to the cadastre and will those links still be valid in the context of a dynamic datum?

Phase 2 – Transition Tasks
• What other information (e.g. Remote Sensing data) could supplement existing data resources to address issues related to moving to a dynamic datum? (link to related research project)
• How can the integrity of the cadastre be maintained in the context of a dynamic datum?

Phase 3 – New Tools & Procedures
• What maintenance systems and processes will be essential to support the digital cadastre and how can current systems be migrated to a dynamic datum?
• What additional tools and services will be required to maintain relationships to other spatial and a-spatial datasets?
• How can the integrity of the cadastre be maintained in the context of a dynamic datum?

During the course of the project, several ancillary research questions have been formulated. Including two phase-1 research questions that were revisited for further work in phase-3, as listed below:

Table 2 Ancillary Research Questions

Ancillary Phase 1 Research Questions
• How does the impact of ATRF differ from that of Datum Modernisation & GDA2020 in general?
• How can the findings for the cadastre be extended to other spatial (foundation) datasets?
• How universal are the findings for NSW, and how can they be enhanced from, or extended to, other jurisdictions?

Ancillary Phase 2 Research Questions
• What sectors and applications will be affected by ATRF, by when, and what is their value proposition for adoption?
• What are the 'gaps' between the GDA2020 implementation plan, and specific ATRF transition needs? (functional, application domains)

Ancillary Phase 3 Research Questions
• What differences exist between jurisdictions in terms of starting point, capability, technology etc?
• How universal are the findings for NSW, and how can they be enhanced from, or extended to, other jurisdictions? (extending from phase-1)
• What are the 'gaps' between the GDA2020 implementation plan, and specific ATRF transition needs? (functional, application domains) (extending from phase-2)
• What are the options (delivery scenarios) for providing ATRF datum transformation to end-users, and how do they compare between jurisdictions

The research addresses all of these questions. Section 6.2 lists the responses to the research questions.

2.5 Strategy Components Model

Figure 5 presents the Strategy Components Model used for the impact analysis and transition planning. The model assesses five key components: Data, Technology, Organisational, Standards and People. Explicitly identifying these components has two key advantages: firstly, it guides the analysis to look beyond data and technology aspects and take a more holistic approach; secondly it provides a classification schema for matching impacts and barriers against future expectations and objectives.

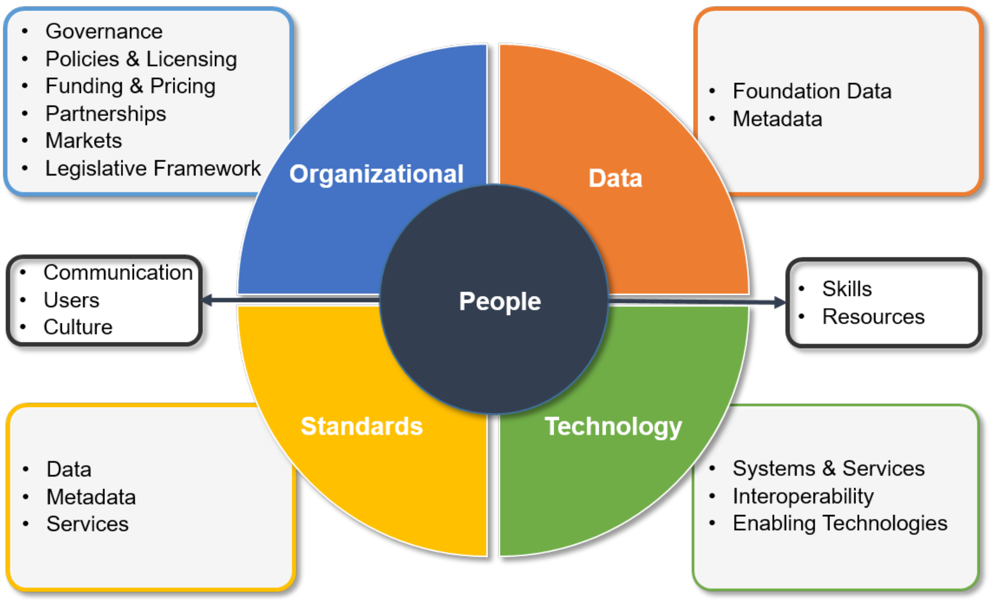

Figure 5 Strategy Components Model (© Dr. Vanessa Lawrence CB, Gilles Albaredes, John Schonegevel, Maurits van der Vlugt)

3 Impact Assessment

This section summarises the findings of the first project phase: "Impact Assessment". More details are available in the full phase 1 interim report[1].

3.1 Research Questions

Relevant research questions for this section are listed in the table below.

Table 3 Research Questions for phase 1

Phase 1 – Impact Assessment
• What legislative barriers exist and what changes might be necessary to support the cadastre in the context of a dynamic reference frame?
• How can the integrity of the cadastre be maintained in the context of a dynamic datum?
• What impact will a dynamic datum have on the legal definition and re-identification of property boundaries?
• What impact will a dynamic datum have on the cadastral data supply chain (e.g. plan preparation by surveyors, data validation, approvals by councils and others etc)?
• What differences exist between jurisdictions in terms of starting point, capability, technology etc?
• How are other spatial and a-spatial datasets linked to the cadastre and will those links still be valid in the context of a dynamic datum?
• How does the impact of ATRF differ from that of Datum Modernisation & GDA2020 in general?
• How can the findings for the cadastre be extended to other spatial (foundation) datasets?
• How universal are the findings for NSW, and how can they be enhanced from, or extended to, other jurisdictions?

Section 6.2 responds to all of the project's research questions.

3.2 Scope & Approach

The Scope of works for the impact assessment was:

- Literature review of research into managing the dynamic cadastre
- Document the impact of a dynamic datum on managing and disseminating the cadastre in NSW
- Present findings to other jurisdictions in Australia and New Zealand with a view to extending the impact assessment where necessary
- Coordinate with related research projects to conduct interviews with other jurisdictions
- Prepare a report on Phase 1

To conduct the impact assessment, four main activities were undertaken:

1. A literature review, consulting a range of research papers, trade publications, project reports and presentations on datum modernisation, geodesy and user requirements. Appendix 2 contains the register of reviewed documents;
2. Interviews with key players and influencers;

[1] Available online: http://www.crcsi.com.au/library/resource/implications-of-a-dynamic-datum-on-the-cadastre-phase-1-report

3. Active engagement through workshops with suppliers; and
4. An online questionnaire for end-users of the cadastre (see Appendix 4)

Appendix 3 contains the full list of interviews and workshops and participants.

3.3 Findings Summary

To summarise the findings, they have been classified using the dimensions of the 'SDI Strategy Components Model' presented in section 2.5; namely: Data, Technology, People, Standards and Organisational. The Impacts of ATRF, Barriers to Implementation and Future Expectations have been summarised against these dimensions in Table 4.

Table 4 Summary of Phase 1 Findings

	ATRF Impacts	Barriers to implementation	Future State with ATRF
Data Cadastral workflow Related data Quality Accessibility	• Positive: GNSS field data will better match Cadastre • Impact on land development: 9% (of respondents) positive, 35% negative • Limited impact on survey plans lodged with NSW LRS (previously LPI) - regulatory requirement to connect to control network • Greater impact on related data when Cadastre moves • High impact in urban centres • Risk of reduced confidence	• NSW DCDB may have to be available in ATRF before user adoption • Variations in, and uncertainty about Cadastral accuracy • DCDB Cadastral update process 'not ready for ATRF' • No topological links with related data	• Sufficiently accurate NSW Cadastre, matching other datasets • Coordinates with known accuracy and reliability • DCDB, SCIMS, usable in both GDA2020 & ATRF • Default for source storage is plate-fixed (GDA2020) • Greater level of topological relationships with downstream/coincident datasets
Technology Architecture Interoperability Software Tools	• Up to 100 different software platforms to be updated • Users with legacy systems will need to upgrade	• 1st-mover disadvantage, software updates delayed • Current COTS can't handle ATRF & time-tagged data • Can we transform bulk imagery 'on the fly'? • Slow user upgrades of legacy software • SCIMS & DCDB won't support multiple coordinates • Risk: solution looking for a problem (or making it worse)	• Technology deals with transformation, "it just works" • Transformations at point of decision making, fully automated • Most COTS software tools are ATRF enabled (conform global standards)
Standards Data & Metadata Business Processes	• Increased reliance on proper metadata (with time tags)	• Confusion re. WGS84 • Some data formats (e.g. DXF) don't enable time-dependency • Legacy processes & (meta-) data standards • Dependence on international standards still under development	• Internationally mandated (meta-) data standards (time-enabled) • Standardised, automated, federated Cadastral supply chain
People Education Behaviours Communication	• "Short-term pain for long-time gain" • Increased effort & possible confusion • Risk: users will abandon NSW Cadastre and manage their own	• Highly variable understanding • Broader benefits variable, not well understood, or hard to articulate • Uncoordinated communication & messaging • No access to knowledge or best-practice examples • No consistent metadata management practice • Risk of confusion	• Change in human knowledge, behaviours and practices • "If you don't make it easy for people to do the right thing, you're wasting money on datum modernisation" • Education & best-practice materials available • End-users shielded
Organisational Legal/ Governance Funding Business Cases Policies	• "Do Nothing" is not an option • Impact & benefits will affect users differently between application domains and over time • Risk of Inconsistency in planning instruments, e.g. between ePlanning portal and 'paper' certificates • Other legislative dependencies: e.g. biodiversity legislation • May be expensive to implement • Little or no impact on legal status of cadastre	• 1st-mover disadvantage (globally) • Legacy datums prescribed in high-level legislation (e.g. NSW surveying Act) • Cadastre: plan is the legal basis vs. Planning act: DB is the legal basis • No jurisdictional implementation plans yet • Legislation and Regulation slow to catch-up • Unknown/prohibitive cost of adoption • Implementation of GDA2020 will impact ATRF timing	• Public awareness drives adoption & investment • User assistance easily accessible • Focus on user domains & applications with highest value proposition & positive ROI • Opening the door to co-ordinated Cadastre (DB is the legal basis)

3.3.1 Impacts

The consensus in the literature is that 'do nothing' is not an option. Increasing user expectations regarding cadastral accuracy, combined with this improved accuracy of consumer GNSS devices and a gap between coordinates from the GDA2020 and ATRF coordinate reference frameworks that will increase over time, all mean that while the impact of ATRF will be small initially, it will grow steadily from 2020 onwards.

On the demand side, the user expectation is that as a fundamental dataset and crucial decision support tool, the cadastre is expected to be of the same accuracy as its related (or 'downstream') datasets, such as transportation, planning or utilities. The accuracy of these datasets is improving, as is the spatial accuracy of the cadastre under the Cadastre NSW program.

The impact of ATRF will therefore grow with increasing downstream data accuracy and evolving user expectations. Different user applications have different requirements regarding data accuracy, and different levels of business impact of reduced data accuracy. Therefore, different user domains will be impacted at different times. Identifying the sectors and domains that will be impacted most (and earliest) will be an important element in implementation planning.

There is limited impact on NSW survey plans lodged with NSW LRS (previously LPI). Data collected using satellite positioning on the other hand, will be more easily aligned with the DCDB when it is ATRF enabled.

There will be possible issues with downstream data products such as planning data, utilities or building footprints, which often coincide, or have a fixed relative spatial relationship with the cadastre. This impact will be highest where the DCDB accuracy is highest, i.e. in urban centres (sub decimetre).

A significant contingent of users with lower data accuracy requirements will not need the complexity of an ATRF. Others may require ATRF base-data while their software won't yet support ATRF to GDA2020 (other plate-fixed datum) transformations.

In the future, when an ATRF is implemented, users are particularly concerned about the impact on the legislative and regulatory aspect of their business, notably the planning regulations and e-planning implementation. There was concern about confusion and possibly being open to legal action when, due to differences is coordinates, discrepancies occur between e.g. the zoning constraints of a property on the e-planning portal, vs. a planning certificate that council has issued.

3.3.2 Barriers

First and foremost, highly variable levels of understanding of datum modernisation in general, and ATRF in particular, will, if unaddressed, prevent broad implementation. This could contribute to possible confusion in the marketplace about the why, when and how of ATRF implementation. Understanding the arguments for adoption for each user domain, and communicating these, will be critical.

There is a risk that ATRF adoption levels will be further reduced if users perceive the implementation to be separate from GDA2020 and involving significant extra disruption and extra cost and effort. Coordination of messaging and implementation will be crucial, as a review of the GDA94 implementation has shown[2].

[2] "Stakeholder Requirements for Modernising Australia's Geocentric Datum", CRCSI Project 1.02 report. July 2015.

A major risk that respondents raised was that if the cost and complexity of ATRF implementation becomes prohibitive, or if the implementation leads to reduced confidence in the (digital) cadastre, even more users may decide to maintain their own cadastre, rather than use the NSW DCDB.

> *If the [NSW] Cadastre is in constant "motion" […] this may dissuade some Councils […] back to managing their own cadastres*

From a technical perspective, over 100 separate pieces of (COTS) software from over 80 vendors are in use to conduct coordinate transformation. Each of these would need to be upgraded or replaced with tools that are ATRF enabled, to facilitate a smooth implementation. In that context, Australia is likely to suffer from a 'first-mover-disadvantage'. As the first country world-wide to implement an earth-fixed, dynamic datum, it may find international technology vendors struggling to upgrade their tools in time for ATRF implementation.

For any implementation to be successful, there will be an increased reliance on accurate and complete metadata to indicate the reference framework and epoch (timestamp) of any set of coordinates. Given the current practices in this regard, a significant behavioural change would be required to achieve the required levels of metadata completeness.

3.3.3 Future Expectations

There is optimism that the ambition of achieving a highly accurate digital cadastre is technically achievable in NSW. Implementing the ATRF will therefore be critical to maintain alignment with global positioning systems and with new global spatial datasets – especially those derived from satellite data.

There is also a strong consensus in the literature that a change in stakeholders' behaviours, knowledge and practices is needed to avoid the risk of getting very low user take-up of ATRF, and thus wasted investment.

Ideally, coordinate transformation will occur at the point of supply to users (be they GIS specialists or mainstream consumers) and will need to be easy. To quote: "If you don't make it easy for people to do the right thing, you're wasting money on datum modernisation"[3]. The community expectation is that in an ATRF implementation (or any datum modernisation for that matter), coordinate transformation 'just works'. Data sources and different datums are aligned 'on the fly', invisible to the end-user: software and applications 'just deal with it'.

Also, with an increasing need to communicate the trustworthiness of (derived) information in machine-to-machine data exchange, knowledge and provenance of coordinate accuracy will play an important role, supported by associated metadata standards.

A thorough understanding of the impact and mitigation strategies would be needed to prevent ATRF being perceived as a 'solution looking for a problem'.

> *as a general comment, this needs careful consideration whether the fix is more harmful than the problem*

Data custodians, providers and professional users will need education and awareness raising so that they become conscious of the issues and possibilities. Awareness raising is also required to alert relevant authorities to possible

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[3] Locate 17 Panel discussion - Impacts of Datum – National and International Perspectives

risks and negative impacts over time of a ‘do nothing’ approach, and the urgency of a sustained and coordinated approach to mitigate these.

4 Implementation Planning

This section summarises the findings of the second project phase (originally titled “Transition Tasks”). More details are available in the full phase 2 interim report[4].

4.1 Research Questions

Relevant research questions for this section are listed in the table below.

Table 5 Research Questions for phase 2

Phase 2 – Transition Tasks
• What other information (eg Remote Sensing data) could supplement existing data resources to address issues related to moving to a dynamic datum? (link to related research project)
• How can the integrity of the cadastre be maintained in the context of a dynamic datum?
• What sectors and applications will be affected by ATRF, by when, and what is their value proposition for adoption?
• What are the ‘gaps’ between the GDA2020 implementation plan, and specific ATRF transition needs? (functional, application domains)
• Should NSW government supply DCDB (and/or SCIMS) data in GDA2020 only, or also in ATRF?

Section 6.2 responds to all of the project’s research questions.

4.2 Scope & Approach

The Scope of works for the implementation planning was:

- Document the tasks (manual and automated) that need to be done in NSW to transition the digital cadastre from a static to a dynamic datum;
- Identify the magnitude, nature, priority and resources required to complete each task;
- Present findings to other jurisdictions with a view to extending the list of required tasks where necessary;
- Coordinate with related research projects to undertake a workshop of initial results, feedback and response; and
- Prepare a report on Phase 2.

To conduct the implementation planning, four main activities were undertaken:

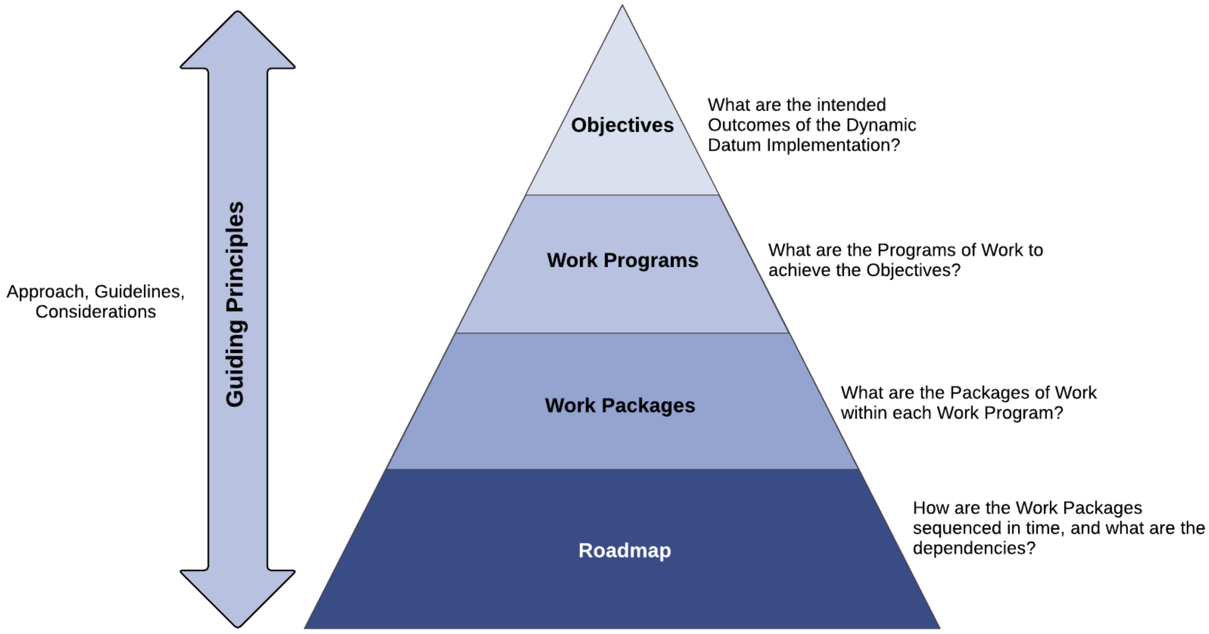
- Two “Transition Planning” workshops with the Project Reference Group and User Representatives;
- Interviews with a variety of Industry Representatives, and Subject Matter Experts;
- A validation workshop with other jurisdictions and (inter-) national Subject Matter Experts
- A desk study exercise to determine cost estimates

This phase takes a top-down approach to developing the Transition Tasks. Working from Business Objectives, we determine the Work Programs required to achieve the Objectives, given the current

[4] Available online: http://www.crcsi.com.au/library/resource/implications-of-a-dynamic-datum-on-the-cadastre-phase-2-interim-report-transition-tasks

state. Work Programs are then broken down into discrete Work Packages, with clear outputs and finite duration. The Work Packages are then sequenced into an Implementation Roadmap.

In addition, a set of guiding principles defines the approach and other considerations to take into account for the Transition Tasks.



4.3 ATRF Transformation for the NSW Cadastre

Several factors influence the decision on how to implement ATRF for the NSW Cadastre. Key questions include:

- How and where in the data supply chain does coordinate transformation need to be implemented to support effective and accurate decision making?
- What is the market impact: when will users be affected, and which market sectors are likely to be impacted first?

In this section we examine the first question: “How and where in the data supply chain does coordinate transformation need to be implemented?”

ATRF-impacted users make decisions based on the location of a GNSS device (e.g. a phone, or GNSS receiver in an autonomous vehicle, or GNSS captured asset locations), in relation to a base-map, such as the DCDB. In other words: it is about ensuring the ‘blue dot’ is properly aligned with the map; e.g. which side of a boundary line or a median strip is it on?

4.3.1 Option 1: Transformation at Point of Supply

In this case (illustrated in Figure 6 below), the user device requests base data from a web service. By specifying the datum, projection and, where relevant, the epoch, the user gets the data in precisely the earth-fixed, dynamic coordinate system they need at that moment. The data custodian assumes the responsibility of transforming the coordinates ‘on demand’ at the time of supply.

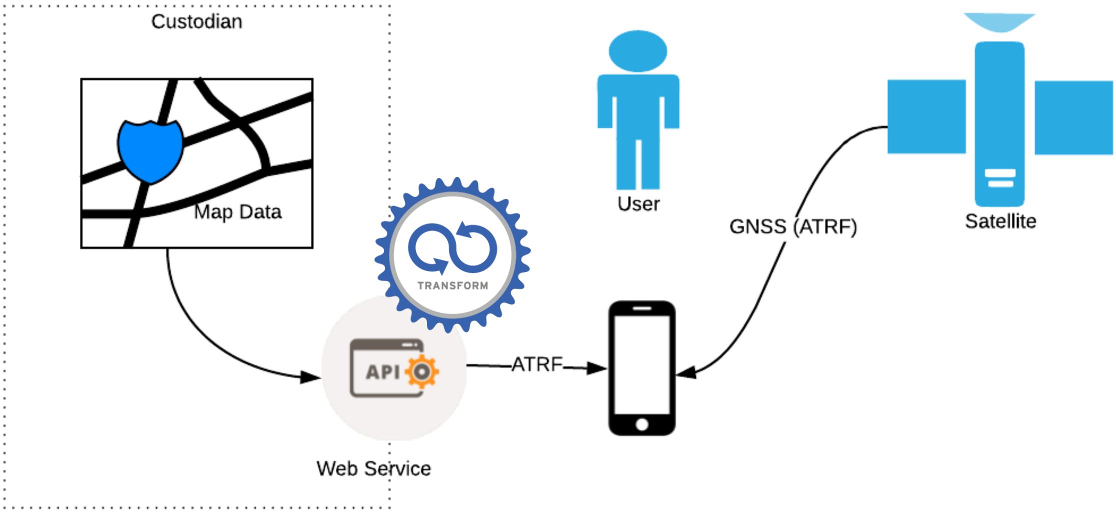


Figure 6 Transformation at Point of Supply

The advantage is that the user can get the coordinates they need, when they need them. Furthermore, there is no further coordinate transformation required in the end-user device, and coordinates will align automatically, provided the right base-data & epoch have been requested.

The disadvantages of this approach are that there needs to be some intelligence in the user (and/or their device) to determine the coordinate system and epoch for which they need to acquire the base-map. Furthermore, this will not work offline, and while the base-map may be cached, it will depend on the user's accuracy requirements to determine how often the cache will need refreshing.

This option also puts the onus on data custodians to supply their data in a multitude of coordinate systems, including time dependent ATRF. Sizeable data transformation requests (large coverage, or LiDar/Imagery data) may lead to prohibitive computational complexity, and unacceptable response times.

4.3.2 Option 2: Transformation at Point of Decision Making

4.3.2.1 Option 2A: 'On the Fly' Transformation

The other main option is that transformations happen at the point of decision making. The main use case is illustrated in Figure 7 below.

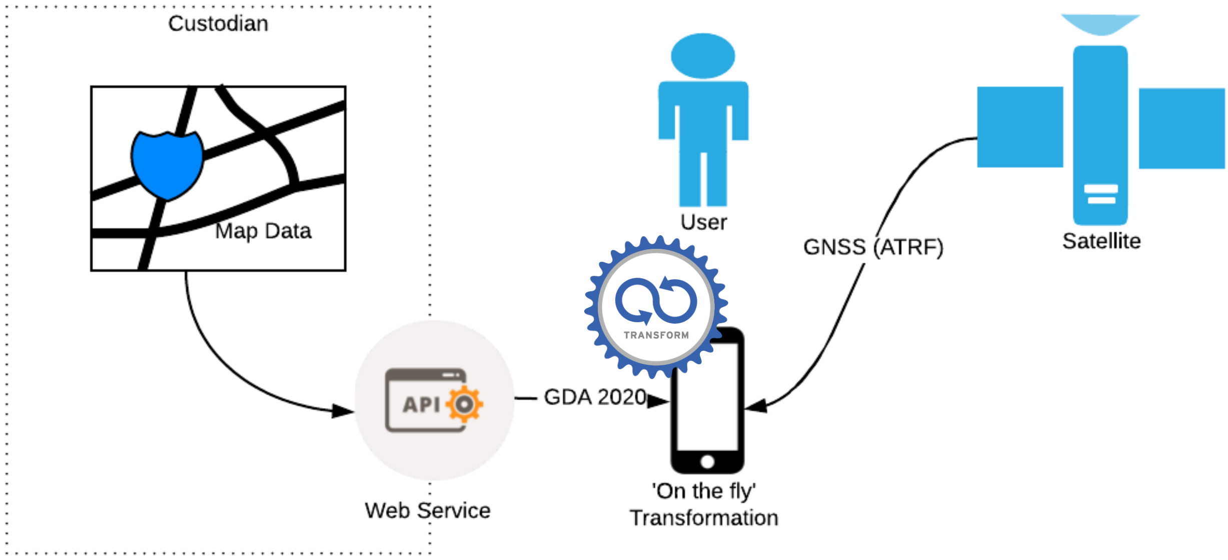


Figure 7 Transformation at Point of Decision Making

The advantage of this option for the user is that the in-device transformation can happen ‘on the fly’, as and when needed, and will therefore always be in the right epoch. Furthermore, it can happen automatically, without user intervention, thus not requiring any user knowledge or awareness. For them ‘it just works’.

The advantage for the custodian is that they can continue to supply their data in a static, earth-fixed datum such as GDA2020, and won’t need to invest in the infrastructure to supply ATRF ‘on demand’.

Additionally, in this scenario, only the GNSS coordinates (often a very small volume of data) need to be transformed to align with the base-map, which has a trivial computational load.

However, for this option to be viable, it assumes a broad market availability of devices that have built in COTS software to transform data on the fly, as well as all base-map data having appropriate metadata for the software to select the proper transformation method.

4.3.2.2 Option 2B: 3rd Party Transformation

Alternatively, sophisticated users may be able to take static (plate-fixed) base data and use a 3rd party transformation service to transform the data into the coordinate system and epoch that matches their GNSS coordinate sets. This is illustrated below in Figure 8.

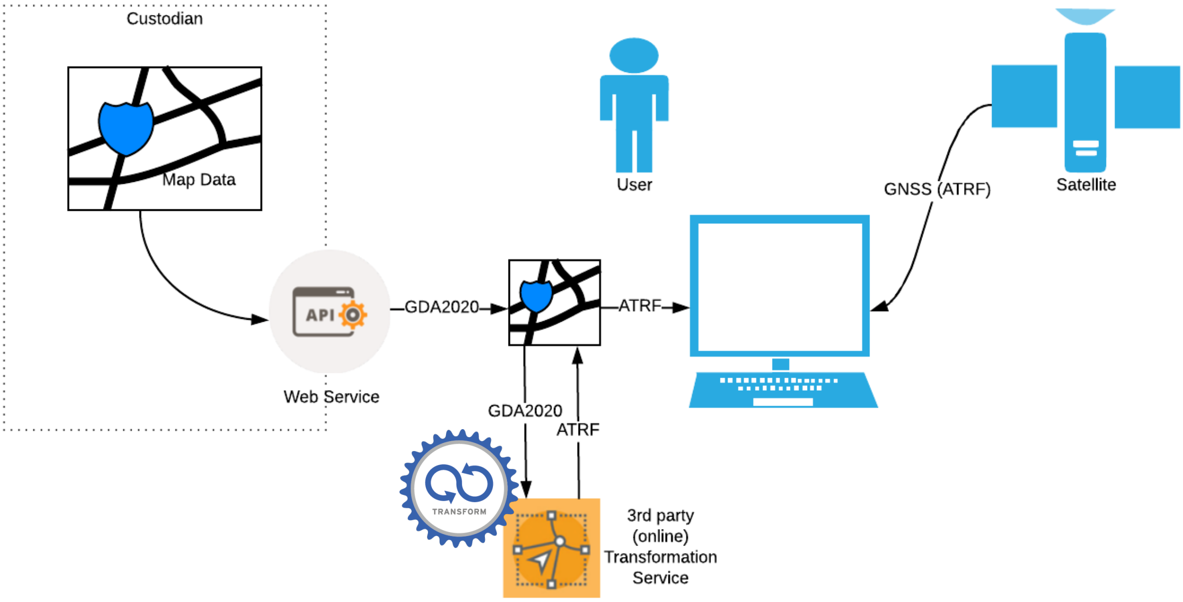


Figure 8 Using a 3rd party transformation service

In this model, custodians can also provide their data in a static, plate-fixed datum, while the user, lacking the COTS transformation capability, can perform one-off transformations as and when needed. This would obviously depend on the availability of a 3rd party transformation service.

4.3.3 Preferred Option

One of the key findings from phase-1 of the project was that for ATRF to be broadly implemented, the technology needs to 'just work', and not require user awareness, especially from non-sophisticated users.

Especially as the vast majority of users only require relative positioning (i.e. GNSS coordinates in relation to base data), in-device transformations at the point of decision making (option 2A) is therefore the preferred option for the long term.

However, the feasibility of this option is dependent on in-device COTS transformation capability being widely available. While this is not the case, users will have to rely on others to provide transformation services: either 3rd parties, or the data custodian themselves.

The implications for the ATRF implementation in NSW will depend on the relative timing of when users will be impacted by ATRF, and when COTS solutions will become widely available. We will explore these questions in more detail in the following section.

4.4 Impact & Market Analysis

This section will address key questions that are critical in determining the ATRF Transition Planning:

1. When and where will the user impact hit?
2. Should the NSW DCDB (and other foundation datasets) be delivered in ATRF?
3. What market segments will be impacted first (and thus be targeted in the Transition Planning)?

4.4.1 Hitting the Sweet Spot

To determine the use-cases in which ATRF is relevant in relation to GDA2020, and where users can be impacted, we need to consider four accuracy factors that must all intersect for ATRF coordinates to deliver value over GDA2020.

1. The accuracy of the devices;
2. The accuracy (positional uncertainty) of the base-data;
3. The user's accuracy requirements[5]; and
4. The coordinate shift between ATRF and GDA2020.

It is only when all four intersect, i.e. are in the same order of magnitude, (as illustrated in Figure 9) that the use of ATRF coordinates is relevant.

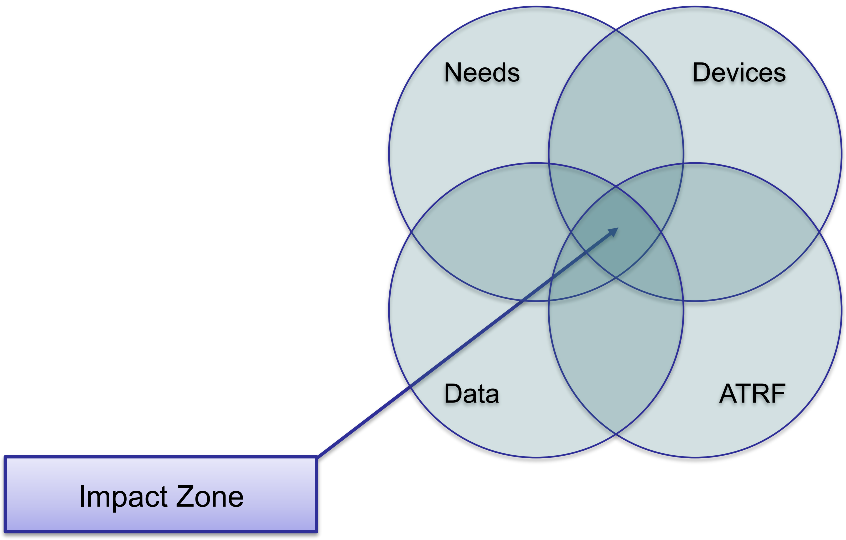


Figure 9 Sweet Spot: when four factors align

There will be no ATRF impact in cases where for instance:

- The user doesn't need high accuracy positioning (e.g. for pizza delivery);
- The base-data has a positional accuracy of more than 1m (e.g. Google Maps);
- The devices in use can't deliver decimetre (or better) GNSS coordinates; or
- The gap between ATRF and GDA2020 has not (yet) grown big enough to be relevant.

So, where and when will the first impact be? Where the business need is in the same order as:

- The ATRF-GDA2020 difference (7 cm pa);
- The base data positional uncertainty; and
- The achievable accuracy of the GNSS devices.

And then only when there is a business need for that level of accuracy, i.e. is the cost or risk of coordinate misalignment big enough to warrant investment in ATRF enablement.

[5] Defined as the accuracy required the user's business activities related to the cadastre

We know or can assume that:

- **Devices** – Positional accuracy will reach sub-decimetre in consumer GNSS receivers within 5 years (2023)[6]
- **Data** – The "Cadastre NSW" program aims at the NSW DCDB having a positional uncertainty (in urban areas) of 20cm or better from 2020 onwards (in a GDA2020 datum)
- **ATRF** – shifts away from GDA2020 at a rate of 7cm pa; reaching 20 cm from 2023.

The impact zone will be where users have a need for 20 cm (or better) positional accuracy when aligning the DCDB with GNSS locations.

We can safely conclude that initially, there will be only a very small number of use-cases, growing over time as ATRF gets further away from GDA2020, ubiquitous devices get more accurate, and the relevant base-data improves its positional accuracy.

4.4.2 Priority Implementation Sectors

Can we expect that some market sectors' need for ATRF coordinates that align with basemaps will precede broad COTS penetration? If so, knowing which sectors these are will help assess the magnitude and relevance of any market lag, and thereby influence implementation planning.

We can classify the impacted sectors in three broad tiers: tier 1 are the first impacted, tier 2 will follow, and tier 3 being the last ones. Any implementation plan would need to focus on the tier 1 sectors.

For the purposes of this study, the sectors are ranked on two indicators: their business dependence on the DCDB (very high, high, medium, low), and the required positional accuracy for their business decision making.

Tier 1 sectors are defined as those who have a high DCDB dependency, and a positional accuracy need in decimetres or smaller.

Table 6 presents a sectoral classification, based on a combination of literature review and analysis of anecdotal feed-back from different user groups. While these findings are preliminary, based on limited and possible dated sources, and will need to be validated in more detail, we are confident that the tier-1 sectors will likely include Asset Management, Land & Property, Smart Buildings and Infrastructure, Smart Cities & Local Government, and Utilities. Environment and Planning (particularly e-Planning) is currently in tier 2 but may well be added to tier 1.

[6] "The combination of modernised, multi-constellation GNSS, technological improvements in GNSS receivers and market growth will inevitably lead to the development of 0.5m accurate GNSS positioning and subsequently 0.1m accurate (or better) positioning in consumer priced GNSS receivers. Based upon the current trends, expert predictions suggest delivery of these capabilities sometime before 2023, possibly as early as 2020". From: "Stakeholder Requirements for Modernising Australia's Geocentric Datum", CRCSI, July 2015.

Table 6 Sectoral impacts of ATRF on the DCDB

Sector[7]	DCDB dependency	Business Accuracy need[8]	Tier	Comments
Asset Management	**High**	**10-50 cm**	**1**	
Land & Property	**Very high**	**20 cm**	**1**	**20cm is the future target for Cadastral positional uncertainty in NSW urban areas**
Smart Buildings and Infrastructure	**High**	**10-30 cm**	**1**	**Includes BIM; high accuracy**
Smart Cities & Local Government	**High**	**10-50 cm**	**1**	**High dependency, with high to medium accuracy needs**
Utilities	**High**	**<5 cm**	**1**	**Utilities are currently often aligned in relation to Cadastral Boundaries. In the future, when utilities are in a position to use an accurate common cadastre, they will be able to align asset records directly from survey accurate sources**
Building & Construction	Medium	<5 cm	2	While high accuracy needs, dependency on cadastre is medium
Planning and Environment	Very high	30-50 cm	2	While very high Cadastral dependency, only medium accuracy needs
Agriculture	Low	10-30 cm	3	Relatively high positional accuracy needs, but little cadastral dependency
Emergency Services, Insurance, Ambulance Services	Low	1-5m?	3	Some sources (ICSM study) claim 10-30 cm for Emergency Services
Forestry	Low	10-100cm	3	Potential GPS applications in (precision) forestry include tree location mapping, forest compartment boundary survey, forest road survey, ground truth activities. with increasing focus on longitudinal datasets (time series) and increasing spatial resolution of remote sensors, 10cm level precision is likely to emerge as a live issue in the next few years.
Logistics	Low	10-50 cm	3	Includes intelligent Transport (10-30cm)

4.4.3 Should the NSW DCDB be supplied in ATRF?

The preferred transformation option is in-device transformations at the point of decision making (option 2A, see section 4.3.2.1). Given the preferred option, and the considerations regarding user impact

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[7] As defined in Acil Allen (2017) "Economic Value of Spatial Information in NSW".

[8] Derived from ICSM (2003), "Business Case Framework for Improved Spatial Accuracy in Digital Cadastral Database (DCDB)", combined with anecdotal feed-back from selected users

(presented in the previous sections), a key question for a DCDB data custodian is: *"should we invest in supplying our base-data in a time dependent (ATRF) coordinate system, or can we rely on user capabilities to align our data with GNSS coordinates?"*

To decide if the NSW DCDB should be supplied in ATRF, three sub-questions need to be addressed:

1. What is the computational load and investment required for 'on-demand' delivery?
2. When will user impact reach critical levels?
3. When will COTS software support automated, in-device transformation?

In conversations with the NSW Spatial Services ICT group, it has become apparent that the 1st question re. computational load cannot be answered definitively without running trials. We therefore recommend that Spatial Services run a proof-of-concept demonstration for ATRF delivery, aimed specifically at testing the feasibility, reliability and performance of 'on-demand', time-dependent DCDB web-services.

The questions re. when user impact will reach critical levels, and how that relates to COTS software support is explored in the following sections.

4.4.3.1 Timing of User Impact and Software Support

For adoption of in-device transformations at the point of decision making (option 2A), it would be necessary for COTS software to be widely available, before the user impacts hit. The diagrams below show typical technology adoption curves (S-curves[9]) over time for user-impact and COTS support respectively. As time progresses (X-axes), the level of market share initially increases slowly, then accelerates and finally slows again as the market reaches saturation.

Figure 10 demonstrates the ideal scenario where there is a wide availability of COTS software support before a majority of users are impacted.

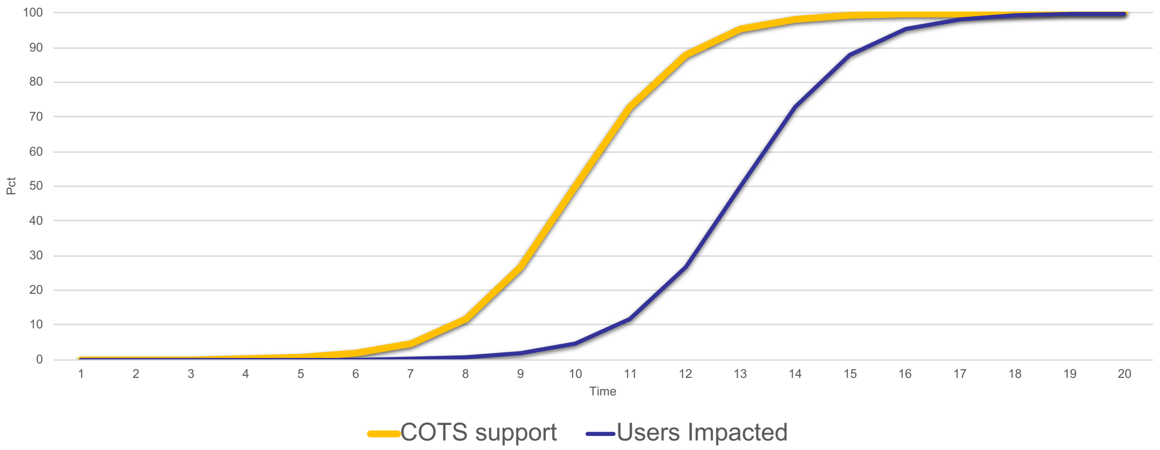


Figure 10 COTS penetration precedes user impact

Conversely, if software support becomes available after user impact, we observe 'market lag', as demonstrated in Figure 11. In this situation there is a market impact and demand that cannot be met

[9] See e.g. https://en.wikipedia.org/wiki/Diffusion_of_innovations

by widely available consumer technology solutions. In that scenario a case can be made for government intervention, at least until the technology vendors have caught up.

The likelihood of this scenario increases due to Australia's '1st mover disadvantage'. Australia is the world's first adopter of a dynamic datum, whereas most technology vendors are global operators, who may well postpone releasing COTS solutions until countries like the USA adopt a dynamic datum (not until 2022 at the earliest).

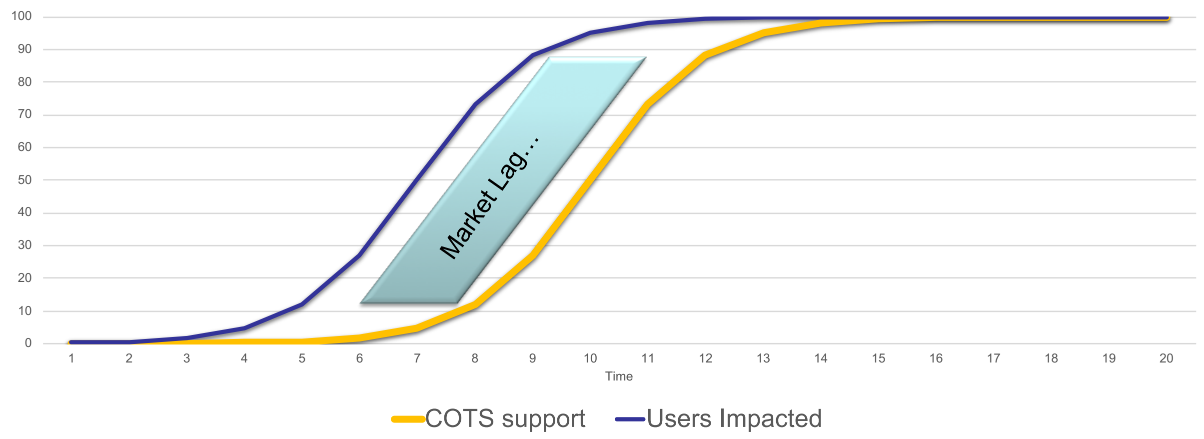


Figure 11 COTS support lags impact

In reality, as we have seen in section 4.4.2, different market sectors might be impacted at different times as illustrated in Figure 12.

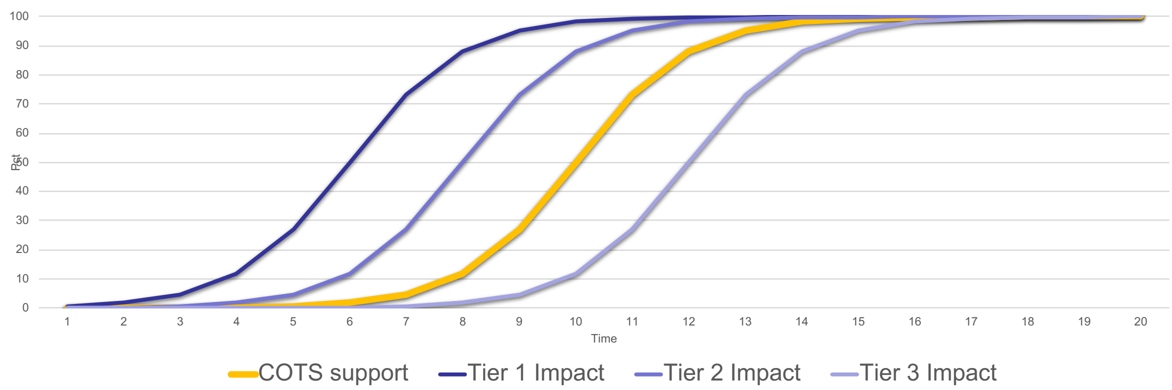


Figure 12 Tiered impact

This sectoral differentiation has implications for implementation, as certain sectors may require earlier targeting than others. The following section explores this and other implications in more detail.

4.5 Implementation Approach

We take a top-down approach to developing the Implementation Approach. Working from Strategic Objectives (defined in section 4.5.1), we determined the five Work Programs (section 4.5.3) required to achieve the Objectives, given the current state: Data Supply, Business Case, Leadership & Coordination, Communication & Awareness, and Skills & Knowledge. These Work Programs were then broken down into discrete Work Packages, with clear outputs and finite duration. The Work Packages are sequenced into an Implementation Roadmap.

In addition, a set of guiding principles defines the approach and other considerations to take into account for the Implementation Approach.

4.5.1 Strategic Objectives

Using the same five Strategic Components that were introduced in the Impact Analysis (Phase 1, see section 2.5), Table 7 shows the Strategic Objectives for the ATRF transition. These objectives were developed based on stakeholder workshops with user representatives and DFSI Spatial Services staff.

Table 7 Strategic Objectives

	Objectives	Description	Comments
Data	Multi datum supply	Cadastral data will be supplied in ATRF and GDA2020, through web-services	NSW Spatial Services current policy is to support multiple datums only for a transition period; Transition plan to provide a target date for completion of transition period.
	Trust & integrity	Consumers will continue to trust cadastral data, its integrity, and advertised accuracy and precision	Maybe enabled through e.g. visibility of changes & updates; Coordinates have known accuracy
	Fit for Purpose	Cadastral data will be available in the format and in the reference frame that is fit for the user's purpose	
	Tightly integrated metadata	Spatial data is integrated with tightly coupled metadata including its reference framework and epoch.	Metadata needs to be 'locked in' with the data source.
	Data alignment	All government/Foundation datasets aligned to the same datum	Ideally through topological relationships, but may be a bridge too far?
Technology	Broad COTS Support	Major software vendors provide 'on the fly' ATRF transformation support	This includes mobile data collection
	'It just works'	Consumer devices seamlessly integrate data from different sources & transform datums.	
	Web-services supply	Web-services supply data in ATRF & GDA2020 when requested	
Standards	Supported by international standards	Time-enabled metadata & data formats standards widely accepted as 'the norm'	
	Broad standards adoption	Standards widely adopted & documented	
	Standards awareness, communication & support	ATRF compliance standards & workarounds published in a single, authoritative location (including transformation parameters & algorithms)	ICSM role?

	Objectives	Description	Comments
People	Communication & Awareness	Behavioural change & increased awareness of the importance of datums, metadata and time-tagging coordinates.	Through e.g. industry best-practice guidelines
	Right skills at the right level	Provide the materials, tools & resources for specialist users to 'self-help' and get support where needed.	Taking into consideration that many organisations have lost relevant skillsets over the years.
	End-users shielded	Non-specialist (end-) users are shielded from need to be aware of coordinate systems, and the need to actively transform data.	Fool-proof: users cannot unintentionally 'break the rules'
Organisational	Sustainably resourced transition	Transition to ATRF has sufficient, dedicated resources allocated for the long term	
	National consistency	National & cross-jurisdictional coordination to ensure consistency	
	Government leadership	Government (state & national) assume an active leadership role	
	Defined Roles & Responsibilities	Clear understanding and allocation of Roles & Responsibilities, both in Cadastral Supply Chain, and in national and jurisdictional coordination	
	implementation scope & scale well understood	Good understanding of the scale of the transition, which sectors to target and the effort required.	

4.5.2 Guiding Principles

The following Guiding Principles should be applied in the planning and implementation of the ATRF transition. These principles must be considered in any work to be undertaken to achieve the Strategic Objectives:

1. **National & cross-jurisdictional coordination**

   Avoiding duplication, reducing cost, ensuring consistency, and (perhaps most importantly) enabling a single voice when engaging with vendors and standards bodies.

2. **Strive for the least amount of effort for user adoption**

   Ensuring "it just works”.

3. **Defined Roles & Responsibilities**

   Clear understanding and allocation of Roles & Responsibilities, both in Cadastral Supply Chain, and in national and jurisdictional coordination.

4. **All government / foundation datasets should align to the same, consistent datum**

   This is essential for consistency in decision making and meeting accuracy requirements. It is also important that foundation data remain consistent without constant accuracy upgrades as constant realigning is a considerable overhead for users.

5. **Allow for adoption by organisations with lower technical knowledge than expected**

   In many cases, even larger and sophisticated organisations have lost or outsourced survey and geodesy skills. Assume lowest common denominator.

6. **Allow for differences in starting point / maturity between organisations**

As above, assume lowest common denominator.

7. **Seamless GDA2020 & ATRF implementation**

   Not necessarily simultaneous, but consistent and coordinated. Facilitates user uptake and reduces risk of people managing their own cadastre.

8. **Maintain Cadastral data integrity**

   Through e.g. DCDB Service reliability, and avoiding duplication (people maintaining multiple cadastres).

4.5.3 Work Programs

To achieve each of the Strategic Objectives, five Work Programs have been identified, as listed in Table 8 below.

Table 8 Proposed Work Programs for Implementation

	Work Program	Description
1	Data Supply	Ensure NSW (Cadastral) data supply meets ATRF requirements: on-demand supply in multiple datums, bulk, web-services & incremental feeds. Maintaining integrity of & trust in NSW Cadastre and downstream datasets. Tightly integrated metadata
2	Business Case	Identify scale of impact and associated investment needs. Make the policy case for investment. Ensure sustainable resourcing and funding
3	Leadership & Coordination	National and international leadership, and a coordinated approach to vendor engagement, pro-active standards management and advocating the ‘policy case'
4	Communication & Awareness	Consistent, ongoing and targeted approach to raising awareness about the impact and implications of ATRF, reaching out to businesses, developers and geospatial specialists
5	Knowledge & Skills	Provide appropriate knowledge resources and skills development to relevant audience(s).

4.5.4 Roadmap

The work programs are set out in a roadmap shown below. It shows the sequencing and dependencies of the work packages, and distinguishes two key transition stages over a 4-year period:

1. Options Analysis and Business Case - this stage is primarily targeted towards preparation, specification and scoping of the transition, and securing any funding requirements.
   This stage will take approximately 18 months, until the GDA2020 epoch: 1 January 2020
2. Coordinated Implementation (from January 2020). There will be about a 2 to 3-year period before mainstream impact of ATRF coordinates.

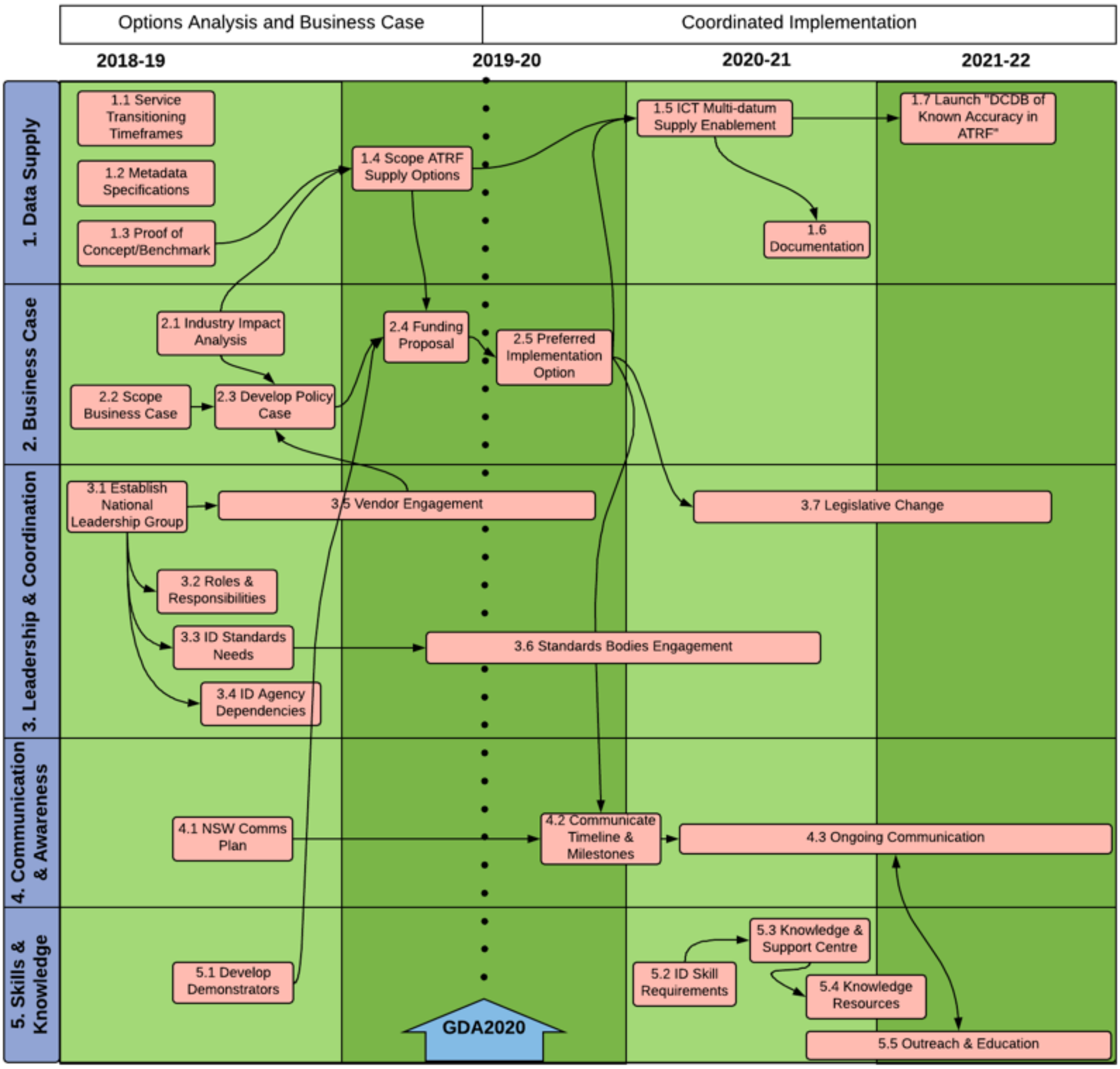


Figure 13 Proposed Transition Roadmap

4.6 Resource Estimates

While it is too early to make definitive statements about the resources required for the Transition, there are some preliminary, Very Rough Order of Magnitude (VROOM) estimates that can be made to give an indication of the scale of the effort and cost required over time.

The following diagram (Figure 14) breaks down the expected cost and effort ranges over time, for the transition of the NSW DCDB to ATRF. Detailed numbers are available in the phase-2 interim report.

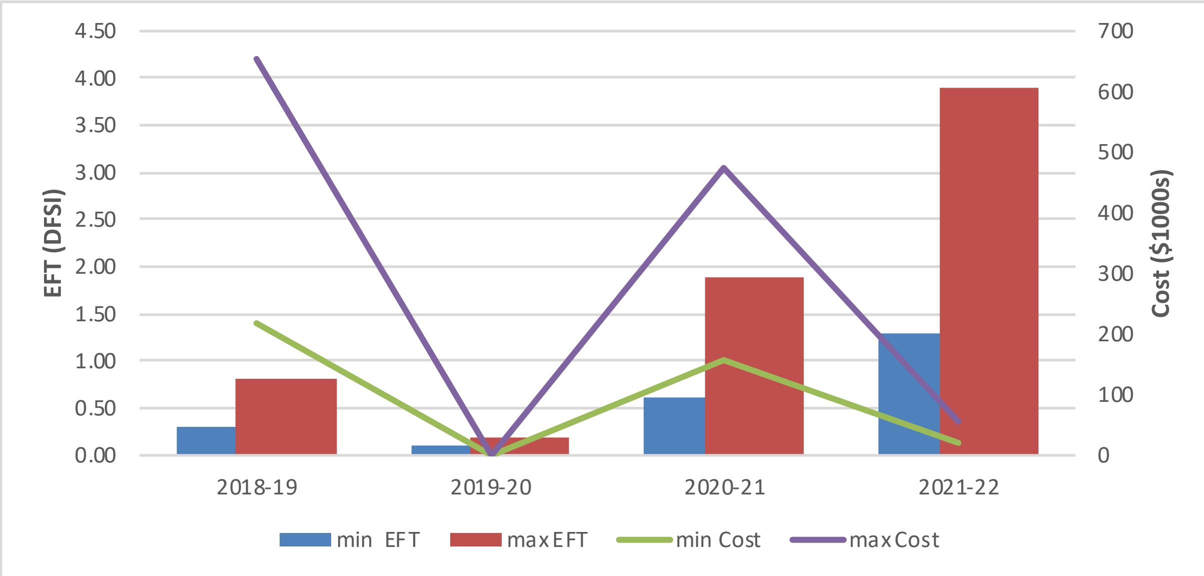


Figure 14 VROOM Cost and Effort estimates for transition

As the diagram shows, the costs for NSW Spatial Services can go up to $650K per year in year 1 (mainly for developing the business case and skills & knowledge management), and year 3 (primarily for technology development), plus up to four full-time equivalent Spatial Services staff in year 4 (mainly for skills & knowledge management). In year 2, the cost and effort for NSW Spatial Services are limited, as most of the activities for (inter-) national coordination.

Note that:

- These costs and efforts are limited to the ATRF transition of the NSW DCDB, and are additional to GDA2020 implementation costs and effort;
- They are initial estimates, and are likely to change when further validated and refined during phase 3 of the project;
- EFT estimates are for DFSI Spatial Services staff only;
- Costs are external costs to DFSI Spatial Services, for technology and external contractors, and don't include any costs for other organisations;
- This excludes any costs or staff requirements to other NSW government departments, other jurisdictions, or users (e.g. local government);
- Collaboration and coordination with other jurisdictions could lead to cost and effort sharing and associated savings.

5 Maintenance and Coordination

This section presents the outcomes of the third project phase (originally titled "New Tools and Procedures"). It covers the original scope as presented in section 2.1, as well as additional scope amendments described in the next section.

The first two project phases have separate (interim) reports with detailed outcomes and are summarised earlier in this final report. The third phase is covered in full in this document.

5.1 Scope & Approach

The original scope of this stage of the project has been reviewed and amended in consultation with the project sponsors CRCSI, ICSM and NSW Spatial Services. This was done to include the experiences and evolving knowledge from the first two project stages, and to ensure best value outcomes for the project sponsors.

The scope was adjusted to include the original three research questions:

Phase 3 – New Tools & Procedures
• What maintenance systems and processes will be essential to support the digital cadastre and how can current systems be migrated to a dynamic datum?
• What additional tools and services will be required to maintain relationships to other spatial and a-spatial datasets?
• How can the integrity of the cadastre be maintained in the context of a dynamic datum?

Augmented with additional research questions:

Ancillary Phase 3 Research Questions
• What differences exist between jurisdictions in terms of starting point, capability, technology etc?
• How universal are the findings for NSW, and how can they be enhanced from, or extended to, other jurisdictions? (extending from phase-1)
• What are the 'gaps' between the GDA2020 implementation plan, and specific ATRF transition needs? (functional, application domains) (extending from phase-2)
• What are the options (delivery scenarios) for providing ATRF datum transformation to end-users, and how do they compare between jurisdictions

To answer these questions, we engaged with all of the jurisdictions through an online questionnaire, followed by a one-on-one phone interview. We compiled initial jurisdictional findings and presented those for discussion and validation to the ICSM Permanent Committee for the cadastre (PCC) on May 14th.

Details of the stakeholders we engaged with, and the questionnaire outcomes, are presented in Appendix 3.

5.2 Ongoing Maintenance

This section looks at the maintenance systems, processes, tools and services that will be required for implementation and enduring support of ATRF for the NSW cadastre specifically, and more generally nationally and for related (downstream) datasets as well.

5.2.1 Systems & Processes

This section addresses the first research question:

What maintenance systems and processes will be essential to support the digital cadastre and how can current systems be migrated to a dynamic datum?

This question is answered within the scope of ATRF enablement of the digital cadastre and assumes GDA2020 implementation is already in place.

The critical systems and processes to be put in place will be largely of a technical nature.

5.2.2 DCDB Maintenance and Supply

The DCDB maintenance database is the authoritative storage mechanism for the NSW digital cadastre. It is where data is continually updated, and topological integrity is maintained. It is separate from the delivery environment, which is the point from where data is supplied to DCDB users.

As part of the GDA2020 implementation, the coordinates in the maintenance database will be transformed from GDA94 to GDA2020. For pragmatic reasons, the maintenance database will need to retain static coordinates; it is simply too problematic and computationally complex to continuously adjust DCDB coordinates with each new epoch.

Hence there will be no need for migrating the DCDB maintenance database to ATRF, i.e. no additional work is needed on the DCDB maintenance database beyond 2020.

As shown in section 4.3, at least for a transitional period, selected users and customers will need to have DCDB coordinates delivered on-demand in ATRF for a given epoch, as well as in GDA94 and GDA2020. This will require the establishment of supply services that can perform real-time coordinate transformations. Such a supply capability will need to be in place at least until automated coordinate transformation is ubiquitously available to end-users.

Supplying ATRF coordinates can be achieved in several ways. One mechanism is to recalculate coordinates in real-time for any given epoch, for a requested set of parcels. Alternatively, the delivery environment could cache ATRF ‘snapshots’ for a given epoch frequency. That way a full transformation would be done for instance every 3 or 6 months, and the customer can request the data for a snapshot epoch closest to their target epoch.

How Spatial Services chooses to implement the ATRF delivery environment will depend on several factors, including users’ positional accuracy needs, computational complexity, and costs. The proposed implementation plan (presented in section 4.5.4) recommends an ‘Industry Impact Analysis’ to further address these factors.

5.2.3 Survey Marks

Coordinates for Survey Marks will need to be available on-demand to users in GDA2020 and ATRF for any given epoch. These coordinates have accuracy requirements that are an order of magnitude higher than DCDB coordinates, so epoch snapshots (which may be several centimetres away from today’s dynamic coordinates) will not be sufficient.

Note that the current NSW Survey Control Information Management System (SCIMS) does not have this capability and will need to be upgraded. A project is under way for this purpose, either as a stand-alone upgrade or replacement, or by adopting, and if needed adapting, Victoria’s Survey Marks Enquiry Service (SMES) solution.

5.2.4 Nationally Shared Resources

A successful and sustainable ATRF implementation in NSW will rely on several resources and artefacts that would ideally be (or already are) implemented as nationally shared resources; saving money and effort and ensuring national consistency.

The transition roadmap (section 4.5.4) strongly recommends the establishment of a national coordination and leadership group. This group should establish, maintain and share resources that can be accessed by all jurisdictions. Until now, ICSM’s GDA Modernisation Implementation Working

Group (GMIWG) leads the coordination, awareness raising, and creation of shared products and tools such as transformation grids and software plugins[10].

For ATRF (and datum modernisation in general) implementation and maintenance, resources that would lend themselves to being shared nationally include:

- Demonstrators
- Education materials
- NTV2 grids (for GDA2020 transformation & distortion parameters)
- ATRF transformation parameters
- Online transformation service (upgrading the current GDA2020 facility at http://positioning.fsdf.org.au/ to ATRF and enabling full dataset transformations)
- Metadata & standards specifications

5.3 Additional Tools and Services

This section addresses the second phase 3 research question:

What additional tools and services will be required to maintain relationships to other spatial and a-spatial datasets?

In addition to providing ATRF coordinates for the DCDB and Survey Marks, there is a large user community that derives business value from relating parcel boundaries to other downstream datasets. For example, a developer may want to place their Building Information Model (BIM) within the parcel footprint; or a utilities manager needs to know which of their assets are inside a property boundary.

Most use-cases rely on relative positioning; that is, as long as both datasets use the same coordinate reference frame, and have known positional uncertainties, the absolute coordinates are less relevant. Even when GNSS data points are included in the analysis, knowledge of, and the ability to transform the coordinates is the minimum requirement for performing meaningful analysis.

In principle, the tools and services to maintain these relationships are already provided under the recommendations in the previous section: transformation tools, and appropriate metadata for a person or machine to identify the coordinate reference systems and positional uncertainties of the datasets to be combined.

These tools are technical, and the primary ones are:

- Metadata specifications and implementation

  So that users can reliably combine data from different sources, understanding their respective positional uncertainties, coordinate reference systems and where applicable, epochs.
- Online self-service transformation service; and
- Off-the-shelf transformation software as it becomes available.

In addition, we have to assume that a significant proportion of the users involved in these kinds of use-cases are casual user who we cannot expect to have an in-depth knowledge and awareness of the issues, tools and best-practices involved.

[10] http://www.icsm.gov.au/datum/who-managing-gda-modernisation

Therefore, what is also needed is an ongoing, targeted approach to raising awareness about the impact and implications of ATRF, reaching out to businesses, developers and geospatial specialists. This is a non-technical, set of tools and services that will require ongoing attention and updates, especially as devices and datasets get more accurate, and the user-base expands.

Tools and services that fall in these categories are expected to include demonstrators, knowledge resources, and outreach and education. The transition roadmap (section 4.5.4) foresees demonstrators to be developed from 2018-19 onwards, and knowledge resources and outreach & education from 2020-21.

5.4 Maintaining Cadastral Integrity

The third research question in this section is:

How can the integrity of the cadastre be maintained in the context of a dynamic datum?

The integrity of the cadastre itself has three key aspects[11]:

1. Guarantee of title (ownership);
2. Accurate representation of parcel shape and size; and
3. Accurate representation of neighbouring parcels ('abuttals').

The only potential impact of a dynamic datum is on the second aspect: representation of the parcel shape and size, and then primarily if there are distortions and rotations in the transformation, which in Australia is rarely the case, and which are considered out of scope for ATRF enablement of the cadastre (see section 2.1.1).

Evidence to determine the legal cadastral boundaries can be broken down into three elements: the real world (physical boundaries) and two man-made representations (documentary and spatial boundaries), as illustrated in Figure 15 below.

[11] Source: verbal communication from Donald Grant, RMIT. The accuracy of the location of the cadastral parcel is of less importance to cadastral integrity, though it becomes important when relating the DCDB to other spatial datasets, as discussed later in this section.

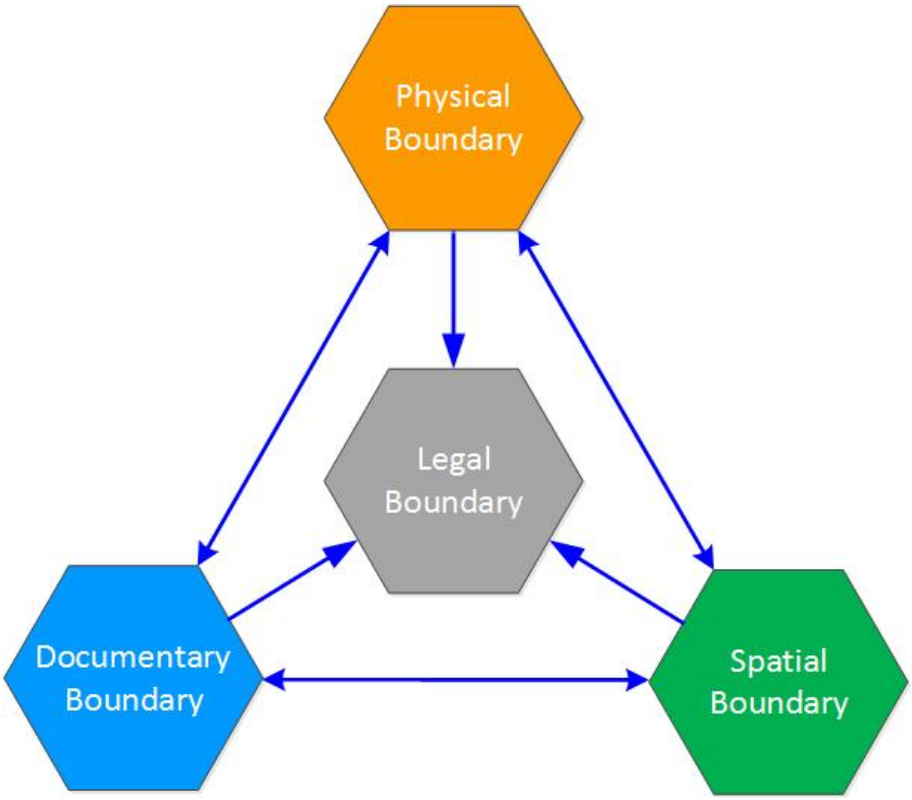


Figure 15 Evidence for determination of legal boundary. Source: Grant, Donald (2018), "Upgrading Spatial Cadastres in Australia and New Zealand: Functions, Benefits and the Optimal Spatial Uncertainty".

The **physical boundary** is made up of monuments, real world phenomena such as creeks, and survey marks. NSW, as most other jurisdictions, has a monumented cadastre, and boundary coordinates are legally defined in terms of bearings and distances connected to Survey Marks. Cadastral integrity is maintained as long as the Survey Mark coordinates are maintained and available in a dynamic datum, and the epoch of survey plan capture is recorded.

The **documentary boundary** is made up of the cadastral records (including digital records). There are no coordinates in the documentary cadastre that would be affected by a dynamic datum, and hence no integrity risk.

The **spatial boundary** is the register of boundary coordinates (aka DCDB). The spatial cadastre (i.e. parcel coordinates) is derived through the survey plan's connection to the survey marks. The integrity is thus maintained by ATRF enablement of the Survey Mark coordinates through SCIMS (or its replacement system). In NSW (and likely in most other jurisdictions as well, as we will see in section 5.5) the DCDB will be maintained in the static datum GDA2020 in the foreseeable future.

Integrity of the spatial cadastre itself is maintained:

- At time of survey plan lodgement by ensuring the DCDB coordinates are derived from the GDA2020 coordinates of the connected marks;
- At time of supply by delivering ATRF coordinates on-demand (derived from transformation)

An important associated aspect of cadastral integrity lies in its function in supporting, through spatial referencing with downstream datasets, the Rights, Responsibilities and Restrictions (RRR) for a piece of land.

Currently, our cadastral systems do not adequately capture the relationships between what can be done on land (rights), what cannot be done (restrictions) and what must be done (responsibilities).

These are currently defined in separate registries, e.g. native title, planning and environmental restrictions, water rights, or fire-and flood zones.

Where the end-user establishes the relationship between RRR registries and the parcel boundaries in the DCDB by spatial overlay, the cadastral integrity becomes important. For instance, the epoch of a dataset becomes extremely important when defending how a specific decision was made (e.g. in court).

As with any relationship with downstream data, this integrity is ensured by the ongoing supply and maintenance of additional tools and services described in section 5.3 above: transformation tools, best-practice guidelines, appropriate metadata, demonstrators, knowledge resources, and outreach & education.

5.5 Jurisdictional Differences and Opportunities

To answer the third and fourth research questions

What differences exist between jurisdictions in terms of starting point, capability, technology etc?; and

How universal are the findings for NSW, and how can they be enhanced from, or extended to, other jurisdictions?

We conducted a questionnaire and a series of telephone interviews with sister agencies in all states and territories, the Commonwealth (through PSMA and Geoscience Australia), as well as New Zealand (through LINZ)[12].

Table 9 summarises the results of the jurisdictional questionnaire and follow-up interviews. For each of the (relevant) research questions, it lists the outcomes that were sought form the jurisdictions, and a summary of responses.

[12] A full list of jurisdictional stakeholders is available in Appendix 3.

Table 9 Summary of Jurisdictional Review

Relevant Research Questions	Outcomes sought from jurisdictions	Summary (interviews & questionnaire)
What differences exist between jurisdictions in terms of starting point, capability, technology etc?	Status of GDA2020 implementation plans (and what are the gaps)	Implementation planning is under way in all jurisdictions. VIC, WA, SA and TAS have documented implementation plans. Trials commenced in several jurisdictions (NSW, WA, SA, GA-marine), but actual implementation is still waiting on funding confirmation or market/legislative imperative. Other jurisdictions (e.g. QLD, VIC) are considering scope, stakeholder impact and costs
	Status of ATRF implementation plans (and what are the gaps)	Initial Implementation Plans in two jurisdictions (TAS, VIC) Focus: post GDA2020 implementation (TAS stated they see it as a seamless evolution from GDA2020 implementation). Concerns: *"Didn't want to create more anxiety on top of GDA2020 anxiety" (NT), "ATRF is not for every user and every application" (WA).* GA Marine: no imperative for ATRF Blank Canvas: opportunity for national approach?
	Target dates (if any): GDA2020	Only 4 jurisdictions have (tentative) implementation dates, majority don't have a date set yet
	Target dates (if any): ATRF	no target dates
	Data supply model (Cadastre, Survey Mark coordinates, Foundation Data)	All: data maintained in static datum: GDA94 or GDA2020 Most plan to transform 'on demand' download and web-service access to ATRF and/or GDA2020 (plus WGS84 for GA), using e.g. Esri or FME services (in the cloud) ATRF supply: subject to data size & accuracy needs (QLD). ACT & GA-Marine: no plans for ATRF supply at this stage NZ: update coordinates in response to major events. No (simple) backward compatibility
	Technology stack / Architecture (now, future) for data supply	Significant diversity in technology stacks, though most have some level of Esri technology included. Many plan to rely on Esri/FME for transformations (in the cloud)
	Key differences in Cadastral environment? (regulation, supply chain, cadastral maintenance systems & processes, other)	There are significant differences in cadastral regulation and lodgement processes. Digital Cadastre systems and maintenance conceptually largely similar (exception: ACT has 'design DCDB', with greater accuracies and different legal status). Impact on ATRF highest where DCDB positional uncertainty is lowest
How universal are the findings for NSW, and how can they be enhanced from, or	Their view of NSW (headline) findings (in general)	Generally deemed to be universal, e.g. - Shield end-users - More than technology - Coordinated approach Many applicable to GDA2020 as well

Relevant Research Questions	Outcomes sought from jurisdictions	Summary (interviews & questionnaire)
extended to, other jurisdictions?		Different expectation levels re. the timely availability of COTS for ATRF transformations ('on the fly') Challenge: overcoming 'fear of change'
	For each of the findings: how do they apply in their jurisdictions. If there are differences, why?	Generally apply universally, with some minor differences: - NZ fundamentally different, semi-dynamic datum only; - GA-marine and ACT have no plans to supply cadastral data in ATRF; - PSMA intends to wait for market signal
	Relevant work, experiences, research, etc. that could be useful to share with NSW (or nationally)	Opportunities: - Tasmania's research for CRCSI (Scott Strong); - SBAS industry group engagement re. accuracy needs (Commonwealth, ICSM have observer role)
	Possible collaboration, cost & effort sharing opportunities	Critical to start now, before jurisdictions are 'locked into' pathways. E.g.: - Shared (hard and soft) infrastructure development (e.g. SMES, transformation tools, factsheets, implementation support, policy and regulation coordination) - Joint efforts to influence international developments to meet specific ANZ needs (e.g. GDAL/Proj4 software library development) - Link to Cadastre 2034 strategy NSW by virtue of leading this project, has an opportunity to set example in a coordinated approach
What are the 'gaps' between the GDA2020 implementation plan, and specific ATRF transition needs? (functional, application domains)	n/a	See section 5.6
What are the options (delivery scenarios) for providing ATRF datum transformation to end-users, and how do they compare between jurisdictions	Delivery model (Cadastre, Survey Mark coordinates, Foundation Data)	All: data maintained in static datum: GDA94 or GDA2020 Most plan to transform 'on demand' download and web-service access to ATRF and/or GDA2020 (plus WGS84 for GA), using e.g. Esri or FME services (in the cloud) ATRF supply: subject to data size & accuracy needs (QLD). ACT & GA-Marine: no plans for ATRF supply at this stage dissenting opinion--> *"Better for government to supply data in a single, authoritative datum ('officially transformed'). Not having to rely on user skills or software reliability."* NZ: update coordinates in response to major events. No (simple) backward compatibility

5.5.1 Key Findings

The main findings from the review with the jurisdictions are:

- GDA2020 implementation is under way in all jurisdictions, albeit at different levels of progress. Most jurisdictions (including NSW) have not committed to dates from which they will deliver (cadastral) data in GDA2020, and some indicate their implementation is still subject to funding and legislative or market demands.
- No jurisdictions have started ATRF implementation planning in earnest, though most recognise the need to do so with the exceptions of GA's Marine Cadastre, New Zealand, and the ACT. The position of the ACT may seem surprising, especially since they have a very high accuracy DCDB, where tectonic movement will start playing a role quite early on. However, the ACT has a more complex set of coordinate reference systems to transform to GDA2020, and seems to be focusing on that issue at the moment;
- The timing of ATRF implementation in the jurisdictions is yet to be determined, creating an opportunity for national harmonisation.
- There is a risk of a disconnect between GDA2020 and ATRF implementation: possibly leading to inconsistency, doubling up on effort, and potential alienation of end-users (as identified in the Impacts Assessment in section 3.3.1). One jurisdiction (Tasmania) explicitly mentioned they see GDA2020 and ATRF implementation as a seamless, evolutionary approach, while others (e.g. NT) are generally concerned about end-user anxiety.

> *"Didn't want to create more anxiety on top of GDA2020 anxiety" (NT)*

- While there are regulatory differences and disparities in the survey plan lodgement process between jurisdictions, these are not considered to have material impact on transforming DCDB management and delivery to ATRF.
- The consensus is that the findings for NSW are generally applicable across all Australian jurisdictions, and everyone is looking forward to an (inter-) nationally coordinated and consistent approach in which NSW, by virtue of its head start, can provide strong national leadership.
  Starting this coordination before individual jurisdictions have committed to a specific course of action, will increase the chances of success.

> *"Coordinated approach now, before jurisdictions are 'locked into' pathways"*

5.6 GDA2020 vs. ATRF Implementation

The relevant research question for this section is:

What are the 'gaps' in implementation between GDA2020 and ATRF?

There are two main observations in response to this research question. Firstly, many of the issues relevant to datum modernisation apply as much to GDA2020 implementation as they do to ATRF implementation. In fact, technically, GDA2020 is equivalent to ATRF with epoch 1 January 2020.

> *"Many of the issues disclosed, whilst focussed on the ATRF, are relevant to stage 1, the GDA2020"*

Secondly, user awareness of ATRF is much lower than of GDA2020. The challenge will be to strike a balance between not overburdening end-users, while delivering a seamless and consistent datum modernisation experience.

5.6.1 Time Dependency

The first implementation gap is the time (epoch) dependency for ATRF. Not only does this require (on-demand) data supply services to be time dependent (and perform time-dependent transformations), more importantly it means ATRF coordinate data will always need to have a timestamp attached to their metadata. That is not trivial, as it requires:

- A broadly adopted metadata schema that supports time-dependent dynamic datums (ISO19111 "Spatial referencing by coordinates" is in the process of adding this in its next version);
- Geospatial data services and related software that support dynamic datums and the relevant standards and transformations; and
- Users and custodians to diligently populate and maintain such metadata.

As Australia is a first mover to implement a dynamic datum, it will need to assume a pro-active position in promoting the development of tools and standards on a global stage. Furthermore, data users and custodians will require education and awareness on the critical importance of time-stamping ATRF datasets.

5.6.2 Adoption

There is a big gap between GDA2020 and ATRF in adoption approach: in market need and timing.

For most stakeholders, adoption of GDA2020 is a must with no alternative. With GDA94 GNSS coordinates will be up to 2 metres 'out', while GDA2020 also improves the distortion grid. The vast majority of data suppliers will deliver GDA2020 (and over time phase out GDA94), and technology vendors are already implementing GDA2020 transformation capabilities across the board.

Adopting GDA2020 will be necessary, and especially with the successful ICSM awareness campaign, relatively easy. States and territories are expected to incrementally supply cadastral and other fundamental data in GDA2020 soon after January 2020.

ATRF on the other hand presents a paradigm shift. Where GDA2020 can be viewed as 'yet another static datum', adding the time dependency adds a significant level of complexity. Market needs are also much lower as presented in section 4.3. The on the ground difference between GDA2020 and GNSS/ATRF coordinates is in the order of centimetres rather than the metre-level between GDA94 and GDA2020. GDA2020 already removes most distortions from GDA94, and initially (in the first 3-5 years) only very few market segments will need to adopt ATRF.

The vast majority of users will therefore move to ATRF implementation well after 2020, and these will be 'disconnected' events. However, early adopters (e.g. councils, asset managers, or utilities) could perceive an implementation gap as disruptive, requiring double work and leading to confusion and an increased risk of users (particularly councils) managing their own cadastre instead.

While all jurisdictions have yet to set a target date for ATRF implementation, it will be critical to a successful ATRF implementation to identify the early adopters and provide them with both technical and educational support.

5.6.3 Overlaps and Similarities

While there are significant implementation gaps between GDA2020 and ATRF, it is important to remember that they are both key planks in Australia's datum modernisation program, and there are many overlaps and similarities in their implementation:

- Both implementations require more than technology to be successful; user awareness training and ongoing communication will be critical;
- Both GDA2020 and ATRF will need to 'just work' for casual and non-expert users. This has implications for the high levels of automation, standards and COTS software support required for implementation;
- National coordination (and for ATRF, international coordination as well) is critical to an efficient and consistent implementation, that maximises take-up and delivers high user satisfaction.

6 Conclusions and Recommendations

6.1 Conclusions

This section presents the outcomes of CRCSI Project 3.20: Implications of a Dynamic Datum on the cadastre, conducted in partnership with NSW Spatial Services and ICSM.

The project's objectives were to document how the cadastre in NSW will be affected by adoption of a dynamic datum, establish and prioritise what tasks need to be undertaken to transition the cadastre in NSW to the dynamic datum (also known as 'ATRF'), and to identify what new procedures and tools will be required for the on-going management of the cadastre once the dynamic datum has been adopted.

While the project scope was focussed on the NSW Cadastre, there are two underlying assumptions. Firstly, that the findings for cadastre can be extended into other Foundation Datasets, and secondly that the findings for NSW can be largely aligned with findings from other jurisdictions.

6.1.1 Impact Assessment

Phase 1 of the project focused on establishing the impact of the dynamic datum. The main conclusions from phase 1 is that while there will potentially be a positive impact of ATRF implementation on the NSW Cadastre, it will be subject to a nationally coordinated implementation that considers many technical, as well as non-technical aspects such as legal and governance issues, user awareness and training, and managing the risk of confusion and complication that might lead cadastral users to managing their own cadastral data, rather than using the government-maintained NSW DCDB.

The analysis identified ATRF impacts, barriers to implementation and expectations regarding the future state. These are summarised below, and also in Table 4 in section 3.3.

6.1.1.1 Impacts

As devices and datasets become more accurate, the impact of ATRF, while small initially, will grow over time, and therefore the 'do-nothing' is not an option. Different user domains will be impacted differently and at different times.

Prospective users are concerned about regulatory impacts, and the complexity of implementing ATRF, especially when transformations are not (yet) supported by off-the-shelf software.

6.1.1.2 Barriers

Variable levels of understanding of datum modernisation and ATRF will be the foremost barrier to implementation. User adoption may be limited through (perceived) complexity and additional efforts required for implementation, and may even drive users away from using the NSW cadastre.

The varied landscape of software tools currently in use will all need to be upgraded to support ATRF transformation, which will take time and may not be ubiquitously available in a timely manner.

For any implementation to be successful, there will be an increased reliance on accurate and complete metadata to indicate the reference framework and epoch (timestamp) of any set of coordinates. Given the current practices in this regard, a significant behavioural change will be required to achieve the required levels of metadata completeness.

6.1.1.3 Future Expectations

Ideally, coordinate transformation will occur at the point of decision making by users (be they GIS specialists or mainstream consumers) and will need to be easy. To quote: "If you don't make it easy for people to do the right thing, you're wasting money on datum modernisation". The community expectation is that in an ATRF implementation (or any datum modernisation for that matter), coordinate transformation 'just works'. Data sources and different datums are aligned 'on the fly', invisible to the end-user: software and applications 'just deal with it'.

A thorough understanding of the impact and mitigation strategies would be needed to prevent ATRF being perceived as a 'solution looking for a problem'.

Data custodians, providers and professional users will need education and awareness raising so that they become conscious of the issues and possibilities. Awareness raising is also required to alert relevant authorities to possible risks and negative impacts over time of a 'do nothing' approach, and the urgency of adopting a sustained and coordinated process.

6.1.2 Transition Tasks

Phase 2 focused on planning for the transition of the NSW Cadastre to ATRF: identifying the transition tasks, devising a roadmap for implementation and providing a cost-estimate. The analysis included identifying the different options to supply ATRF coordinate transformation to end-users; and a market impact analysis to determine which users would be impacted first.

There are two basic options for delivering coordinate transformation: Transformation at Point of Supply (i.e. the data custodian), or Transformation at Point of Decision Making (i.e. the user's device).

For reasons of efficiency and user convenience, in-device transformations at the point of decision making is the preferred option for the long term. However, the feasibility of this option is primarily dependent on in-device commercial off-the-shelf (COTS) transformation capability being widely available. While this is not the case, users will have to rely on others to provide transformation services: either 3rd parties, or the data custodian themselves.

To determine the use-cases in which ATRF coordinates are materially different to GDA2020, and where users can be impacted, we need to consider four accuracy factors that must all intersect for ATRF coordinates to deliver value over GDA2020.

1. The accuracy of the devices;
2. The accuracy (positional uncertainty) of the base-data;
3. The user's accuracy requirements; and
4. The coordinate shift between ATRF and GDA2020.

It is only when all four intersect, i.e. are in the same order of magnitude, (as illustrated in the diagram below) that the use of ATRF coordinates is relevant or required.

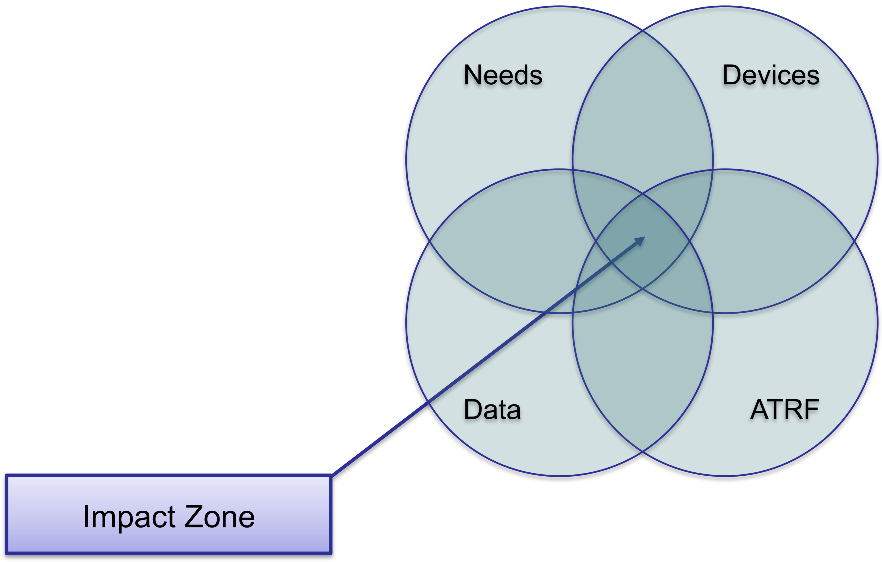


Figure 16 Sweet Spot: when four factors intersect

We know or can assume that:

- **Devices** – Positional accuracy will reach sub-decimetre in consumer GNSS receivers within 5 years (2023)
- **Data** – The "Cadastre NSW" program aims at the NSW DCDB having a positional uncertainty (in urban areas) of 20cm or better from 2020 onwards (in a GDA2020 datum)
- **ATRF** – shifts away from GDA2020 at a rate of 7cm pa; reaching 20 cm from 2023.

The impact zone will only exist where users have a need for 20 cm (or better) positional accuracy when aligning the DCDB with GNSS locations. There is unlikely to be a major market impact before 2023.

The market sectors where the impact will hit first (tier 1) will likely include Asset Management, Land & Property, Smart Buildings and Infrastructure, Smart Cities & Local Government, Utilities, and potentially Environment and Planning (particularly e-Planning).

The ATRF Transition Tasks and Implementation Roadmap consists of five Work Programs required to achieve the Objectives, given the current state. These are Data Supply, Business Case, Leadership & Coordination, Communication & Awareness, and Skills & Knowledge (see Table 8).

The implementation roadmap distinguishes two key transition stages over a 4-year period:

1. Options Analysis and Business Case - this stage is primarily targeted towards preparation, specification and scoping of the transition, and securing any funding requirements.
   This stage will take approximately 18 months, until the GDA2020 epoch: 1 January 2020
2. Coordinated Implementation (from January 2020). There will be about a 2 to 3-year period before mainstream impact of ATRF coordinates.

While it is too early to make definitive statements about the resources required for the Transition, there are some preliminary, Very Rough Order of Magnitude (VROOM) estimates that can be made to give an indication of the scale of the effort required by Spatial Services NSW, and the cost required over time. As shown in Figure 14, the costs for NSW Spatial Services go up to approximately $650K in year 1 (mainly for developing the business case and skills & knowledge management), and $500K in year 3 (primarily for technology development), plus up to four full-time equivalent Spatial Services staff in year 4 (mainly for skills & knowledge management). In year 2, the cost and effort for NSW Spatial Services are limited, as most of the activities are related to (inter-) national coordination.

6.1.3 Maintenance and Coordination

The maintenance systems, processes, tools and services that will be required for implementation and enduring support of ATRF for the NSW cadastre specifically, and more generally nationally and for related (downstream) datasets as well, should include:

- DCDB maintenance can remain with a static datum (GDA2020);
- Supply DCDB coordinates 'on-demand' with transformation to other datums and projections, including GD94 and ATRF;
- Upgrading the Survey Marks database to supply both GDA2020 and ATRF coordinates;
- Coordinate with other jurisdictions to ensure the national supply of shared resources such as transformation parameters, demonstrators, educational materials, as well as nationally coordinated influence on standards and technology development;

It is also critical to maintain the relationships with other, downstream datasets. Needed tools and services include metadata services and implementation, online transformation services, COTS software as it becomes available, knowledge and educational services.

ATRF has limited potential impact on cadastral integrity. The relatively minor risks in this area can be mitigated through ATRF enablement of the Survey Mark database and the DCDB, as well as the other identified tools and services.

The main outcomes from the review of the NSW findings with other jurisdictions are:

- GDA2020 implementation is under way in all jurisdictions, albeit at different levels of progress. Most jurisdictions (including NSW) have not committed to dates from which they will deliver (cadastral) data in GDA2020, and some indicate their implementation is still subject to funding and legislative or market demands.
- No jurisdictions have started ATRF implementation planning in earnest, though most recognise the need to do so with the exception of GA's Marine Cadastre, New Zealand, and the ACT.
- The timing of ATRF implementation in the jurisdictions is yet to be determined, creating an opportunity for national harmonisation.
- There is a risk of a disconnect between GDA2020 and ATRF implementation: possibly leading to inconsistency, doubling up on effort, and potential alienation of end-users.
- While there are regulatory differences and disparities in the survey plan lodgement process between jurisdictions, these are not considered to have material impact on transforming DCDB management and delivery to ATRF.
- The consensus is that the findings for NSW are generally applicable across all Australian jurisdictions, and everyone is looking forward to an (inter-) nationally coordinated and consistent approach in which NSW, by virtue of its head start, can provide strong national leadership.

Regarding the relationship between GDA2020 and ATRF, there are two main observations. Firstly, many of the issues relevant to datum modernisation apply as much to GDA2020 implementation as they do to ATRF implementation. Secondly, user awareness of ATRF is much lower than of GDA2020. The challenge will be to strike a balance between not overburdening end-users, while delivering a seamless and consistent datum modernisation experience.

As Australia is a first mover to implement a dynamic datum, it will need to assume a pro-active position in promoting the development of tools and standards on a global stage. Furthermore, data users and custodians will require education and awareness on the critical importance of time-stamping ATRF datasets.

For most stakeholders, adoption of GDA2020 is a must. ATRF on the other hand presents a paradigm shift, adding the time dependency adds a significant level of complexity. Market needs for ATRF are also much lower and initially (in the first 3-5 years) very few market segments will be sufficiently affected to warrant adoption of ATRF.

The vast majority of users will therefore commence ATRF implementation well after GDA2020, and these will be 'disconnected' events. However, early adopters (e.g. councils, asset managers, or utilities) could perceive an implementation gap as disruptive, requiring double work and leading to confusion and an increased risk of users (particularly councils) managing their own cadastre instead.

While all jurisdictions have yet to set a target date for ATRF implementation, it will be critical to a successful ATRF implementation to identify the early adopters and provide them with both technical and educational support.

6.2 Consolidated Research Questions

The table below consolidates the research questions for this project, and summarises the responses. It combines both the original research questions, and the ancillary research questions that were added during the course of the project.

Table 10 Consolidated Responses to Project Research Questions

Research Question	Response
What legislative barriers exist and what changes might be necessary to support the cadastre in the context of a dynamic reference frame?	As a legal barrier to datum modernisation in NSW, the NSW Surveying and Spatial Information Act prescribes that surveys in NSW must be carried out by reference the "Geocentric Datum of Australia" (as adopted by ICSM in 1990; i.e. GDA94) as the coordinate reference system to be used[13]. Any formal change to GDA2020 or ATRF would therefore require a legislative change. Councils are concerned about confusion and possibly being open to legal action when, due to differences in coordinates, discrepancies occur between e.g. the zoning constraints of a property on the e-planning portal, vs. a section-149 certificate council has issued.
How can the integrity of the cadastre be maintained in the context of a dynamic datum?	The main challenge won't be technical or legal, but instead managing the people-factor. A major risk that respondents raised was that if the cost and complexity of ATRF implementation becomes prohibitive, or it the implementation leads to reduced confidence in the (digital) cadastre, even more users may decide to maintain their own cadastre, rather than use the NSW DCDB. Any implementation must focus on the required change in human knowledge, behaviours and practices. It must be easy for people to 'do the right thing'. Stakeholders expect the digital cadastre to continue to be maintained and supplied in a plate fixed reference frame (GDA2020) for the foreseeable future. At the same time, the data and technology providers must shield end-users from coordinate transformation details. It 'should just

[13] http://www8.austlii.edu.au/cgi-bin/viewdoc/au/legis/nsw/consol_act/sasia2002362/s4.html

Research Question	Response
	work', and will be enabled by rich metadata, mandated standards and a broad availability of ATRF-enabled COTS software. The dynamic datum/ATRF presents no issues with Survey Plans, which are presented as measurement, and have timestamped coordinate listings. However, SCIMS may be ATRF enabled to meet demand to supply coordinates for any given epoch. The DCDB will require proper metadata management and availability of transformation services to ensure proper coordinate alignment. The impact of ATRF on cadastral integrity is limited to the accuracy and integrity of Survey Mark coordinates, and the ability to supply DCDB coordinates of a known datum and positional uncertainty. Early ATRF enablement of SCIMS (or its successor) and the DCDB supply services will address integrity maintenance. Integrity of associations with (not physically linked) Rights, Responsibilities and Restrictions registries can be ensured through maintenance of relationships with downstream databases as described in the previous research question.
What impact will a dynamic datum have on the legal definition and re-identification of property boundaries?	Several stakeholders identified as key barriers the lack of a coordinated and mandated cadastral update process, user uncertainty about cadastral accuracy, and the lack of a single, co-ordinated cadastre. They raised the possibility that with improved accuracy and ATRF, the DCDB could further evolve into the de-facto authoritative source of parcel information, which over time could open the door to the establishment of a co-ordinated cadastre, where the DCDB becomes the (de-facto) authoritative source and legal basis for property boundaries.
What impact will a dynamic datum have on the cadastral data supply chain (eg plan preparation by surveyors, data validation, approvals by councils and others etc)?	Only 9% of users expect ATRF to have a positive impact on the land development process, as opposed to 35% who think it will have a negative impact. There will be limited impact on survey plans lodged with NSW LRS (previously LPI). There is a regulatory requirement to connect these to the control network. This is done by listing the relevant permanent survey mark IDs on the plan, as well as the survey date. The coordinates of these marks are obtained from the SCIMS database, which can be made time dependent when ATRF is implemented. Stakeholders expect the digital cadastre to continue to be maintained in a plate fixed reference frame (GDA2020) for the foreseeable future. Councils are concerned about confusion and possibly being open to legal action when, due to differences in coordinates, discrepancies occur between e.g. the zoning constraints of a property on the e-planning portal, vs. a section-149 certificate council has issued.

Research Question	Response
What differences exist between jurisdictions in terms of starting point, capability, technology etc?	Currently, no jurisdictions have any published plans for ATRF implementation. In that light, it is difficult and possibly premature to draw definitive conclusions regarding their capabilities or technical readiness. Material differences between jurisdictions in legislation/regulation and cadastral accuracy determine differences in expected impact of ATRF implementation.
How are other spatial and a-spatial datasets linked to the cadastre and will those links still be valid in the context of a dynamic datum?	The user expectation is that as a key fundamental dataset and crucial decision support tool, the cadastre should be of the same accuracy as its related (or 'downstream') datasets, such as transportation, planning or utilities, which often coincide, or have a fixed relative spatial relationship with the cadastre. The accuracy of these datasets is improving, as is the spatial accuracy of the cadastre under the Cadastre NSW program. The impact of ATRF will therefore grow with increasing downstream data accuracy and evolving user expectations. There are, however, possible issues with downstream data products. In the majority of cases, similar or related spatial features are not topologically linked between datasets, so when the DCDB moves over time in an ATRF context, other datasets that are not ATRF enabled, will increasingly shift away from the cadastre. This impact will be highest where the DCDB accuracy is highest, i.e. in urban centres (sub decimetre). For other areas, DCDB accuracy will need improvement before the difference between GDA2020 and ATRF will become relevant.
How does the impact of ATRF differ from that of Datum Modernisation & GDA2020 in general?	The main differences identified so far are: • Where GDA2020 implementation planning is well advanced, there are no published ATRF implementation plans; • While GDA2020 is fundamentally a 're-set' of a plate-fixed reference system, ATRF represents a paradigm shift to an earth-fixed, time dependent system; • ATRF will require substantial upgrades to software, databases and (meta-) data formats to include time-enabled coordinates and coordinate transformations; • Existing NSW infrastructure (such as SCIMS and the DCDB) does not (yet) support the delivery of data in multiple reference systems (e.g. both GDA2020 and ATRF).
How can the findings for the cadastre be extended to other spatial (foundation) datasets?	Findings for the cadastre regarding technology, standards and people impacts are largely equally relevant for other datasets. The main exceptions are findings that are specific for the (NSW) cadastre, such as the legal barriers, and the risk of stakeholders (e.g. councils) abandoning the DCDB and maintaining their own. Different spatial (foundation) datasets have different requirements regarding data accuracy, and different levels of business impact of reduced data accuracy. Therefore, different data- and user domains will be impacted at different times, and identifying the ones that will be impacted earliest will be crucial for transition planning. ATRF will potentially impact providers of larger data stores, such as imagery, as 'on the fly' coordinate conversions in many cases may become too computationally complex. These providers would be limited in their ability to deliver data in ATRF.

Research Question	Response
How universal are the findings for NSW, and how can be enhanced from other jurisdictions?	Currently, no jurisdictions have any published plans for ATRF implementation. In that light, it is difficult and possibly premature to draw definitive conclusions regarding ability to enhance NSW findings. Material differences between jurisdictions in legislation/regulation and cadastral accuracy determine differences in expected impact of ATRF implementation. While there are regulatory differences and disparities in the survey plan lodgement process between jurisdictions, these are not considered to have material impact on transforming DCDB management and delivery to ATRF. The consensus is that the findings for NSW are generally applicable across all Australian jurisdictions, and everyone is looking forward to an (inter-) nationally coordinated and consistent approach in which NSW, by virtue of its head start, can provide strong national leadership.
What other information (eg Remote Sensing data) could supplement existing data resources to address issues related to moving to a dynamic datum? (link to related research project "Upgrading the spatial accuracy of the digital cadastre – a pilot study")	This is of little impact in NSW, as Survey Plans are connected to survey control, and a cadastral upgrade program is already under way (Cadastre NSW) to improve DCDB accuracy. It might play a more relevant role in other jurisdictions (e.g. QLD) where plans are not always connected to control. The related research project shows early encouraging results in this area, but the methodology would need further maturing.
What sectors and applications will be affected by ATRF, by when, and what is their value proposition for adoption?	See section 4.3. Sectors likely to be affected first include Asset Management, Land & Property, Smart Buildings and Infrastructure, Smart Cities & Local Government, Utilities and possible Environment and Planning (particularly e-Planning).
Should NSW government supply DCDB (and/or SCIMS) data in GDA2020 only, or also in ATRF?	This will depend on the technical and financial feasibility of providing 'on demand' ATRF web-services for the DCDB and on whether the impacted user communities will have access to in-device transformation capabilities. This will need further analysis during the Transition: conducting a proof-of-concept demonstrator to assess the feasibility and engaging with (international) vendors to determine the expected timeline for availability of in-device transformation software.
What maintenance systems and processes will be essential to support the digital cadastre and how can current systems be migrated to a dynamic datum?	The DCDB will not need to be migrated to ATRF but will need to be delivered on-demand with ATRF to any given epoch. Coordinates for Survey Marks will need to be available on-demand to users in GDA2020 and ATRF for any given epoch. A successful and sustainable ATRF implementation in NSW will rely on several nationally coordinated resources, including demonstrators, education materials, transformation parameters and tools, and metadata standards.
What additional tools and services will be required to maintain relationships to other spatial and a-spatial datasets?	The main technical tools required for maintaining these relationships are metadata specifications and implementation, online self-service transformation services, and off the shelf transformation software. Non-technical tools and services include demonstrators, knowledge resources, and outreach & education. The transition roadmap

Research Question	Response
	foresees demonstrators to be developed from 2018-19 onwards, and knowledge resources and outreach & education from 2020-21.
What are the 'gaps' between the GDA2020 implementation plan, and specific ATRF transition needs? (functional, application domains)	The main gap is the time-dependency of ATRF, which means ATRF coordinate data will always need to have a timestamp attached to their metadata. That is not trivial, and requires technology and metadata upgrades, and an improvement in ATRF awareness and metadata diligence. Another big gap between GDA2020 and ATRF is in the adoption approach: in market need and timing. For most stakeholders, adoption of GDA2020 is a must. ATRF on the other hand presents a paradigm shift. Adding the time dependency adds a level of complexity. Market needs for ATRF are also much lower as presented in section 4.3. The vast majority of users will therefore undertake ATRF implementation well after GDA2020, and these will be 'disconnected' events, possibly leading to inconsistency, doubling up on effort and alienation of end-users. While all jurisdictions have yet to set a target data for ATRF implementation, it will be critical to a successful ATRF implementation to identify the early adopters and provide them with both technical and educational support.
What are the options (delivery scenarios) for providing ATRF datum transformation to end-users, and how do they compare between jurisdictions	All jurisdictions aim to maintain the digital cadastre in a static datum: GDA94 or GDA2020. Three main delivery options were identified: transformation to ATRF by the custodian on delivery; transformation by the user 'in device'; and transformation by the user utilising a 3rd party transformation service. Most jurisdictions plan to transform data to ATRF as 'on demand' download and web-service access using e.g. Esri or FME services (in the cloud).

6.3 Recommendations

In conclusion, we make several recommendations for ATRF implementation, for the NSW cadastre, and also for other jurisdictions and (foundation) datasets:

Recommendation 1: 'Do nothing' is not an option. Increasing user expectations regarding cadastral accuracy, combined with improved accuracy of consumer GNSS devices means that while the impact of ATRF will be small initially, it will grow steadily from 2020 onwards.

Recommendation 2: Any implementation must focus on the required change in human knowledge, behaviours and practices. It must be easy for people to 'do the right thing', and datum transformation should 'just work' for end-users.

Recommendation 3: Ensure a national, and where relevant, internationally coordinated implementation approach. This will support consistency between jurisdictions in e.g. synchronization of epoch snapshots, metadata standards and implementation approach, as well as the shared development of knowledge resources and tools.

Recommendation 4: ANZLIC and ICSM should maintain responsibility for national coordination, in collaboration with the Permanent Committees for the Cadastre and Geodesy (PCC and PCG), and clear accountabilities across the jurisdictions.

Recommendation 5: Utilise expertise and applied research capabilities available through FrontierSI in implementing specific national work packages, e.g. developing metadata specifications, demonstrators or knowledge resources; conducting industry impact analysis; and outreach and education.

Recommendation 6: Establish funded working groups with dedicated personnel at both jurisdictional and national levels, to drive consistent and sustainable implementation and maintenance over the long term.

Recommendation 7: As Australia is a first mover to implement a dynamic datum, it will need to assume a pro-active position in promoting the development of tools and standards on a global stage.

Recommendation 8: Capitalise on the 'blank canvas' opportunity. While no jurisdictions have started ATRF implementation planning, a nationally coordinated approach is more likely to succeed.

Recommendation 9: Specifically for NSW, maintain the momentum that flows from this impact assessment. Start execution of transition roadmap stage 1 (Options Analysis & Business Case) early in FY19, in parallel with GDA2020 implementation.

Recommendation 10: Integrate GDA2020 and ATRF implementation into a coordinated datum modernisation experience.

Recommendation 11: Conduct further industry impact analysis to identify early adopters and target them with both technical and educational support.

Recommendation 12: Make sure the ATRF (and GDA2020) implementation addresses not only data and technology aspects, but also standards, people and governance dimensions.

Recommendation 13: Upgrade NSW SCIMS (or equivalent) to enable delivery of coordinates in both static (GDA2020) and dynamic (ATRF) datums.

Recommendation 14: Maintain NSW DCDB coordinates in a static (GDA2020) datum. Enable 'on-demand' supply of DCDB coordinates in ATRF, at least for a transitional period.

Recommendation 15: NSW Spatial Services should conduct proof-of-concept demonstration trials to test the feasibility and computational complexity of on-demand ATRF delivery of the DCDB.

Appendix 1. Glossary & Definition of Terms

Term	Definition
AGD66	Australian Geodetic Datum 1966 (AGD66), since replaced with GDA94. http://www.icsm.gov.au/gda/agd.html
ATRF	Australian Terrestrial Reference Frame. Earth fixed, and therefore time dependent coordinate, reference frame
Cadastre	A Cadastre is normally a parcel based, and up-to-date land information system containing a record of interests in land (e.g. rights, restrictions and responsibilities). It usually includes a geometric description of land parcels linked to other records describing the nature of the interests, the ownership or control of those interests, and often the value of the parcel and its improvements
Cadastre NSW	Cadastre NSW is a Spatial Services program to address key barriers to the adoption of a single land cadastre for NSW
COTS	Commercial Off The Shelf – mostly referring to software products
CRCSI	Cooperative Research Centre for Spatial Information. http://www.crcsi.com.au/
DCDB	The NSW Spatial Services' Digital Cadastral Database (DCDB) is a digital representation of the cadastre of New South Wales (NSW). http://spatialservices.finance.nsw.gov.au/mapping_and_imagery/cadastral_data
Digital Cadastre	A database of cadastral survey data relating to cadastral boundaries within a jurisdiction. The Digital Cadastre is also often referred to as the Digital Cadastral Database (DCDB) or the Spatial Cadastral Database (SDCB) in the case of Western Australia
Downstream Data	Datasets that are derived from, or have a fixed spatial relationship with the cadastre, such as transportation, planning or utilities. (see also Impacted Data).
Dynamic Datum	A dynamic datum (alternative term often used instead of Earth Fixed Reference Frame) allows the changes in coordinates of points on the Earth's "dynamic" surface to be referenced and represented. ATRF is an Australian example of a dynamic datum. http://www.ga.gov.au/scientific-topics/positioning-navigation/datum-modernisation
Earth-fixed	As an alternative to a "plate-fixed" datum, a national geodetic datum may be defined like the ITRF so that its axes appear to co-rotate with Earth in its motion in space and are "fixed" to the whole solid Earth, rather than a tectonic plate.
Epoch	Timestamp of a reference frame
FrontierSI	Successor of CRCSI, post July 2018
GDA2020	The Geocentric Datum of Australia 2020 (GDA2020) is a new Australian plate fixed national datum that will replace the current GDA94 by 1 January 2020. http://www.ga.gov.au/scientific-topics/positioning-navigation/datum-modernisation
GDA94	Geocentric Datum of Australia 1994 (plate fixed). http://www.icsm.gov.au/gda/gda94.html
GNSS	Global Navigation Satellite System.The standard generic term for satellite navigation systems that provide autonomous geo-spatial positioning with global coverage. Common GNSS Systems are GPS, GLONASS, Galileo, Beidou and other regional systems.
GPS	The GPS (Global Positioning System) is a "constellation" of approximately 30 well-spaced satellites that orbit the Earth and make it possible for people with ground receivers to pinpoint their geographic location.
ICSM	Intergovernmental Committee on Surveying and Mapping. ICSM's role is to provide leadership through coordination and cooperation in surveying, mapping and charting. http://www.icsm.gov.au/
ICSM PCC	Permanent Committee on Cadastre. Subcommittee of ICSM
ISO TC211	A standard technical committee formed within ISO, tasked with covering the areas of digital geographic information and geomatics. http://www.isotc211.org/
Impacted Data	Datasets that are often used in analysis of their relationship to the cadastre, for instance bushfire zones or imagery (see also Downstream Data).
ITRF	International Terrestrial Reference Frame. International realisation of an Earth fixed geocentric system of coordinates. http://itrf.ensg.ign.fr/
LandXML	LandXML is a specialized XML (eXtensible Mark-up Language) data file format containing civil engineering and survey measurement data commonly used in the Land Development and Transportation Industries.
OGC	Open Geospatial Consortium. An international not-for-profit organization committed to making quality open standards for the global geospatial community. http://www.opengeospatial.org/

Term	Definition
Plate-fixed	A national geodetic datum may be defined by reference points that are said to be “fixed” to one of the Earth’s tectonic plates. The reference points move along with the tectonic plate and the coordinates appear to be unchanging with time.
SCIMS	The NSW Survey Control Information Management System (SCIMS) is a database that contains all of the coordinates, heights and related information for NSW survey marks that form the official State Survey Control Network (SCIMS). http://spatialservices.finance.nsw.gov.au/surveying/scims_online
SMES	Survey Marks Enquiry Service (Victorian equivalent of SCIMS)
Positional Accuracy	Also known as absolute or spatial accuracy, spatial accuracy refers to the quality of a coordinate with respect to the coordinate reference system
Relative Accuracy	The quality of a coordinate with respect to nearby features
WGS84	WGS84 is an Earth-centred, Earth-fixed terrestrial reference system and geodetic datum used by the US Military for its GPS navigation satellite system. https://en.wikipedia.org/wiki/World_Geodetic_System

Appendix 2. Document Register

The table below lists all documents received and consulted as part of this research.

Title	Date	Type	Source
2017-09-01-vic-spatial-summit-gda2020-fraser.pptx	1-Sep-17	Presentation	Roger Fraser (VIC office of Surveyor General)
20170331_Gowans_CSA_conf_GDA2020	14-Aug-17	Presentation	Nic Gowans, through Adrian White
Australia on the move: how GPS keeps up with a continent in constant motion	6-Feb-17	General publication	Chris Rizos (UNSW) & Donald Grant (RMIT), in "The Conversation"
Cadastral Case Study FINAL (002)	26-Oct-17	Research report	Kylie Armstrong (CRCSI)
Cadastre NSW - Stakeholder Analysis Report	6-Apr-16	Research report	Jacobs
Cadastre NSW - Update May 2017.PDF	8-Aug-17	Presentation	Adrian White
Cadastre2034.pdf	7-Jul-05	General publication	ICSM
CORS & Geodesy - Action Plan - 1718 - V1.1	14-Aug-17	Other	Simon McElroy through Adrian White
CRCSI P1.02 Work Package 3 Tasks 2 3 and 4 Consultants Report_July_2017	1-Jul-17	Research report	CRCSI / TAS DPIPWE
Datum Modernisation Implementation Project Plan - Phase 1	1-Apr-16	Trade publication	ICSM
DatumMattersFactSheet1	6-Aug-17	General publication	ICSM
DatumMattersFactSheet2	6-Aug-17	General publication	ICSM
Enabling GDA2020 In the current cadastral and geodetic environment	1-Jul-17	Presentation	Matt Higgins, Geodesy and Positioning Manager. QLD DNRM
GDA2020 Implementation Land Tasmania DRAFT Jurisdictional Plan	1-Aug-16	Research report	TAS DPIPWE Julian Gill | Manager (Spatial Operations) Geodata Services | Land Tasmania
GDA2020, AUSGeoid2020 and ATRF: An Introduction	1-Jan-14	Academic paper	Volker Jansen - NSW Spatial Services, Research@Locate 2014
InterimReleaseNoteV1.0	3-Mar-17	Trade publication	ICSM PCC
Locate 17 Panel discussion - Impacts of Datum – National and International Perspectives	1-Apr-17	Presentation	Michael Giudici, John Dawson, Scott Strong
PCG-SSSC_2013_Canberra	2013	Presentation	ICSM PCC
Report on ACT coordinate datum upgrade (v1.4)	1-Sep-16	Research report	Bill Hirst
Single Land Cadastre for NSW. Co-design workshop, summary of outcomes	2015	Research report	Cofluence
Stakeholder-Requirements-for-Modernising-Australias-Geocentric-Datum	7-Jul-05	Research report	ICSM
SummaryDatumQuestionnaire	1-Jul-16	Research report	ICSM
Utilities and LGA event_GDA2020 100817	10-Aug-17	Presentation	Narelle Underwood
Utilities and LGA event_GDA2020 100817 UPDATED.pptx	10-Aug-17	Presentation	Darren Burns, QLD DNRM
Business Case Framework for Improved Spatial Accuracy in Digital Cadastral Database (DCDB)	1-Jul-03	Research report	Cadastre Limited, commissioned by ICSM
Australia and New Zealand Cadastral Systems Questions and Answers	1-May-11	Research report	ICSM
1Spatial Australian Local Government GIS Survey	1-Oct-14	Research report	1Spatial Australia

Title	Date	Type	Source
Annual Project Delivery Plan. GDA2020 Implementation Project Stage Two (Western Australia)	17-Apr-18	Project document	Landgate WA
GDA2020 Options Evaluation Report (Western Australia)	3-Nov-18	Project document	Landgate WA
GDA2020 DELWP Implementation Plan (Victoria)	1-May-18	Project document	VIC DELWP
Land Tasmania Jurisdicational Report. GDA2020 Implementation v1.3	1-Jul-17	Project document	Land Tasmania
South Australian Government GDA2020 Implementation Project Plan	1-Apr-18	Project document	SA Government
SPEAR Technical Architecture (v1.0)	1-Oct-17	Project document	VIC DELWP
Upgrading Spatial Cadastres in Australia and New Zealand: Functions, Benefits and the Optimal Spatial Uncertainty	1-Jun-18	Project document	RMIT

Appendix 3. Stakeholder Engagement Details

Phase-1 Interviewees

Date	Interviewee(s)	Role	Organisation
13/11/17	Joseph Abhayaratna	CIO	PSMA Australia
	Michael Dixon	Group Manager, Products and Services	
	Brian Burbidge	Product Management	
	Luke Caruan	Data sourcing & Partner management	
13/11/17	John Dawson	Section Leader, Positioning. Geodesy and Seismic Monitoring Branch	Geoscience Australia
18/9/17	Craig Roberts	Senior lecturer	UNSW, School of Surveying and Spatial Information
20/9/17	Mohsen Kalantari	Lecturer in Geomatics	University of Melbourne
5/10/17	Mark Strong	Project Manager, GDA2020 implementation	NSW Spatial Services
17/10/17	Peter Bowen	Manager Spatial Delivery, Business and Information Systems	NSW Department of Planning and Environment
29/8/17	Prof. Clive Fraser		University of Melbourne
Various	Wayne Patterson	Director Spatial Operations	NSW Spatial Services
Various	Narelle Underwood	Surveyor General	NSW Spatial Services
Various	Bruce Thompson	Executive Director	NSW Spatial Services
7/12/17 (TBC)	Lars Hansen	Senior Program Development Manager (SDI)	NSW Spatial Services
	Shem Semple	Manager Design and Delivery	
	Tony Hope	Manager Integrated Spatial Systems	

Phase-1 Workshop Participants

Surveyor's Workshop (ACS NSW, 7 September 2017)

Name	Organisation
Narelle Underwood	NSW Spatial Services
Adrian White	NSW Spatial Services
Ben Meyer	Craig & Rhodes
Craig Turner	SDG
Ruiyuan Li	SDG
Mitchell Ayres	Linker Surveying
Joseph Monardo	Lockley

Supplier's Workshop (Esri Australia, 13 September 2017)

Name	Organisation
Selin Ozdemir	Esri Australia

Name	Organisation
Chris Hoar	NGIS Australia
Dan Smith	AAM
Ed Garvin	Omnilink
Richard Ingham	CR Kennedy
Brett Madsen	Map Data Services
Johan Nel	Open Spatial
Richard Lemon	Jacobs

Phase-2 Workshop Participants

Project Reference Group & User Representatives: Transition Planning Workshops (12 & 20 Dec 2017)

Name	Organisation
Thomas Grinter	NSW Spatial Services
Adrian White	NSW Spatial Services
Melissa Daley	Sutherland Shire Council
Peter Bowen	NSW Office of the Environment and Heritage
Takis Ellis	Sydney Water

CRC Project 3.19 ("Functions & Benefits of the Spatial Cadastre ") Validation Workshop (15-16 Feb 2018)

Name	Organisation
Assoc Prof Don Grant	RMIT (Project Leader)
Assoc Prof David Mitchell	RMIT
Dr Geoff McCamley	RMIT
Dr Russell Priebbenow	QLD Government
Narelle Underwood	NSW Surveyor General
Jeffrey Brown	ACT Surveyor General
Craig Sandy	VIC Surveyor General
Michael Giudici	TAS Surveyor General
Bradley Slape	SA Government
Murray Dolling	WA Government
Mark Dyer	NZ Surveyor General
Eric Sharpham	NSW Government
David Boyle	VIC Government
Roger Fraser	VIC Government

Name	Organisation
Sudarshan Karki	QLD government
Dr Phil Collier	CRCSI Research Director
Prof. Stig Enemark	Aarlborg University, Denmark
Prof. Jaap Zevenbergen	University of Twente, Netherlands

Phase-2 Interviews

Name	Organisation
Brett Madsen	Map Data Services
Richard Lemon	Jacobs
Chris Body	Standards Australia
Lars Hansen, Shem Semple, Tony Hope	NSW Spatial Services, ICT
Shaun Bunyan (and team members)	NSW Spatial Services, Business Development
Simon McElroy, Volker Janssen, Joel Haasdyk, Nic Gowans, Anthony Watson	NSW Spatial Services, Geodesy
Wayne Patterson	NSW Spatial Services
Marc Strong	NSW Spatial Services, GDA2020 Project Manager
Scott Strong	Tasmania, DPIPWE
Michael Giudici	Tasmania, Surveyor General
John Dawson	Geoscience Australia

Phase-3 Questionnaire and Interviews

Name	Organisation
Murray Dolling, Irek Baran	Principal Consultant - Spatial positioning, WA Landgate
Robert Sarib	Surveyor General, NT
Michael Dixon	National Data Aggregator, PSMA Australia
Bradley Slape	Cadastral Specialist, SA
Greg Ledwidge	Deputy Surveyor-General, ACT
Steve Tarbit	Senior Survey Advisor, QLD
Craig Sandy	Surveyor General, VIC
Nic Donnely	Manager Geodetic Infrastructure, Land Information New Zealand
Michael Giudici	Surveyor General, TAS
Mark Alcock, Jonah Sullivan	Director, Maritime Jurisdiction Advice, Geoscience Australia

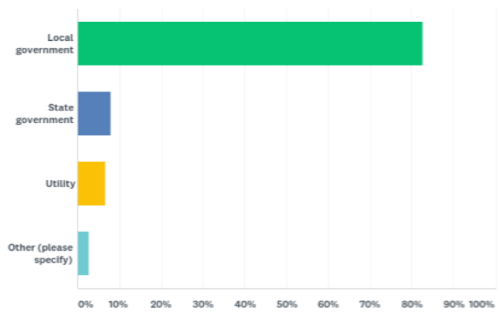
Appendix 4. User Questionnaire Outcomes

This appendix summarises the outcomes of the user questionnaire conducted as part of the Impact Assessment.

About the Survey

- Audience: Cadastral Users in NSW, approached through Spatial Services – BD
- Conducted: 7-15 September 2017
- High response rate: 75 out of approximately 190 approached (~ 40%)
- Respondents:
  - Largely (83%) Local Government, some State Government & Utilities
  - Majority (81%) GIS professionals, some IT/engineering staff

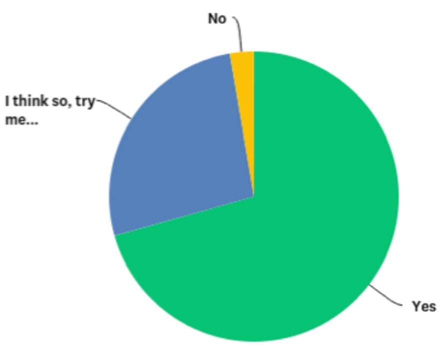
Q1 What best describes the organization you work for?



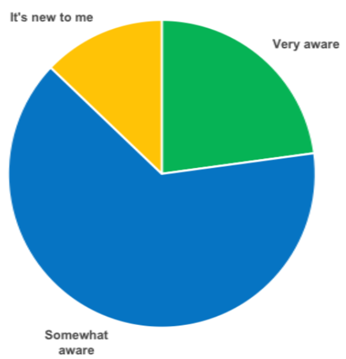
2

Most users know about Datums & Datum Modernisation

Do you know what a 'geodetic datum' or 'geodetic reference frame' is?



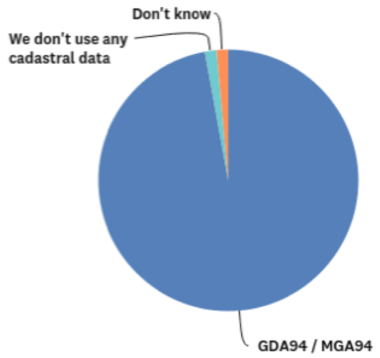
How aware are you of Australia's Datum Modernisation Program?



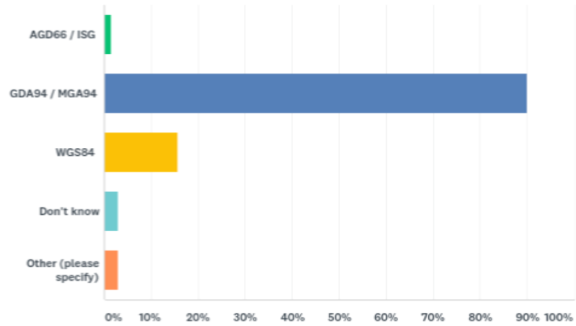
3

GDA94 currently most popular (note 16% WGS84 for other data)

What geodetic datum / coordinate system does your organisation use **for its cadastral data**?



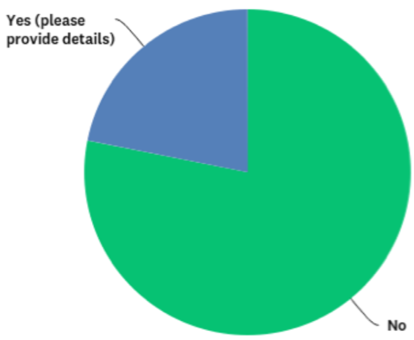
What geodetic datum / coordinate system does your organisation use **for its other spatial data**?



4

Only 20% experience alignment issues GPS vs. GDA94

Have you experienced any data alignment issues as a result of the 1.8m difference between raw GPS coordinates and GDA94?



Misalignment experienced with:

- Assets & utilities (36%)
- GPS data (29%)
- 3rd party data (21%)
- Imagery (21%)
- Cadastral data (14%)

5

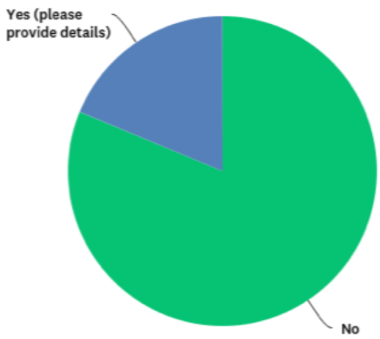
Future Expectations

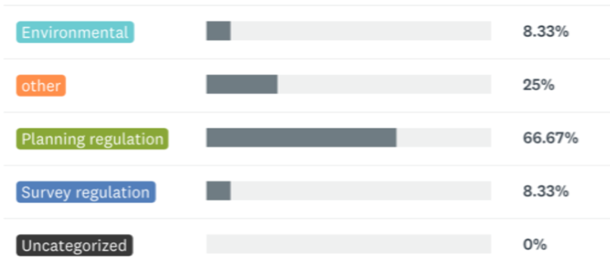
- Legislative of Regulatory issues?
- Impact on Cadastral Integrity?
- Impact on Land Development Process?
- Impact on Related (Linked) Datasets?

6

Some legislative/regulatory issues identified. Mainly regarding Planning (LEPs, 149 Certificates)

Are you aware of any legislative or regulatory issues that would affect or limit the adoption of the dynamic datum for your organisation?

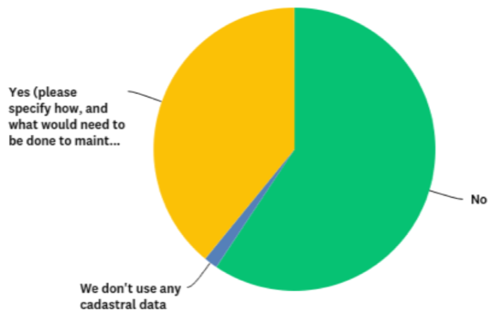




7

40% are concerned about Cadastral Data Integrity being affected: reduced confidence and need for tools to auto-align related data

Would a dynamic datum impact the integrity of your cadastral data, how and what need to be done?



impact: confusion	4%
Impact: less confidence	28.00%
Impact: matches GPS	16%
Need: auto alignment	28.00%
Need: Education	16%
Need: more resources	12%
Need: Tools	28.00%
Other/unknown	16%
Uncategorized	0%

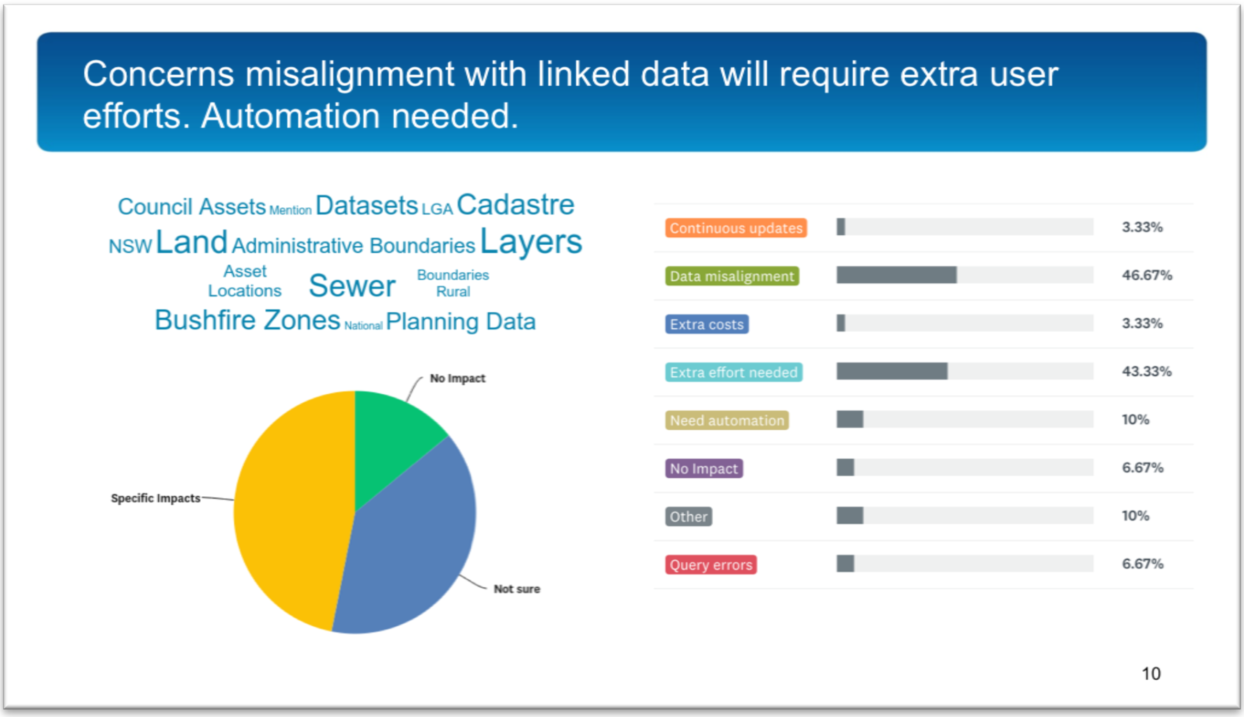
8

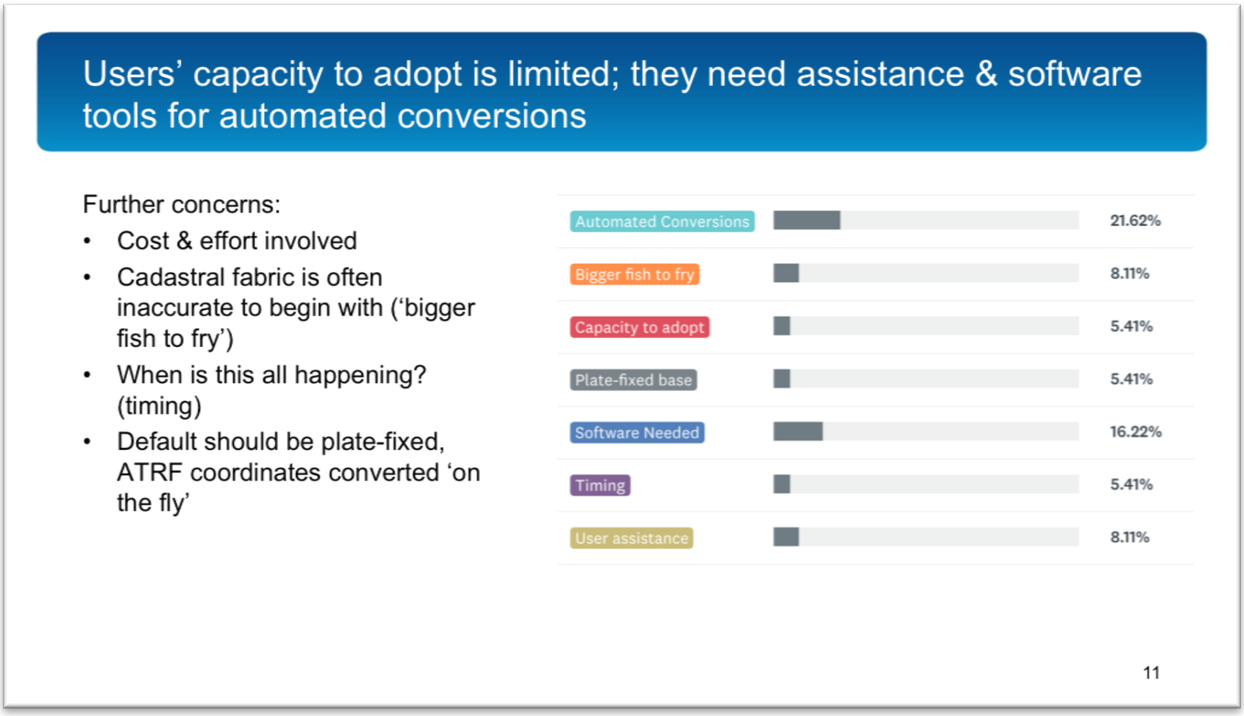
What impact might a dynamic datum have on land development (such as subdivision plan preparation, construction, and approvals)?

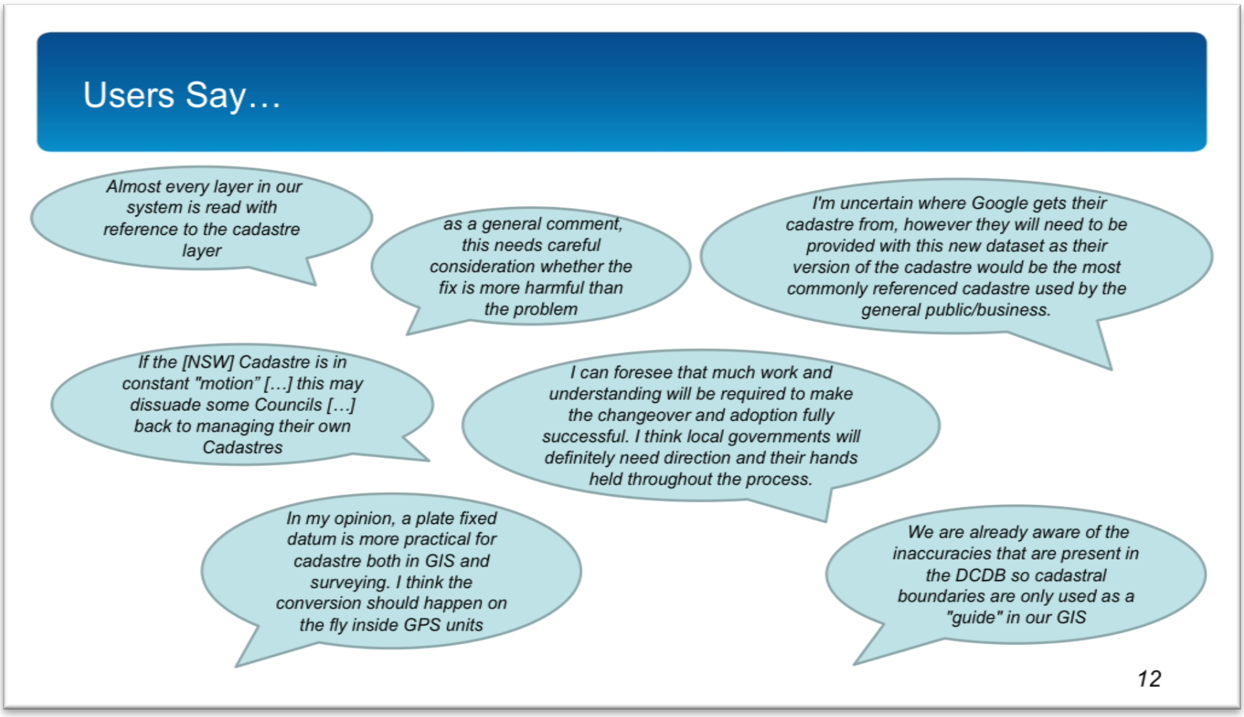
- **Only 9% expect positive impact**
- 55% unsure or no impact
- 20% concerned about data misalignment
- Other concerns include:
  - Confusion and reduced confidence in the process
  - Need for tools to manage transformations

Confusion	9.38%
Extra work	1.56%
Improved accuracy	7.81%
Misalignment linked data	20.31%
No impact	21.88%
Positive	1.56%
reduced confidence	3.13%
Tools needed	6.25%
Unsure	34.38%

9


Concerns misalignment with linked data will require extra user efforts. Automation needed.
Council Assets Mention Datasets LGA Cadastre NSW Land Administrative Boundaries Layers Asset Locations Sewer Boundaries Rural Bushfire Zones National Planning Data
No Impact
Specific Impacts
Not sure
Continuous updates 3.33%
Data misalignment 46.67%
Extra costs 3.33%
Extra effort needed 43.33%
Need automation 10%
No Impact 6.67%
Other 10%
Query errors 6.67%
10


Users' capacity to adopt is limited; they need assistance & software tools for automated conversions
Further concerns:
• Cost & effort involved
• Cadastral fabric is often inaccurate to begin with ('bigger fish to fry')
• When is this all happening? (timing)
• Default should be plate-fixed, ATRF coordinates converted 'on the fly'
Automated Conversions 21.62%
Bigger fish to fry 8.11%
Capacity to adopt 5.41%
Plate-fixed base 5.41%
Software Needed 16.22%
Timing 5.41%
User assistance 8.11%
11



Conclusions

- Reasonable user awareness that GDA2020 and ATRF are imminent
  - Uncertainty of timing and how it will affect their work
- Currently:
  - High adoption levels of GDA94;
  - 80% don't experience GPS alignment issues
- NSW Cadastral ATRF Future:
  - Impacts: Confusion, reduced confidence in Cadastre & Planning process, and misalignment with linked data
  - Risk: Perceived as solution looking for a problem?
  - Needed: Education, Assistance & Automation

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