Implications of a Dynamic Datum on the Cadastre

Phase 2 Interim Report: Transition Tasks

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Version 1.0

Document Control

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Contents

Executive Summary

This document is the interim report presenting the outcomes of phase-2 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 are 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 (technically 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.

Phase 1 of the project focused on establishing the impact of the dynamic datum. The phase-1 findings are summarised in section 1 and a separate phase-1 interim report.

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.

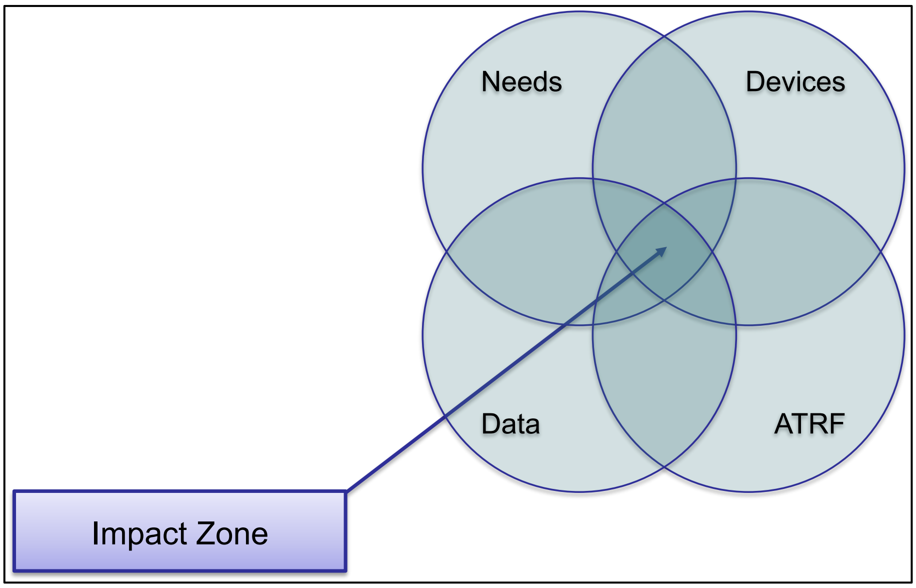
There are two basic options for delivering coordinate transformation: Transformation at Point of Supply (i.e. the data custodian), or Transformation at Point of Decision Making (i.e. the user’s device).

For reasons of efficiency and user convenience, in-device transformations at the point of decision making is the most 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 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; 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.



We know or can assume that:

- **Devices** – Positional accuracy will reach sub-decimeter 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 following Guiding Principles should be applied in the planning and implementation of the ATRF transition:

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 be able 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

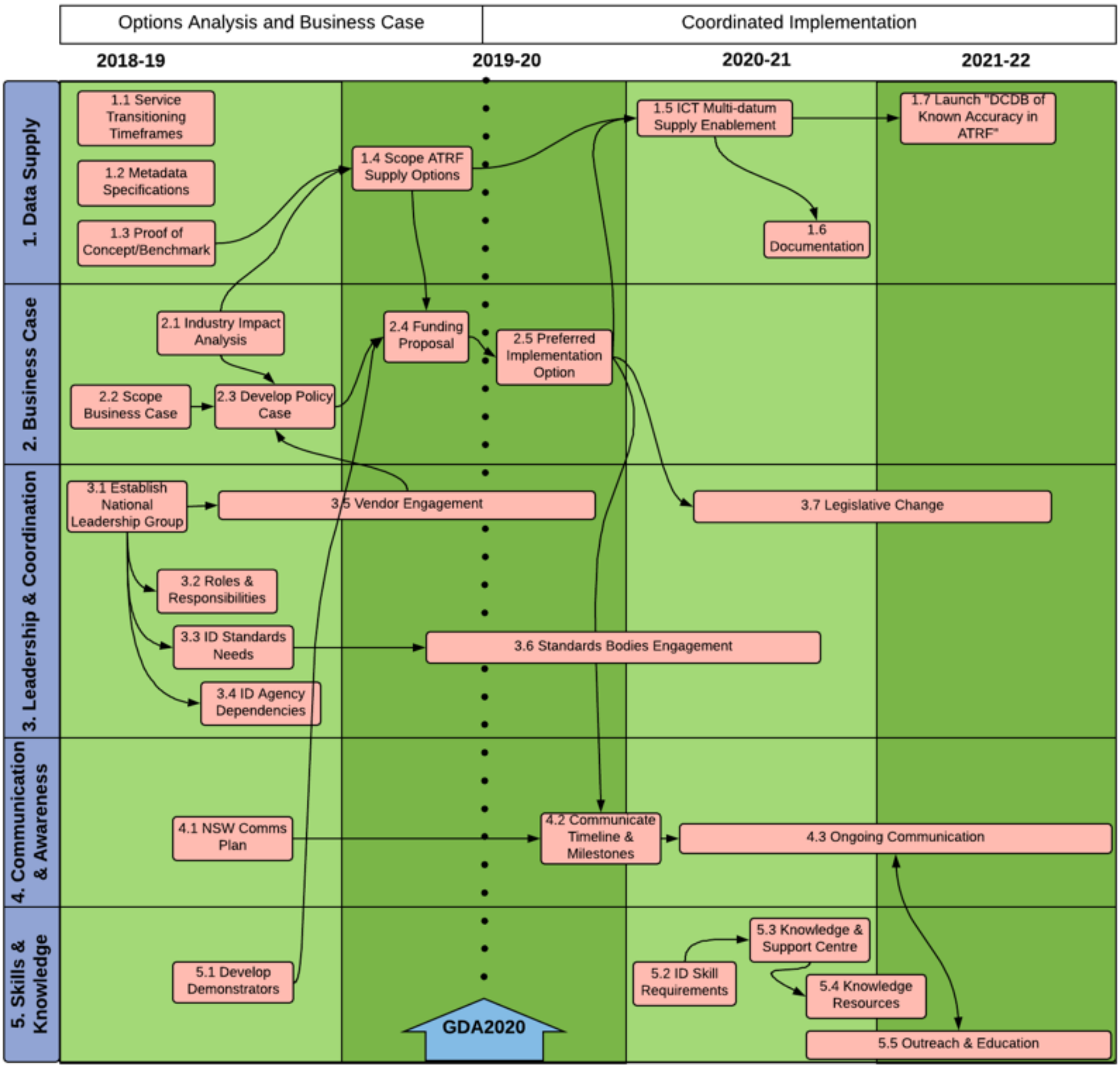
8. **Maintain Cadastral data integrity**
   Through e.g. DCDB Service reliability, and avoiding duplication (people maintaining multiple Cadastres)

The ATRF Transition Tasks and Implementation Roadmap were developed using a top-down approach. Working from Business Objectives, we determined the five Work Programs 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.

The Transition Tasks are in the 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.

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 cost required over time. 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.



This phase 2 of the project addressed five Research Questions, which are listed with their responses in the table below.

Research Question	Response
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.
How can the integrity of the cadastre be maintained in the context of a dynamic datum?	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.
What sectors and applications will be affected by ATRF, by when, and what is their value proposition for adoption?	See section 5.2. 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).
What are the 'gaps' between the GDA2020 implementation plan, and specific ATRF transition needs? (functional, application domains)	The current GDA2020 plan has strong technical focus. Further research is needed to understand the gaps regarding people, standards and organisational aspects. This can be addressed in phase 3, in collaboration with the newly appointed GDA2020 Program Manager has commenced (from April 2018).
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.

1 Introduction

1.1 Project Background and Objectives

A datum is a system that allows locations on the Earth's surface to be identified. It includes a reference surface, a coordinate system, and a set of defined reference points. 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 the national datum 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 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 will focus on NSW initially in each phase, and then expand 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 Project Timeline & Deliverables

The high-level timeline for delivery of the project is:

1. Impact Assessment: August – October 2017
2. Transition Tasks: November 2017 – February 2018

3. New Tools and Procedures: March 2018 – June 2018

1.3 Related 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 will explore 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

1.4 About this document

This document is an interim report for phase 2 of the CRCSI 3.20 project. Its content will be included, and may be modified, in the final project outcomes report. It is organised as follows:

- Section 2: Presents the phase 2 approach and Methodology
- Section 3: Summarises the outcomes of phase-1: "Impact Analysis"
- Section 4: Identifies the different scenarios for ATRF datum transformation
- Section 5: Analyses the market impact and affected sectors for ATRF
- Section 6: Presents the Transition Objectives, Tasks and Roadmap
- Section 7: Very Rough Order Of Magnitude cost and resource estimates
- Section 8: Lists the responses to initial and ancillary phase 2 research questions

2 Approach & Methodology

2.1 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.

'Intent'

- Broad datum adoption
- Future proofing the Cadastre
- ID Gap vs. current state
- Define future information management practices
- Define investment implications

Strategic Drivers *(what drives the project?)*

- GDA2020 & Datum Modernisation
- Cadastre NSW transformation program

Current Reality (*where are we now?*)

- GDA94
- Non coordinated Cadastre
- Disconnected (foundation) datasets (no topological relationships)
- Cadastral transformation program underway
- Unclear how Dynamic Datum will affect supply chain

How to get there?

Guiding Principles:

- AGILE approach (monthly meetings, with '4 voices of design' represented)
- ICSM (PCC) engagement critical

Context & Constraints

- NSW move to digital supply chain
- 'Cadastre NSW' program
- Needs for real-time data
- Cadastre 2034
- ICSM GMIWG only beginning to look at technical details of Dyn Datum

Future Reality (*"at the end of the project we will..."*)

- know the impacts on the Cadastre
- know where we are in addressing these impacts
- understand the risks (incl. of no action), and barriers to implementation
- have a (nationally coordinated) roadmap
- understand the options for using COTS vs. bespoke technology
- understand the potential for a Dynamic Datum to hinder (or support) the implementation of 'Cadastre NSW'

Figure 1 Statement of Intent for CRCSI Project 3.20

2.2 Scope & Approach

The Project will have three distinct phases:

1. Impact Assessment
2. Transition Tasks
3. New Tools and Procedures

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 Phase 1

Phase 2: Transition Tasks

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 Phase 2

Phase 3: New Tools and Procedures

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 Phase 3

2.3 Phase-2 Research Questions

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

The phase-2 research questions are listed in the tables below.

Table 1 Original 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?

During phase 1, three ancillary research questions have been formulated for phase 2:

Table 2 Ancillary Research Questions

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)
• Should NSW government supply DCDB (and/or SCIMS) data in GDA2020 only, or also in ATRF?

2.4 Stakeholders & Stakeholder Engagement

Phase 2 stakeholder engagement was conducted through:

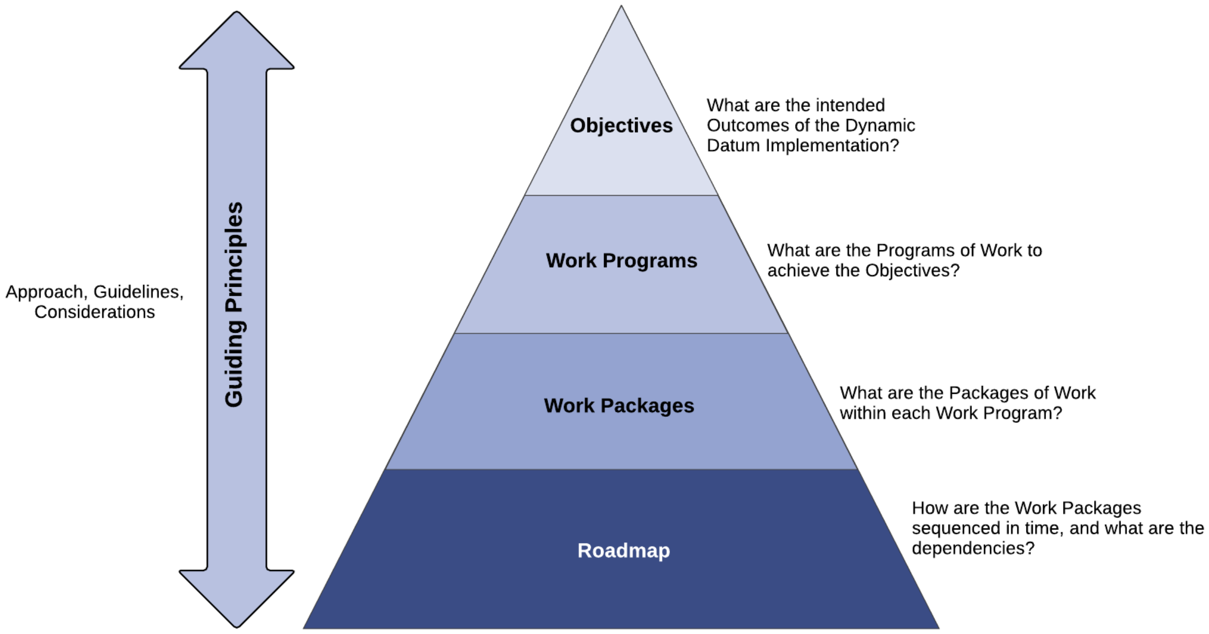
- Two "Transition Planning" workshops with the Project Reference Group and User Representatives
- Interviews with a variety of Industry Representatives, and Subject Matter Experts
- A validation workshop with other jurisdictions and (inter-) national Subject Matter Experts

See Appendix 1 for a complete list of engaged stakeholders.

2.5 Phase 2 Methodology

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 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.



3 Summary of Impacts

The Impacts, Barriers and Future Expectations as identified in phase 1 have been summarised against five dimensions in the table below.

Table 3 Summary of 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 transforming 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)

The main conclusions from the findings 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 the NSW DCDB.

4 ATRF Transformation for the NSW Cadastre

Several factors influence the decision on how to implement ATRF for the NSW Cadastre. Key questions to answer 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?”

Before answering that question, we must realise that 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. As the ATRF is time dependent, the basemap and GNSS coordinates should be in the same epoch, and in many cases a coordinate transformation needs to occur.

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?

4.1 Option 1: Transformation at Point of Supply

In this case (illustrated in Figure 2 below), the user device requests base data from a web service providing the base data. 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 in that moment. The data custodian assumes the responsibility of transforming the coordinates ‘on demand’ at the time of supply.

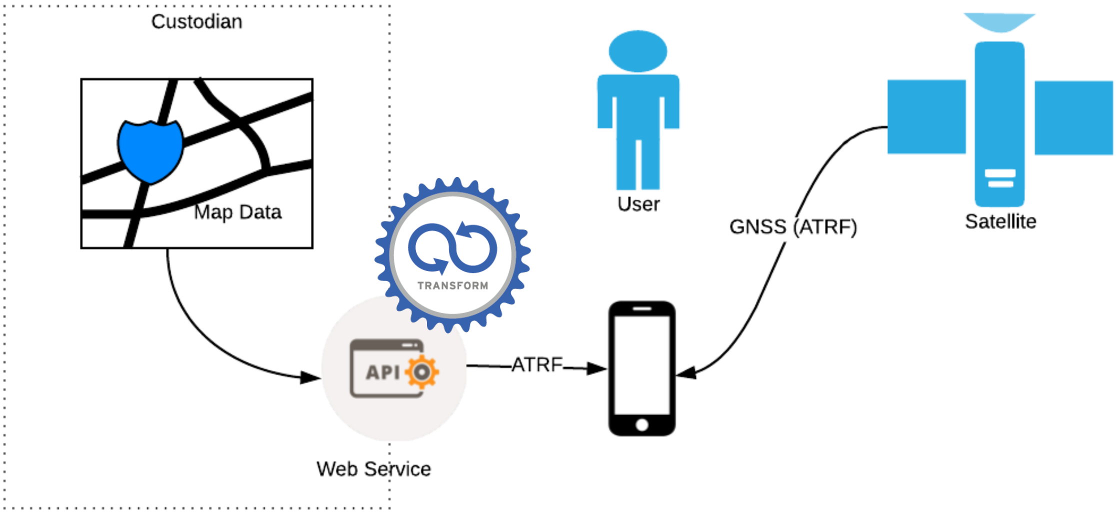


Figure 2: Transformation at Point of Supply

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.

4.2 Option 2: Transformation at Point of Decision Making

4.2.1 Option 2A: 'On the Fly' Transformation

The other main option is that transformation happen at the point of decision making. The main use case is illustrated in Figure 3 below.

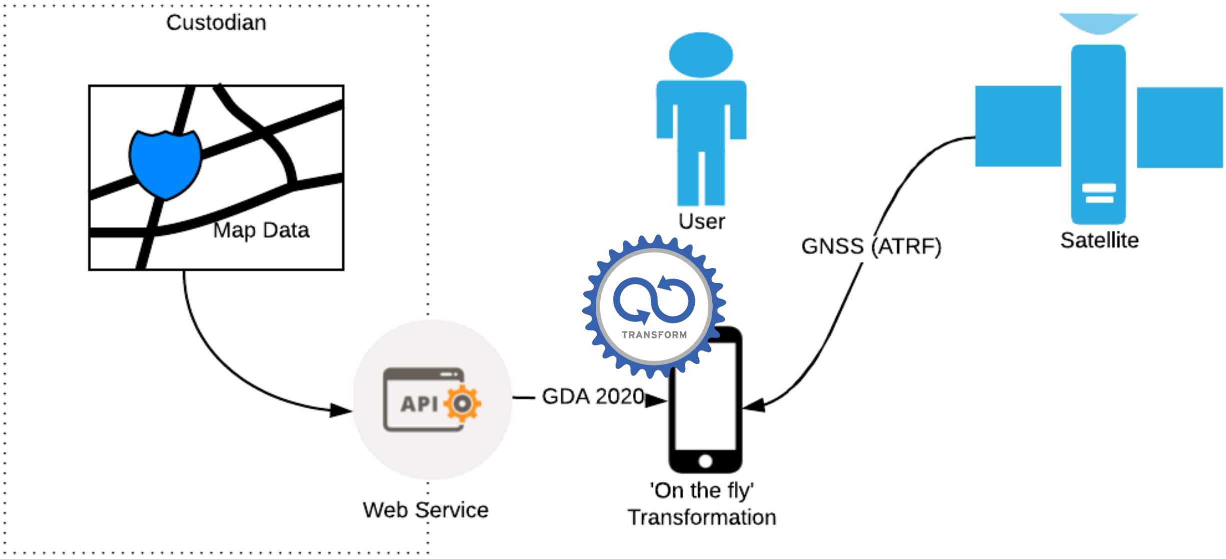


Figure 3 Transformation at Point of Decision Making

The first advantage of this option 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'.

A second advantage is that custodians 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'.

Thirdly, 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 complexity.

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.

4.2.2 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 4.

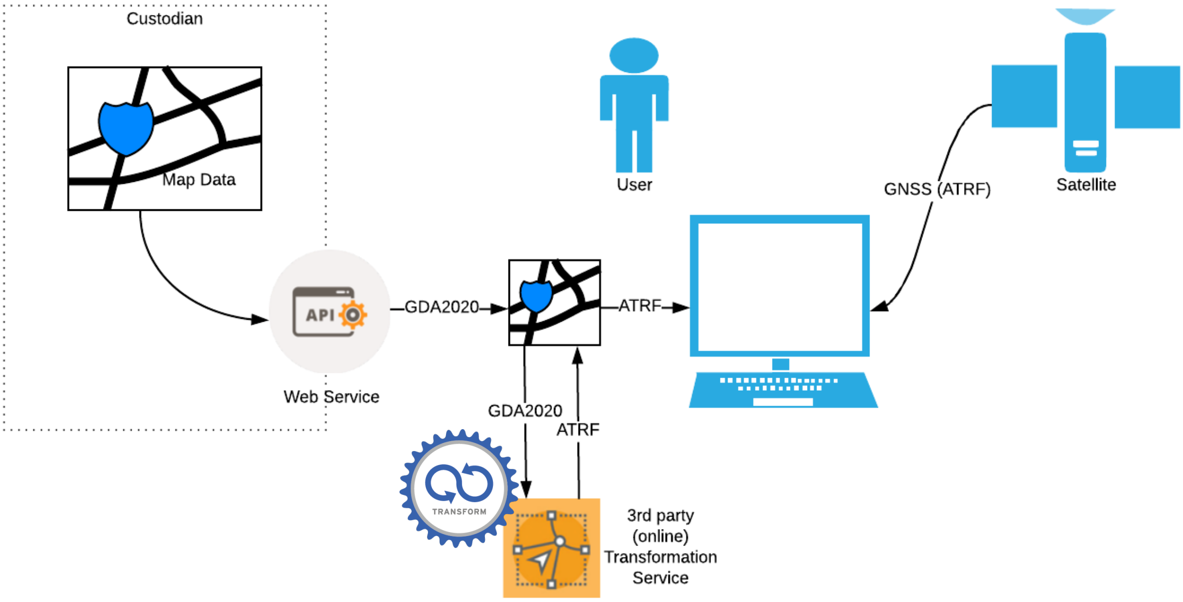


Figure 4 Using a 3rd party transformation service

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 such a 3rd party transformation service.

4.3 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 requiring 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 most preferred option for the long term.

However, the feasibility of this option is primarily 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.

5 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)?

5.1 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; 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 5) that the use of ATRF coordinates is relevant.

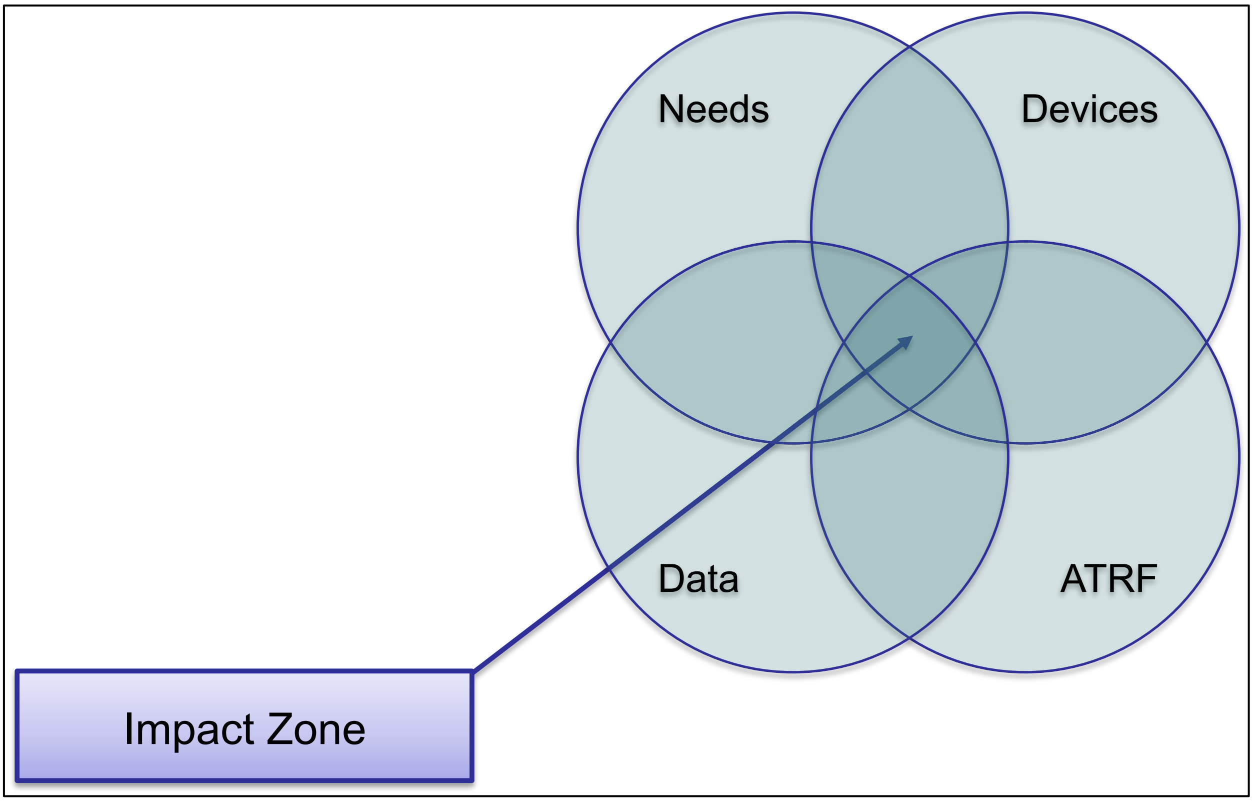


Figure 5 Sweet Spot: when four factors align

Figure 6 illustrates how when any of these four accuracy factors fall away, there is no value in using ATRF and the user can happily plot their GNSS coordinates on a GDA2020 base layer.

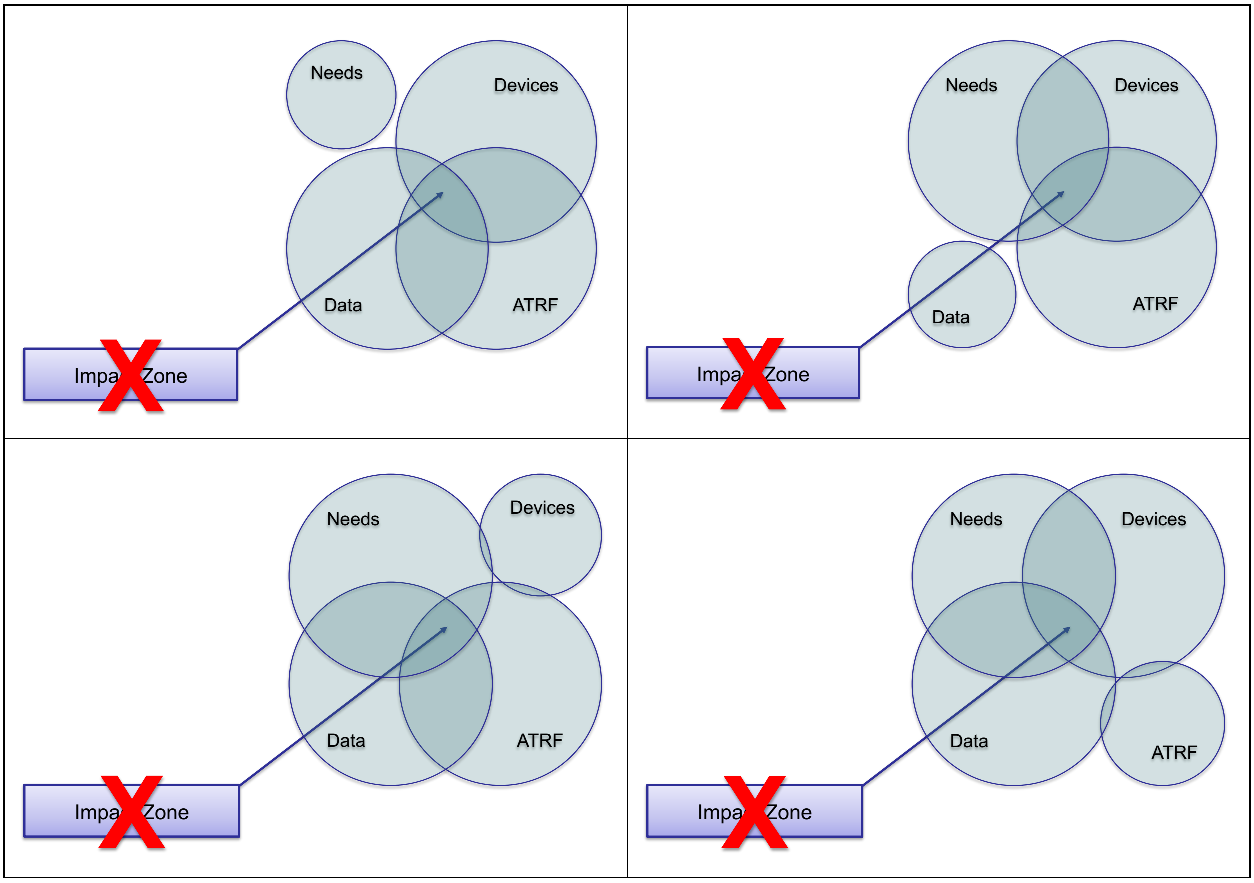


Figure 6 No ATRF Impact

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.

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.

We know or can assume that:

- **Devices** – Positional accuracy will reach sub-decimeter in consumer GNSS receivers within 5 years (2023)[1]
- **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 there 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 set 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.

The initially affected users will not only be small in numbers, but likely to be specialist 'early adopters', with access to the skills and tools to perform their own, ad-hoc coordinate transformations.

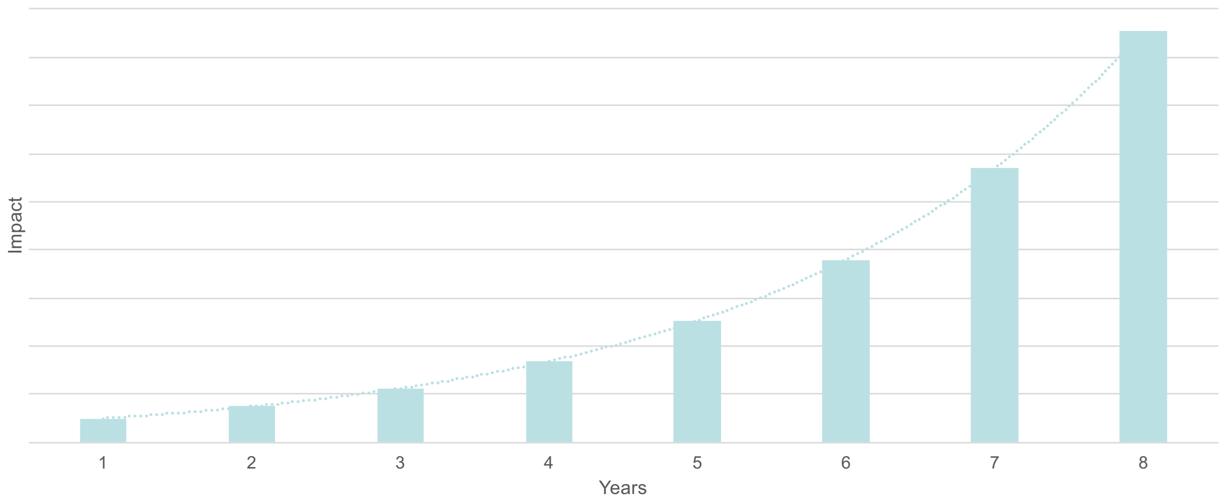


Figure 7 ATRF impact will grow over time

5.2 Priority Implementation Sectors

Can we expect that some market sectors 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 the 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.

[1] "*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.

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 decimeters or smaller.

Table 4 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.

Table 4 Sectoral impacts of ATRF on the DCDB

Sector[2]	DCDB dependency	Accuracy need[3]	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

[2] As defined in Acil Allen (2017) “Economic Value of Spatial Information in NSW”.
[3] Derived from ICSM (2003), “Business Case Framework for Improved Spatial Accuracy in Digital Cadastral Database (DCDB)”, combined with anecdotal feed-back from selected users

Sector[2]	DCDB dependency	Accuracy need[3]	Tier	Comments
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)

5.3 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 4.2.1). Given the preferred option, and the considerations regarding user impact (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?"*

The baseline for custodians (NSW Spatial Services in the case of the DCDB) will be that the data will be maintained in a plate-fixed system, most likely to be GDA2020. And as part of the GDA2020 implementation, users can expect base-data, including the DCDB to be available in GDA2020, from at least the 1st of January 2020. Note that at that time GDA2020 and ATRF will be equivalent, i.e. GDA2020 is equivalent to ATRF with a 1/1/2020 epoch.

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. Currently (April 2018) similar proofs-of-concept are being conducted for GDA2020 transformation, and it seems likely these could be readily extended to ATRF transformation. The running and outcomes of ATRF delivery trials should be coordinated with other jurisdictions to maximise efficiency and strengthen the conclusions.

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

5.3.1 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[4]) 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 8 demonstrates the ideal scenario where there is a wide availability of COTS software support before a majority of users are impacted.

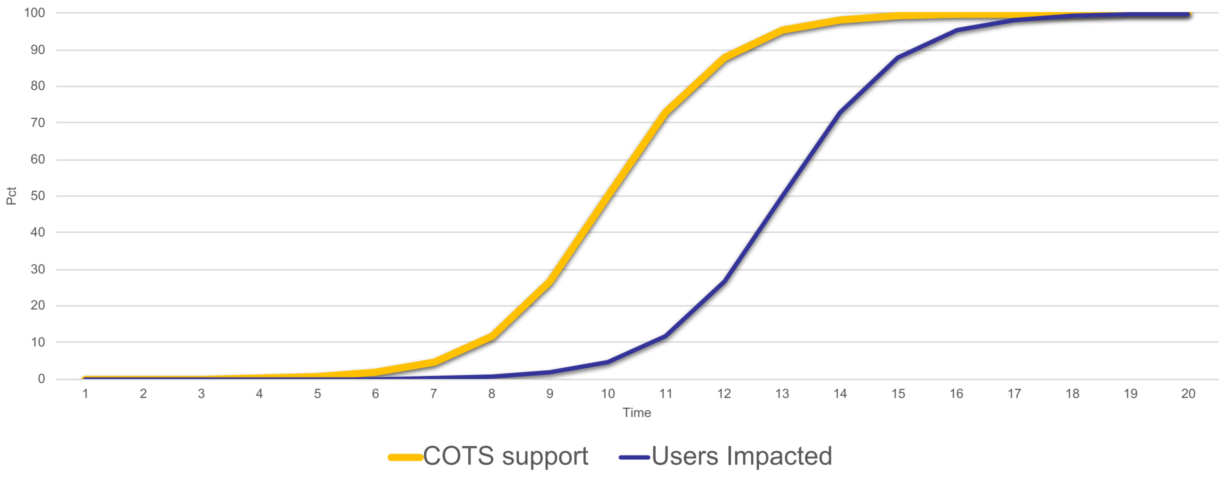


Figure 8 COTS penetration precedes user impact

Conversely, if software support becomes available after user impact, we observe 'market lag', as demonstrated in Figure 9. In this situation there is a market impact and demand that cannot be met 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 wait releasing COTS solutions until countries like the USA adopt a dynamic datum (not until 2022 at the earliest).

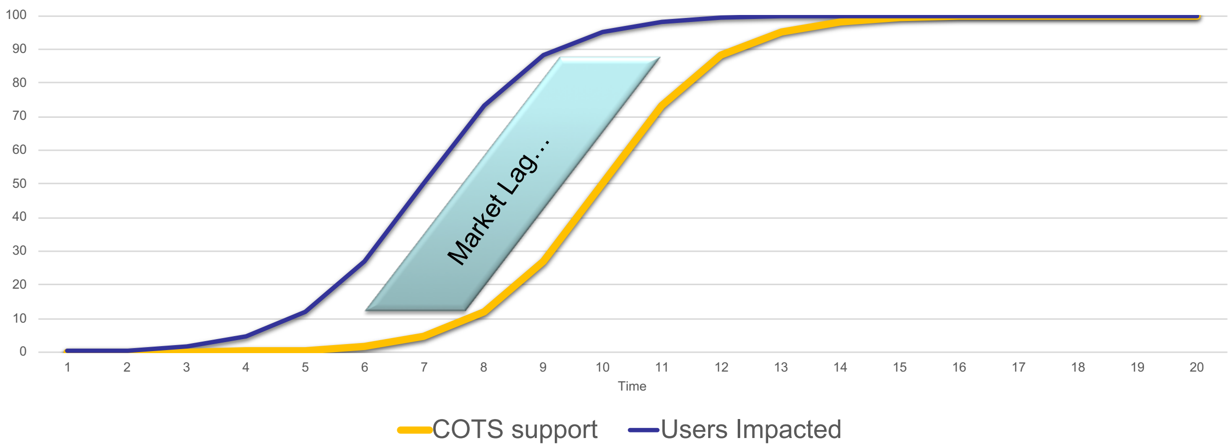


Figure 9 COTS support lags impact

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

In reality, as we have seen in section 5.2, different market sectors might be impacted at different times as illustrated in Figure 10.

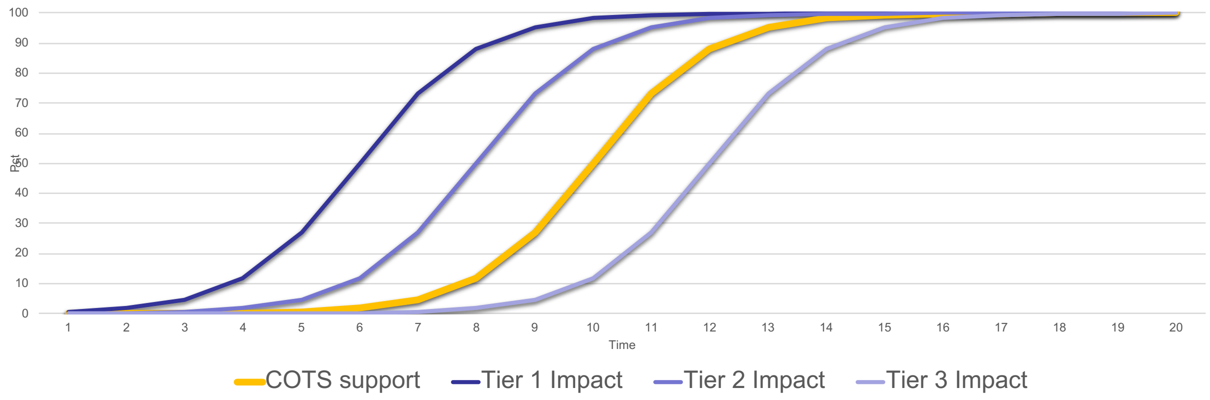


Figure 10 Tiered impact

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

5.4 Considerations for Implementation

The Impact and Market Analysis allows several conclusions and implications to be drawn for the Implementation and Transition Planning.

The questions posed at the start of the analysis were:

1. When and where will the user impact hit?

User impact will likely hit in earnest from 2022/23 onwards, when ATRF and GDA2020 coordinates will differ by 20cm or more, consumer GNSS devices will have sub-decimeter accuracy, the DCDB will have 20cm or better accuracy, and for users who depend on 20 cm or better accuracy for their decision making.

2. Should the NSW DCDB (and other foundation datasets) be delivered 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 Planning: 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.

3. What market segments will be impacted first (and thus be targeted in the Transition Planning)?

Initial analysis suggests that tier-1 sectors likely include Asset Management, Land & Property, Smart Buildings and Infrastructure, Smart Cities & Local Government, Utilities, and possibly Environment and Planning (particularly e-Planning).

In summary, it is likely there will be no major ATRF impact on DCDB users until 2022/23, and then only on specific (tier-1) user segments. Whether the DCDB should be made available in ATRF coordinates is a multifaceted decision. Considerations in this decision include the technical feasibility and expectations regarding a possible market lag. More analysis and (inter-) nationally coordinated vendor engagement will be needed to address these considerations.

6 Transition Tasks

This phase takes a top-down approach to developing the Transition Tasks. Working from Business Objectives, we determined the five Work Programs 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 Transition Tasks.

This methodology is presented in more detail in section 2.5.

6.1 Strategic Objectives

Using the same five Strategic Components that were introduced in the Impact Analysis (Phase 1), Table 5 shows the Strategic Objectives for the ATRF transition.

Table 5 Strategic Objectives

	Objectives	Description	Comments
Data	Multi datum supply	Cadastral data will be supplied in ATRF and GDA2020, incl. 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	May be enabled through e.g. visibility of changes & updates; Coordinates have known accuracy
	Fit for Purpose	Cadastral data will be available in the format, through the service, and with 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.	'locked in'
	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'	

	Objectives	Description	Comments
	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?
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.	

6.2 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 be able 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)

6.3 Work Programs

To achieve each of the Strategic Outcomes, five strategic Work Programs have been identified, as listed in Table 6 below.

Table 6 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 internationally 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).

Table 7 below shows how the Work Programs address each of the Strategic Objectives.

Table 7 Matching Objectives and Work Programs

Objectives		Data Supply	Business Case	Leadership & Coordination	Communication & Awareness	Knowledge & Skills
Data	Multi datum supply	✓				
	Trust & integrity	✓				
	Fit for Purpose	✓			✓	
	Tightly integrated metadata	✓		✓	✓	✓
	Data alignment	✓			✓	
Technology	Broad COTS Support			✓		
	'It just works'		✓	✓	✓	
	Web-services supply	✓				✓
Standards	Supported by international standards			✓		
	Broad standards adoption			✓	✓	✓
	Standards awareness, communication & support			✓	✓	✓
People	Communication & Awareness			✓	✓	
	Right skills at the right level		✓	✓	✓	✓
	End-users shielded				✓	
Organisational	Sustainably resourced transition		✓		✓	
	National consistency			✓	✓	
	Government leadership	✓	✓	✓		
	implementation scope & scale well understood		✓			

6.4 Work Packages

Table 8 identifies a number of individual Work Packages to deliver each of the Work Programs defined in section 6.2.

Table 8 Work Packages for Transition

	Work Packages	Description
1	**Data Supply**	
1.1	Service Transitioning Timeframes	Setting target milestones for when services and facilities become available or will be shot down
1.2	Define metadata specifications	Standards, Profiles, minimum requirements. For data and services
1.3	Proof of Concept / Benchmark	Run Proof-of-Concept to test performance and feasibility of ATRF transformation
1.4	Scope ATRF Supply Options	Identify and scope & plan relevant option(s) for cadastral data in multiple datums (incl. ATRF) supply
1.5	ICT multi-datum supply enablement	Enable data supply, with multiple datum transformations enabled
1.6	Update associated documentation	Identify and update all current relevant information to specify GDA2020 / ATRF, e.g. business glossaries, data dictionaries
1.7	Launch "DCDB of Known Accuracy in ATRF"	Cadastral accuracy is known and exposed. Accuracy sufficiently consistent for ATRF to be relevant
2	**Business Case**	
2.1	Industry Impact Analysis	Identify scope, sector(s) with biggest impact (and when impacted) and quantify impact where possible. Liaise with GA's EY analysis.
2.2	Define scope for Business Case	All of NSW, NSW government, or specific agencies? Allocate roles & responsibilities
2.3	Develop Policy Case	As baseline for funding request (e.g. treasury bid): develop the case for change (incl. legislative), and funding quantum
2.4	Funding Proposal	Prepare and submit funding proposal for state-wide implementation; Considering required lead times
2.5	Select preferred Implementation Option	Subject to available funding and other considerations, select preferred implementation option for ATRF enablement
3	**Leadership & Coordination**	***In coordination with other jurisdictions***
3.1	Establish national leadership group	Establish national leadership group responsible for ATRF implementation and coordination
3.2	Define Roles and Responsibilities	Define and agree roles and responsibilities between industry, agencies & jurisdictions. Communicate expectations
3.3	Identify Standards Needs	User analysis to determine need for (data and metadata) standards and identify any gaps. (Inter-) national coordination with relevant standards bodies

	Work Packages	Description
3.4	Identify Cross-Agency dependencies	Identify which agencies and datasets depend on the (NSW) cadastre and how ATRF might impact these depenencies
3.5	Vendor Engagement	(Inter-) national coordination to engage international vendors, through peak bodies etc.
3.6	Standards Bodies Engagement	(Inter-) national coordination to engage and influence standards development, through peak bodies etc.
3.7	Legislative Change	Prepare and implement the regulatory changes required for ATRF & GDA2020. Coordinate between jurisdictions to ensure consistency and avoid overlaps
4	**Communication & Awareness**	***In coordination with other jurisdictions***
4.1	Develop NSW Communications plan	Define target audiences, messages and timeline. Simplified messages for non-technical/non-expert audiences.
4.2	Communicate implementation plan, timeline and milestones	Ensure relevant stakeholders have timely awareness of timeline and milestones.
4.3	Ongoing communication	Ongoing communication as per NSW Comms Plan
5	**Knowledge & Skills**	***In coordination with other jurisdictions***
5.1	Develop Demonstrators	Conduct and demonstrate pilots/proofs of concept for ATRF use and transformations.
5.2	Determine skill requirements	Identify user groups and skills required to implement ATRF
5.3	Knowledge and Support Centre	Set-up group of skilled resources to provide (technical) support.
5.4	Knowledge resources	Prepare and publish relevant documentation and skills/knowledge resources. In coordination with other jurisdictions
5.5	Outreach & Education	Organise awareness & skill development / demonstration sessions and tools

6.5 Roadmap

The work packages described in section 6.4 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 (see section 5.4)

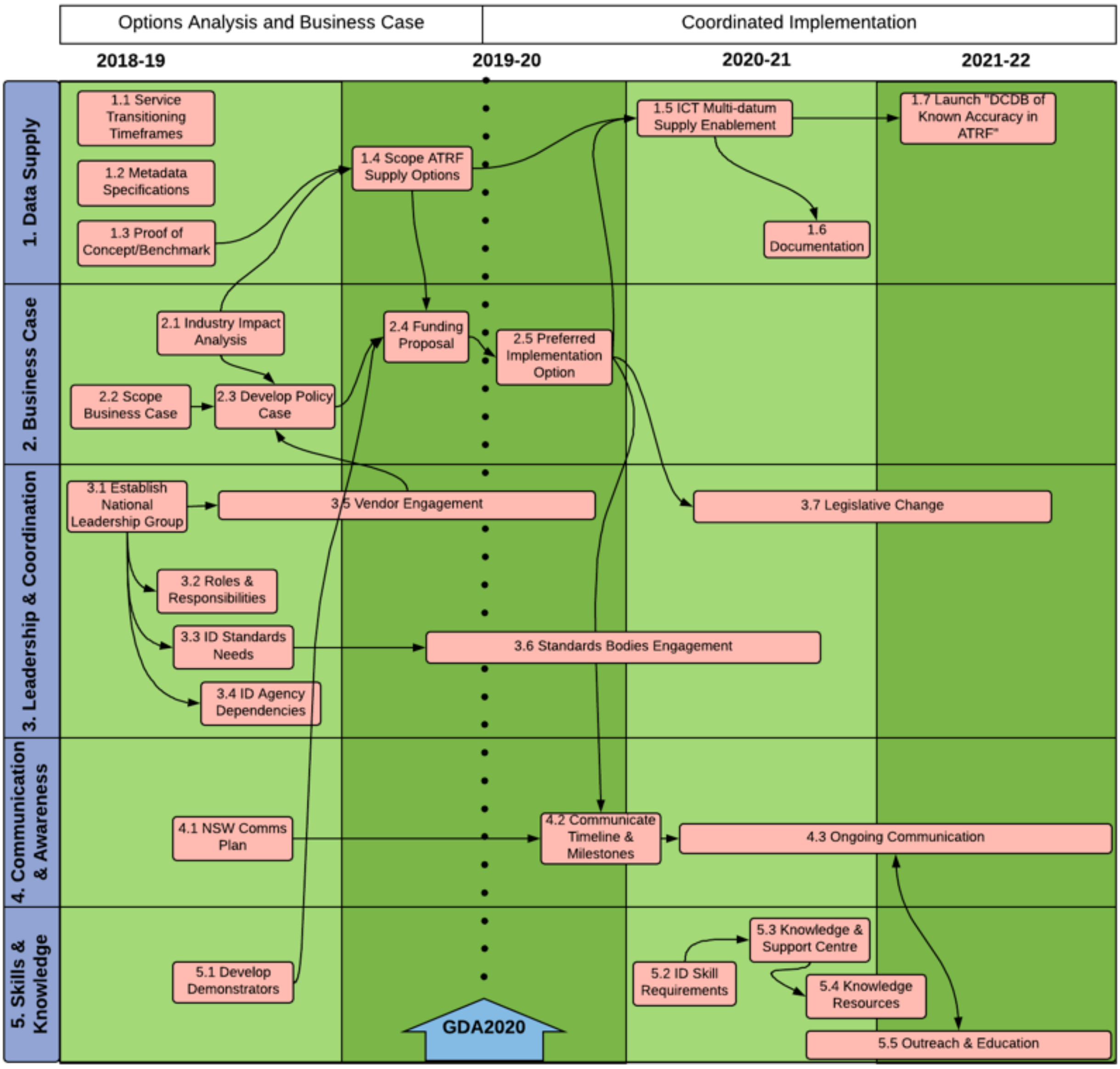


Figure 11 Proposed Transition Roadmap

7 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 12) breaks down the expected cost and effort ranges over time, for the transition of the NSW DCDB to ATRF. Detailed numbers are available in Appendix 3.

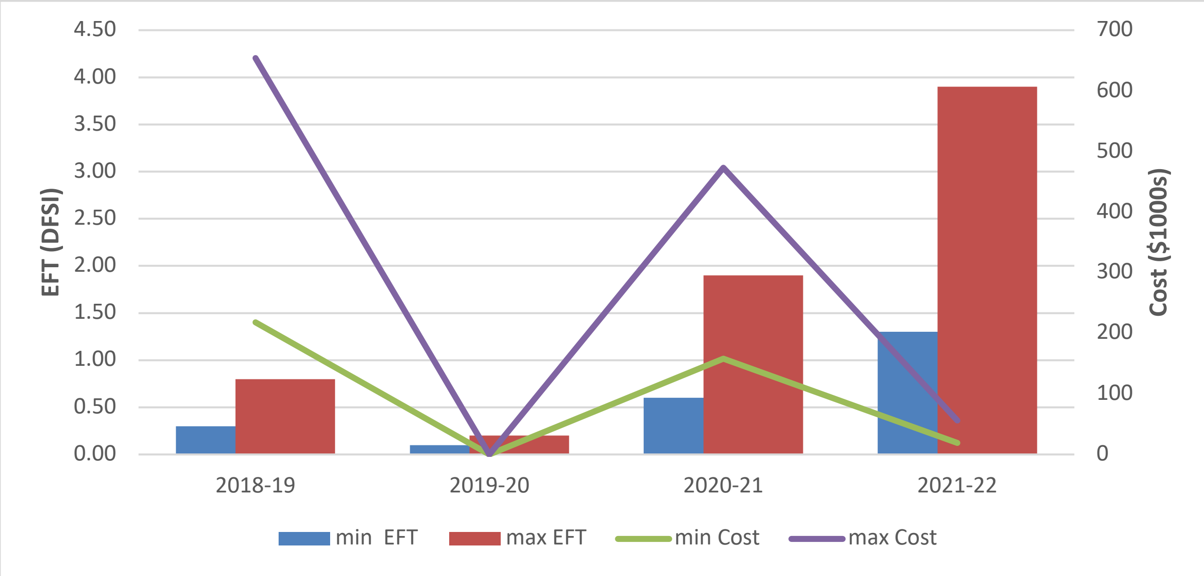


Figure 12 VROOM Cost and Effort estimates for transition

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 the incremental in relation to GDA2020 implementation;
- 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 - savings.

8 Responses to Research Questions

The tables below address the research questions relevant for phase 2, as identified in section 2.3.

Table 9 Response to Research Questions for Phase 2

Research Question	Response
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.
How can the integrity of the cadastre be maintained in the context of a dynamic datum?	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.
What sectors and applications will be affected by ATRF, by when, and what is their value proposition for adoption?	See section 5.2. 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).
What are the 'gaps' between the GDA2020 implementation plan, and specific ATRF transition needs? (functional, application domains)	The current GDA2020 plan has strong technical focus. Further research is needed to understand the gaps regarding people, standards and organisational aspects. This can be addressed in phase 3, in collaboration with the newly appointed GDA2020 Program Manager has commenced (from April 2018).
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.

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 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
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
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
ICSM	Intergovernmental Committee on Surveying and Mapping. ICSM's role is to provide leadership through coordination and cooperation in surveying, mapping and charting.

Term	Definition
	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/
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
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. Stakeholder Engagement Details

Phase 2 stakeholder engagement was conducted through:

- 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

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

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 Guidici	Tasmania, Surveyor General
John Dawson	Geoscience Australia

Appendix 3. Detailed Resource Estimates

	Year 1 (FY18-19)			
	Staff (EFT)		Cost	
	From	To	From	To
1 - Data Supply	0.10	0.30	$ 47,000.00	$141,000.00
2 - Business Case	0.10	0.20	$ 85,000.00	$255,000.00
3 - Leadership & Coordination	0.10	0.20	$ 24,000.00	$ 71,000.00
4 - Communication & Awareness	0.00	0.10	$ -	$ -
5 - Skills & Knowledge	0.00	0.10	$ 63,000.00	$188,000.00
Total	0.30	0.80	$218,000.00	$654,000.00

	Year 2 (FY19-20)			
	Staff (EFT)		Cost	
	From	To	From	To
1 - Data Supply	0.00	0.00	$ -	$ -
2 - Business Case	0.00	0.10	$ -	$ -
3 - Leadership & Coordination	0.00	0.10	$ -	$ -
4 - Communication & Awareness	0.00	0.00	$ -	$ -
5 - Skills & Knowledge	0.00	0.00	$ -	$ -
Total	0.10	0.20	$ -	$ -

	Year 3 (FY20-21)			
	Staff (EFT)		Cost	
	From	To	From	To
1 - Data Supply	0.10	0.20	$ 139,000.00	$ 416,000.00
2 - Business Case	0.00	0.00	$ -	$ -
3 - Leadership & Coordination	0.10	0.40	$ -	$ -
4 - Communication & Awareness	0.10	0.20	$ -	$ -
5 - Skills & Knowledge	0.40	1.20	$ 19,000.00	$ 56,000.00
Total	0.60	1.90	$ 158,000.00	$ 473,000.00

	Year 4 (FY21-22)			
	Staff (EFT)		Cost	
	From	To	From	To
1 - Data Supply	0.00	0.10	$ -	$ -
2 - Business Case	0.00	0.00	$ -	$ -
3 - Leadership & Coordination	0.00	0.10	$ -	$ -
4 - Communication & Awareness	0.10	0.20	$ -	$ -
5 - Skills & Knowledge	1.20	3.50	$19,000.00	$56,000.00
Total	1.30	3.90	$19,000.00	$56,000.00