Transitioning to a New Paradigm – the Development and Implementation of a Modernised National Datum from a Regional Perspective

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SUMMARY

Australia is transitioning to a new national datum *GDA2020* from 2017. Preceding this implementation, there has been a decade of planning, design, development and refinement of a national geodetic adjustment, leading to datum realisation and ongoing enhancement. Through a collaborative national effort, individual jurisdictions have worked in a unified capacity to contribute to, and ultimately deliver, a product that will continue to support positioning and geospatial information management into the foreseeable future.

This paper will reflect on the Territory's practical undertakings to achieve a modernised datum through a national collaborative framework. It will discuss both the assessment of legacy and implementation of new business rules and systems to support the process and way we acquire, validate, store, manipulate, exchange and manage our spatial data. The paper will also value the significant role of standards and consistency in achieving a fit-for-purpose national datum, providing users with an accurate, interoperable and maintained reference frame.

Finally, as we move into the implementation phase and ultimately adoption of a time-dependent realisation of the reference frame, the paper will demonstrate how a collaborative framework will manage national issues at the jurisdiction level, and converse, can be supported in a transparent and productive environment.

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1. BACKGROUND

As Australia's jurisdictions transition into a new national datum, it seems timely to reflect on the extensive body of work and contributions made over the last decade that has led to its development and impending implementation. It has long been recognised that Australia's official datum, the Geocentric Datum of Australia 1994 (GDA94), had become increasingly "unfit for purpose" due to its inability to account for crustal dynamics and regional deformation, its misalignment with the International Terrestrial Reference Frame, and its inherent local distortions. In order to address these inadequacies, as discussed in depth by Johnston and Morgan, 2010 and Donnelly et.al 2014, a unified and national approach to datum modernisation would be required. Under the leadership and coordination of the Intergovernmental Committee on Surveying and Mapping (ICSM - a standing committee of the Australia New Zealand Land Information Council), the representative members from the Permanent Committee of Geodesy (PCG), comprising of Commonwealth, State and Territory government surveying and mapping agencies[1], have worked collaboratively to largely deliver on the Vision, Mission and those Objectives and Outcomes (refer to figures 1.1 and 1.2 respectively) outlined in the 5-year geodetic strategy summarised by Blick and Sarib, 2010:

> ***Vision:***
> *An accurate geospatial reference system (GRS) that is accessible, and enables the efficient use of geospatial information to support economic growth, environmental sustainability and social prosperity across Australia and New Zealand.*
>
> ***Mission:***
> *The provision of an accurate geospatial reference system or GRS that:*
> - *is mathematically connected to and contributes to the global reference system such as the International Terrestrial Reference Frame (ITRF) ;*
> - *enables spatial consistency between diverse geospatial datasets; and*
> - *enables spatial consistency over time for datasets relating to physical environment*

Objective	**Outcome**	**Status**
Provision of a semi –dynamic national 3-Dimensional datum	GDA2020 plate fixed datum based on APREF – ITRF, with a plate velocity model. Further development on Australian Terrestrial Reference Frame (ATRF)	✓
Establishment of a modernized Vertical	AusGeoid2020 – model to convert between	✓

[1] Note: New Zealand is also a member of the PCG.

Reference Frame for Australasia	ellipsoidal heights GDA2020 and mean sea level (AHD). Further integration with other vertical surfaces to be analysed	
Provision of a Unified Geodetic Data Model and XML schema	Geography Markup Language (GML) application schema called GeodesyML for transferring geodetic data and metadata	✓
Ability to integrate all geodetic data sets within eGeodesy	National and Jurisdictional Adjustment Datasets combined for GDA2020 propagation	✓
Development of National Geodetic Adjustment software package DynaNet	DynaNet adjustment engine and tools, ZED interface used by jurisdictions for GDA2020	✓
Development of a National Geodetic Data Archive	National and jurisdictional GDA2020 data archived in a standard framework / system	✓
Development of a Geodetic GNSS Data Analysis or Central Bureau for the Asia Pacific Region	Geoscience Australia Regional GNSS data centre operational.	✓
A unified CORS network across Australasia	AUSCORS comprising of AuScope, Australian Regional, and South Pacific Regional GNSS Networks	✓
AuScope is the primary scientific network underpinning geospatial activity	Organisations support AuScope GNSS CORS as critical geospatial infrastructure	✓
Implementation of a modern automated web-based GNSS post processing system	AUSPOS Service - operational and on-line	✓
Development of internationally accepted geodetic standards across Australasia	SP1 - Survey Control documentation being used by industry	✓
Implementation of systems that allow calibration and standardization of GNSS measuring devices	Industry is using "Regulation 13" GNSS CORS, SP1, and Geoscience Australia's GNSS Antenna Calibration Facility.	✓
Development of a strategy to assist with monitoring and measurement of climate change through activities such as for the geodetic component of sea level monitoring	Australian Baseline and Pacific Sea Level Monitoring Project operational; and GNSS CORS networks determining / monitoring the vertical height of the tide gauges.	✓
Monitor the impact of Positioning Technology and Infrastructure	National Positioning Infrastructure capability is recognised as an integral part of society with applications across numerous sectors.	✓

Figure 1.1 – Status of work objectives / outcomes of geodetic strategy.

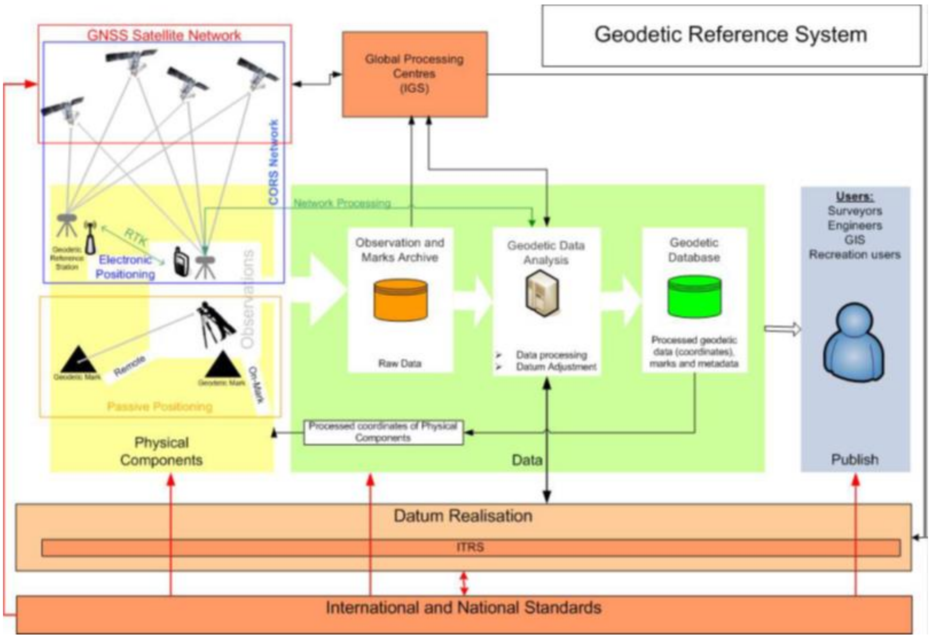

Figure 1.2 – Geodetic Reference System

Many of these milestones have been discussed previously in detail by Donnelly et.al, 2014 as progress towards a new geodetic datum for Australia, and indeed celebrated in geodetic spheres as significant achievements in realising a truly unified and collegial approach to national geodesy.

Fundamentally, the need to understand and study crustal deformation has remained a key driver for refinement of the International Terrestrial Reference Frame (ITRF), the establishment of the Global Geodetic Observing System (GGOS) and hence at the heart of refinement of the Australian National Geospatial Reference System (NGRS). The national approach to realising a world-class, dynamic datum has been centred on improving our contribution to the ITRF, through the regional densification of the Asia-Pacific Reference Frame (APREF). Almost ten years ago, the Asia-Pacific region aspired to create and maintain an accurate geodetic framework as per that already established in Europe and the Americas, where densely located, accurate and accessible positioning infrastructure was available for not only datum realisation but also industry and science-based applications. The 'APREF project' commenced under the mutual recognition of member countries of the 18th United Nations Regional Cartographic Conference for Asia and the Pacific (UNRCC-AP; October 2009, Bangkok) with the need to proactively contribute to the improvement of the regional geodetic framework. As at the time of publication, 28 countries now contribute data to APREF from approximately 420 Asia Pacific stations, with over 600 stations routinely analysed. This geodetic analysis and modelling of long time-series data has improved our understanding of the motion and deformation of the Australian plate, once regarded as rigid, and led to the establishment of a velocity field model which will continue to assist the maintenance of the reference frame. The premise that a contributing nation can align its datum to APREF provides benefit from the global compatibility of coordinates, where differences will remain up-to-date and unaffected by local distortion and tectonics into the future.

2. THE NORTHERN TERRITORY EXPERIENCE – DATUM MODERNISATION

As a sparsely populated jurisdiction of 235,000 people occupying one-fifth of Australia's land mass, the Northern Territory (NT) boasts '*climatic zones ranging from monsoonal tropics across the 'Top End' to the arid red-ochre deserts of Central Australia including the Tanami, Great Sandy and Simpson Deserts'*.[2] For this reason, much of the NT has remained void of sustainable industry, opportunity and inhabitants – and indeed the infrastructure necessary to support these. Whilst Peterson and Sarib have previously discussed the drivers for modernising the NT Geospatial Reference System (GRS; Peterson and Sarib 2012), the idea that spatial data underpins decision making and policy development is still fundamental. More recently an Australian government white paper entitled "Developing the North" (Department of the Prime Minister and Cabinet, 2014) spearheaded a campaign to explore the future development and potential of Northern Australia, which lies as the geographical neighbour and economic trading partner to Asia. If the political motivation to modernise the GRS was thought to be waning, the ability for positioning technologies and the spatial data it underpins to support decision making, indefensible science, research and development and the provision of a platform for innovation in the non-traditional spatial sectors such as pastoralism, mining, agriculture, health, education, defence and tourism renders investment in positioning infrastructure critical to future regional development.

Interestingly, challenges to past economic development in the north – such as relatively poor infrastructure (communications, road access), vast distances inhibiting service delivery and the task of attracting and retaining a skilled/Professional workforce, have also shaped the progress and direction of datum modernisation in the Northern Territory. Notwithstanding these, the Survey Services work unit of the Surveyor-Generals office, being the agent responsible for maintaining the NT-GRS, has strategically undertaken key activities first outlined as priorities in Peterson and Sarib 2012, which would ultimately assist in the progression of the national datum modernisation agenda. At the jurisdictional level, the investment in infrastructure has been strategically aligned to building national scientific capability, but more notably in developing the positioning infrastructure and / or location intelligence to support economic development. The key milestones which have now been completed as steps towards datum modernisation include:

2.1 The rollout of geodetic quality permanent GNSS CORS across the Territory

The NT contribution to the AuScope CORS network now comprises of 18 operational Tier[3] 2 CORS, with an additional five 'local' Tier 3 CORS located in the major population centres of Darwin and Alice Springs. Together with the three (3) Australian Regional Geodetic Network CORS (ARGN) sites that have been contributing to the regional solution for over 20 years, the network provides a regional densification through APREF. Given the allocation of continued funding to support the establishment of positioning infrastructure, additional sites will continue to be investigated and prepared for construction, primarily across the northern limits of the NT which remains an area of interest due to the prevailing weather events, the proximity to shipping channels and our northern neighbours. Since project inception, a framework has been developed and refined

[2] Northern Territory Government – Australia's Northern Territory
[3] Burns and Sarib (2010)

to guide the building of positioning infrastructure in the NT, matured with the experiences in progressing sites subject to sensitive land approval processes. As we move towards a National Positioning Infrastructure (NPI) plan and projects supporting economic development in the region, consultants may be engaged to undertake site establishment based on the framework.

As previously articulated, the GNSS CORS network has been designed coincident to major road corridors and transects, at a minimum spacing of 200-300kms. Due largely to the physical distance and therefore travel required to some of these sites, along with resourcing and budgetary constraints, any repairs and maintenance to sites remain on a reactive basis rather than a scheduled preventative schedule. Despite this, the CORS have maintained a steady operational record, with few failures reported across the network. Some of the first sites established under the project are now approaching eight years in operation, and the requirement to replace components, particularly outdated receivers and ageing batteries is critical to their ongoing health and value in the network. Improvement of mobile phone network coverage and services across the NT also provides the opportunity to re-evaluate communication links vital for data transfer and hence integrity of the network. At 13 remote sites across the NT, the network is reliant on VSAT satellite communications, a technology which is on average eight times more expensive than a 4G based wireless mobile data connection. The ability to leverage off mobile communications technology will allow operational costs to be minimised.

With these factors in mind, the total cost of both using and maintaining the network over time must be analysed and presented for budgetary consideration. Having demonstrated the value of the network, the immediate need is to now transfer a portion of the ongoing budget for the establishment of sites into a repairs and maintenance cycle, such that the longevity of the sites can be guaranteed. Although the network is well-supported at the National level across the areas of administration, operations, and hardware and software, comparable and relative jurisdictional support is also vital; not only from a resourcing perspective but also from a business objective and political view. Furthermore, as positioning moves into the sphere of being an essential infrastructure, underinvestment in maintaining and improving the infrastructure will necessitate eventual replacement, or at the very least negatively affect the sectors it serves to benefit.

Originally it was planned for the NT to develop its' own IT and communication capability to facilitate GNSS data streams to third parties, who would subsequently value add and provide positioning and location intelligence services. This role however is now being managed at the national level by Geoscience Australia and in alignment with Australia's NPI strategy.

2.2 Performing connections between previously observed marks

Over two consecutive field campaigns, GNSS observations (in excess of 6hrs) at marks previously occupied for the GDA94 campaign were performed. These 110 marks, referred to as TGN or Territory Geodetic Network marks are geographically spread across the NT and have formally provided the basis or primary constraint to the NT-GRS or GDA94 datasets respectively. The baselines observed between the old passive (ground) marks and the new active marks (GNSS

CORS) now provide the crucial link between the old and new datum, and subsequent connections to the existing ground mark network and also terrestrial data.

2.3 Re-processing of critical GDA 94 campaign data / baselines with present day techniques

Whilst the original intention at project inception was to reprocess all baselines from the Territory's primary control tier, NTR2 and underlying regional geodetic datasets, the core strategy adopted and hence bulk of work has instead focused on incorporating long 6hr+ continuous observations over survey control ground marks, such as those mentioned above, into the National GNSS Campaign Archive. The submitted data comprises of non-CORS RINEX, which is then processed with the offline version of AUSPOS against the nearest seven IGS CORS and the nearest eight non-IGS CORS, held as reference stations. The former provides a good connection to the ITRF and the latter provides a good local solution. [4] The NGCA underpins the National GNSS campaign solution, and for the Northern Territory, the current submission of 800+ observations over approximately 650 unique stations, provides the new constraints for the legacy geodetic adjustments. This figure is a six-fold increase on the number of marks used in the GDA94 realisation.

The key to recognising and achieving consistency across the jurisdictions in the assembly of the NGCA has relied on the development of guidelines and processes, and the enforcement of rules (such as naming conventions) to facilitate and manage the transfer and adjustment of data and reporting of results. This process has largely been managed and guided by a dedicated geodetic scientist and supported by an *Adjustment Working Group* representing the jurisdictions as a subset of the PCG. Over two years the NGCA process, and indeed the other major component – the underlying Jurisdictional Adjustment, has been continuously refined and streamlined over much iteration towards a truly national geodetic adjustment.

2.4 Convert existing geodetic least squares adjustment data file format to the "DynaNet" format and engine platform.

Previously, geodetic adjustments in the NT were performed using NEWGAN, a DOS-based geodetic adjustment software developed by Dr JS Allman. The ICSM endorsed transition to DynaNet[5] has provided both the ability to perform rigorous phased network adjustments unrestricted by data input and the ability to propagate positional uncertainty. A translator to assist with the migration of NEWGAN datasets to DynaNet was made available by the then Geodesy Technical Sub-Committee of ICSM, and has assisted in the conversion process.

2.5 Readjustment of the entire Territory geodetic network and subsequent survey control networks.

Whilst progress in cleansing, migrating, combining and assembling the existing or 'legacy' least squares adjustments into a seamless jurisdictional adjustment has been ad-hoc without dedicated

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[4] NADJ Guidelines v3.0, Geoscience Australia

[5] DynaNet is a Windows based least squares adjustment program originally developed by Dr Phil Collier and A/Prof. Frank Leahy of the Department of Geomatics, University of Melbourne and with current development performed by Dr Roger Fraser

resourcing, many modern datasets such as those created for the Remote Indigenous Community Surveys[6] exist in DynaNet format, and are now adequately constrained by the NGCA given the initial survey brief requirement for at least two long-session observations in each community. Another major focus of work against this milestone has been the preparation of data sets from geodetic data supplied by Licensed Surveyors of the Northern Territory since July 2014. In the three years since the Surveyor-General issued a Directive requiring that Surveyors coordinate new ground control marks and submit the observational data with their cadastral Plan of Survey, over 150 distinct coordination projects have been lodged, which include RINEX data, log sheets, provisional coordinates, adjustment results, control mark diagrams and metadata. The internal processes supporting the lodgement and validation of data, the storage and management of observations and creation of project adjustments has developed in parallel to the requirements of the national adjustment, enabling the jurisdiction to leverage its national geodetic contribution off the work of local surveyors.

Currently, all new data is checked, adjusted and resultant baselines exported from Leica Geo-Office and fed into DynaNet. The product 'Zed'[7], an interfacing shell for DynaNet, has been a valuable tool for many of the visual and quality checks on data. Smaller campaigns are adjusted holding the NGCA constrained, before being appended to other projects over time. Connectivity is achieved either by the observation of common marks or via the constraints produced by the NGCA process. Schematically, the aggregation method for projects existing in the legacy hierarchy, that is discrete flat-file adjustments, is demonstrated in figure 2.5.1.

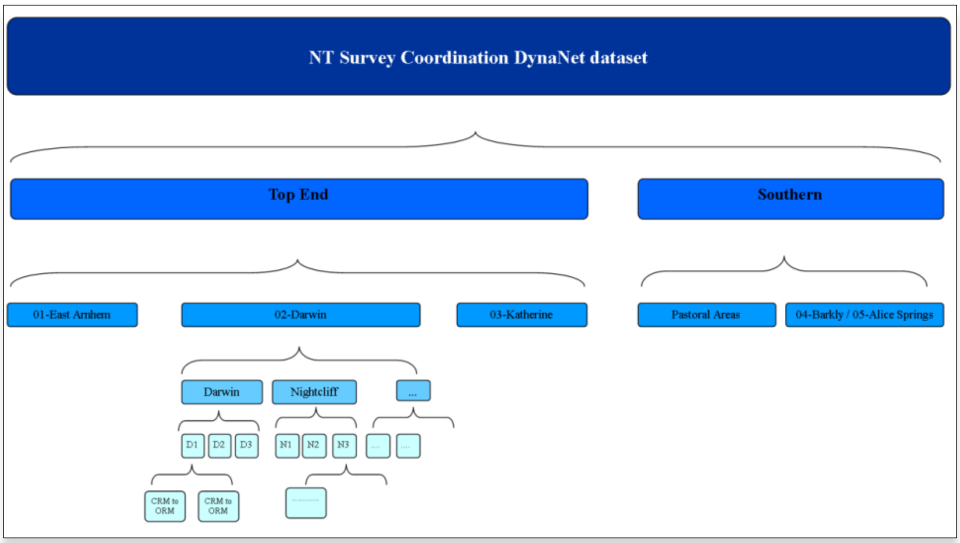

Figure 2.5.1 – Aggregation method for combining NEWGAN datasets

[6] RICs surveys performed for the normalisation of tenure in remote communities
[7] ZED developed by Steve Tarbit – Queensland Government

The sectioned flat-file adjustments of the past were necessary given the size limitations of NEWGAN, and were constrained via 'fiducials' produced in the overarching adjustment. Whilst it did maintain traceability back to datum, the approach now taken in a combined 'mega' adjustment provides direct traceability, maximum connectivity, no duplication and rigorous estimate of uncertainty. Today, the inputs to the Australian continental geodetic adjustment, referred to as the 'national adjustment', far surpass that contributed to the combined State and Territory NEWGAN adjustment of 1995-1997, performed by Dr J.S. Allman. Figure 2.5.2 provides comparison between the two successive national adjustments. Run on the National Computing Infrastructure in Canberra (NCI), the last national adjustment (v1.3) took around 150 hours and converged after four iterations. It is believed to be the largest continental-scale geodetic adjustment in the world.

	Stations	*Directions*	*Distances*	*Azimuths*	*GPS Baselines*	*GPS Multi-baselines*	*GPS Multi-station*	*Total Observations*
1995-1997 (GDA94)	~8000	46,412	13,698	1,167	4,044	5,839	230	71,390
2015-2017 (GDA2020)	250,889	324,020	46,064	1,711	1,212,357	45,483	1,686	1,969,705

Figure 2.5.2 – Comparison of inputs from the GDA94 and GDA2020 national adjustments

Although the NT is yet to contribute an underlying jurisdictional adjustment, the national approach to assembling the adjustment can be simply expressed as per figure 2.5.3 below

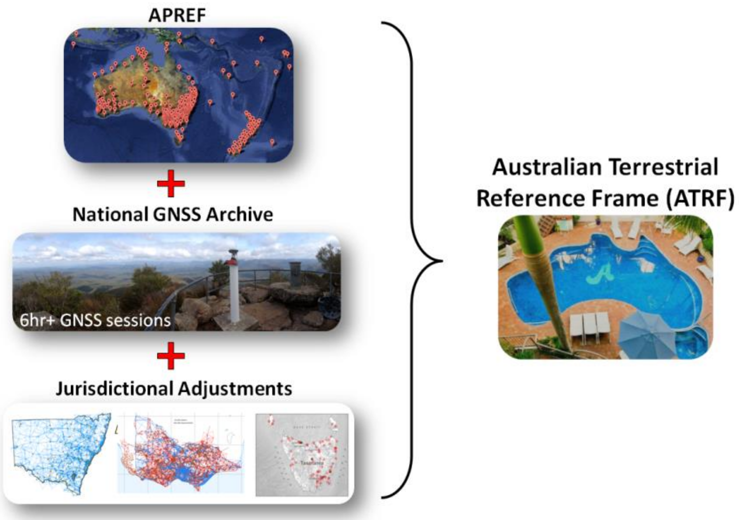

Figure 2.5.3 –Inputs to the national adjustment- Geoscience Australia

2.6 Propagate the positional uncertainties for geodetic control *and*
2.7 Integrate survey control positional uncertainty information into the Territory's geodetic survey control data base known as NTGESS

Adopted across Australia in 2005, positional uncertainty (PU) refers to the uncertainty of the coordinates or height of a point, in metres at the 95% confidence level, with respect to the defined reference frame (ICSM). A significant feature of DynaNet is its ability to propagate positional uncertainty.

Given the long standing commitment to developing and maintaining a fully coordinated cadastre in the NT (as provisioned under directions for Coordinated Survey Areas) and the ability for users to directly access the datum through CORS, the desire to realise PU at the cadastral or 'street' level is now imperative. As previously indicated by Roberts et al (2009), the implementation of PU into geodetic networks and the dissemination of this information to users has not been consistent across the nation. In the NT, the primary barrier to realising, storing and distributing PU has been the operational need to migrate to an extensible, standards-based database and automated approach to processing and data management. As the primary users of this information, surveyors are familiar with how PU and also Survey Uncertainty (SU) are derived, and are now well-practiced in calculating these quantities and lodging together with their coordination data under the requirements of the Survey Practice Directions. It has been acknowledged however that deficiencies in our current geodetic (survey control) database, the slow progress towards achieving a seamless single geodetic dataset, and the transition away from the expression of *Order* (but without implementation of PU), have overall caused ambiguity among surveyors and hindered their complete uptake of the "uncertainty" regime.

During the last twelve months however, a political shift towards, and acceptance of 'open data policies' has provided the opportunity for the Surveyor-General's office to negotiate the use of the Victorian database and application SMES (Survey Mark Enquiry System), which will provide the new repository for all observational data, metadata and adjustment results relating to geodetic marks across the NT. The ability to leverage off the significant investment made by a larger jurisdiction is of great benefit to the NT and again demonstrates the efficiencies to be gained by working collaboratively rather than duplicating effort for the same outcomes. In the future SMES will provide linkage to the Survey Approvals Online application which was developed to streamline the allocation, transfer, lodgement and approval of survey data. Providing visibility of data to users in a timely fashion is critical; ironically it has been the recent provision of geodetic data for public access through ILIS (Integrated Land Information System – of which SAO is a module) that has allowed the re-direction of resources from managing queries to higher-value work such as system and process development and geodetic processing.

Many of the tasks undertaken in managing lodged or future 'crowd-sourced' geodetic data will be automated through SMES. Given the geodetic dataset underpins the cadastral fabric, providing functionality for Surveyors to access, request and pre-lodge geodetic data together with cadastral datasets in a one-stop application will streamline processing both internally and externally. This level of integration, coupled with the propagation of PU via an automated empirical method across the two major foundation spatial data sets relating to land, and the accessibility of these, will finally provide users with an opportunity to realise the benefits of a new modernised datum and the improved order of accuracy the project has achieved.

2.8 Adoption of the new standards and best practices for datum control surveys both nationally and locally.

Through the ICSM – PCG new standards and guidelines for survey control were adopted by the State and Territory jurisdictions in September 2014. These outcomes based documents, colloquially known as “SP1”, were collaboratively developed over a period of several years and involved consultation with the geodetic community, the survey industry, and academia. The main purpose of these documents was to form a consolidated view on the specifications and practices for the delivery and maintenance of Australia’s next generation GRS and geodetic datum.

From a NT point of view the techniques in these documents were familiar to most surveyors as establishing survey control, because of the NT’s vastness, has been typically co-ordinated by GNSS measurements. As discussed above, the main transition for NT surveyors into a modernised datum era was to shift from a CLASS and ORDER regime to the ISO standard of “uncertainty”, as the basis for evaluating and expressing the quality of measurements and positions. This also meant that an NT cadastral surveyor had to consider or be more aware of concepts associated with reference frames, geodetic datum, and dataset interoperability.

In order to engender ownership of this type of change and others, the Surveyors Board of the NT embarked on producing additional guidelines and recommendations that articulated to surveyors the new “SP1” survey control requirements but in manner relevant to the NT. After considerable consultation, *provisional* guidelines for survey control and the use of GNSS on cadastral surveys were adopted by the Surveyors Board of the NT in February 2017. To review these documents navigate to websites –
http://www.icsm.gov.au/geodesy/sp1.html and https://surveyorsboard.nt.gov.au/information

2.9 Implementation of eGeodesy as the geodetic data model and standard for the exchange of geodetic information

Over the last decade, the ICSM supported eGeodesy project has developed a comprehensive single data model for managing geodetic data and metadata with the aim to standardise the processes of exchanging, publishing, recording and archiving geodetic information and observations (Fraser and Donnelley, 2010). A major component of the project has been the development of Geodesy Mark-up language (GeodesyML), an internationally recognised XML-based standard for geodesy facilitating the discovery, sharing and integration of geodetic data (Brown, 2016). Whilst the project did not set out to build a single geodetic system for implementation, it has become apparent that the jurisdictions are largely focused on either modernising or updating their current geodetic control databases to incorporate the elements of the eGeodesy model, and may by default arrive at a common system and indeed a *‘national solution to a jurisdictional problem’* (Fraser, 2016).

Much of the work undertaken in preparing the national adjustment has required compliance to a set of standards and processes to ensure the seamless integration of measurements. The natural extension to this for the NT is to adopt and implement an observational database, with the view to automating much of the process-driven work that is currently performed by the Survey Services unit for the purpose of maintaining the geodetic framework. As discussed under *milestones 6 and 7*, the opportunity to leverage off the immense investment made by the Victorian Office of the Surveyor General in this space is of huge value to a small resource-constrained jurisdiction such as the NT. As an extensible and scalable system, SMES will be tailored to support our jurisdictional objectives aligned with datum modernisation, the management of Crown land transactions, the administration of survey data in line with e Land Development, and the shift to a fully digital environment. The system provides multi-datum capability and will be fundamental in supporting implementation of the new Australian datum.

2.10 Creation of a vertical DynaNet data set for the Territory's bench mark network.

As previously articulated by Peterson and Sarib, the official vertical reference datum for the Northern Territory is the Australian Height Datum (AHD), an onshore realisation of mean sea level from numerous tide gauges and terrestrial levelling networks. Essentially, it represents a normal orthometric surface, based on normal gravity. Previously, absolute values for orthometric heights were held independently in geodetic adjustments, with no distinct relationship expressed between marks in the vertical component. Since the last jurisdictional update of 2012, the Survey Services work unit has digitised and adjusted level run data spanning thousands of kilometres across the jurisdiction in order to create observational-based height difference datasets. Moving forward, this data is to be incorporated with all other geodetic datasets so as to realise a true, rigorous 3-dimensional adjustment.

Due to the gradual transition away from routine spirit levelling to the now predominant use of GNSS techniques for heighting, a geoid model is required to convert ellipsoidal heights to physical heights on the "working height datum" of AHD. A new national geoid model AusGeoid2020 has been created as a product of datum modernisation, combining gravimetric and geometric components into a single national grid. GNSS remains the most-effective method of transferring height into remote locations and is being used more extensively across the region. As such, AHD is neither being actively densified nor maintained and the opportunity to occupy benchmarks realised on AHD with GNSS are infrequent. For this reason, the NT contribution of co-located data for the new geoid model is sparse. The remoteness and inaccessibility of areas pose a challenge for continuous improvement of, and verification of the model.

Providing access to AHD and the advocacy of the relationships between the various vertical surfaces (especially in intertidal zones) will remain a key role for Survey Services into the future.

2.11 Proliferate "Regulation 13" certificates to eligible survey control marks, to allow surveyors to achieve legal traceability of their GNSS measurements via position and comply with the National Measurement Act (NMA) 1960.

Across the NT CORS network, 12 of the 24 operational sites hold current verification as a reference standard of position-measurement in accordance with Regulation 13 of the National Measurement Regulations 1999 and the National Measurement Act 1960. The certification, colloquially referred to as 'Reg13' is a legal document detailing a station coordinate and the uncertainty of that coordinate, and provides a direct connection to datum. Gazettal of GDA2020 will see the recognised-value standard (RVS) updated from the 21 Australian Fiducial Network (AFN) sites to 109 AFN sites (ARGN + AuScope stations), following which verification will be issued for other NT sites contributing to APREF.

Across Australia, Reg13 certificates have been issued for over 500 CORS sites. In the past, Australian-wide certification campaigns have been run across a pre-determined GPS-week, with the objective of improving consistency of legally traceable CORS positions across Australia, and the stated uncertainties. Hu and Dawson (2013) provide an overview of the processing and analysis of the campaign data in order to satisfy the position verification requirements.

As a consequence, NT surveyors can achieve legal traceability of GNSS measurements via position through a direct connection to Reg13 sites and the use of acceptable measuring techniques. Surveyors can also validate their GNSS measurement devices over the EDM baseline calibrated against the national standard of length. In this situation, comparisons of derived/calculated length *based on position* merely provide an assessment of observation technique, reduction and processing of GNSS data, confirming the surveyor's ability to perform coordination activities in establishing new ground control, ultimately linking the cadastre to datum.

2.12 Support and actively participate in ICSM endorsed initiatives that preserve and facilitate the development and maintenance of the Territory's geodetic datum.

There are two ICSM groups comprising of technical specialists from each jurisdiction that the NT contributes to and is involved with, namely the PCG and the GDA Modernisation Implementation Working Group (GMIWG). The current work program for both groups has been focused on ensuring that the practical implementation of Australia's next generation datum, "GDA2020", occurs seamlessly and with minimal disruption to existing systems and processes. This co-operative effort primarily involves determining the parameters of the new datum, developing or modifying the necessary technical utilities and tools for the transformation of data, and communicating and consulting with all users (both traditional and non-traditional geospatial sectors) about the transition and / or challenges. For more information about the two groups, refer to websites –
http://www.icsm.gov.au/geodesy/index.html and http://www.icsm.gov.au/gda2020/index.html

Looking forward, the PCG goals over the next few years may include:

- The provision of technical advice on the implementation of GDA2020
- Further development of standards to ensure machine to machine transfer of GNSS data and metadata (GeodesyML)
- Developing better interoperability and models between Australia's vertical reference surfaces
- Preparation for a 4D datum (Australian Terrestrial Reference Frame – working title) which is closely aligned to ITRF

2.13 Support and actively participate in national initiatives that promote positioning networks as enabling or critical infrastructure.

Through the impetus of national geodetic or geospatial initiatives over the last decade, the profile of "positioning infrastructure" or "location intelligence" within governments has overall gained prominence, especially as a crucial output of a GRS, and also as an important component to assist decision and policy making in a variety of sectors. For the NT, recent active involvement in such initiatives has resulted in two significant pillars of the NT GRS, being a unified GNSS CORS network that is part of a national and regional system; and a modernised datum linked to a global geodetic reference frame. The next development phase of the NT GRS is to ensure all users can realise the benefits from the GRS by having access to "reliable positioning" that is available anytime and anywhere. To achieve this the NT needs to support and participate in the National Positioning Infrastructure (NPI) initiative which aims to (a) improve the on-ground operational infrastructure and services (i.e. GNSS CORS, open data formats, safety to life or security applications etc.) and (b) utilise satellite communications to deliver positioning services in regions where mobile and radio services cannot. Successful rollout and implementation of the NPI capability will achieve accurate and reliable positioning anytime and anywhere.

For more information about NPI refer to website - http://www.ga.gov.au/scientific-topics/positioning-navigation/positioning-for-the-future/national-positioning-infrastructure .
From a NT perspective, the important facets of datum modernisation can be depicted by Figure 2.13.1, where overarching global positioning strategies are deeply embedded in the operational work and positioning futures at a grass roots, regional level.

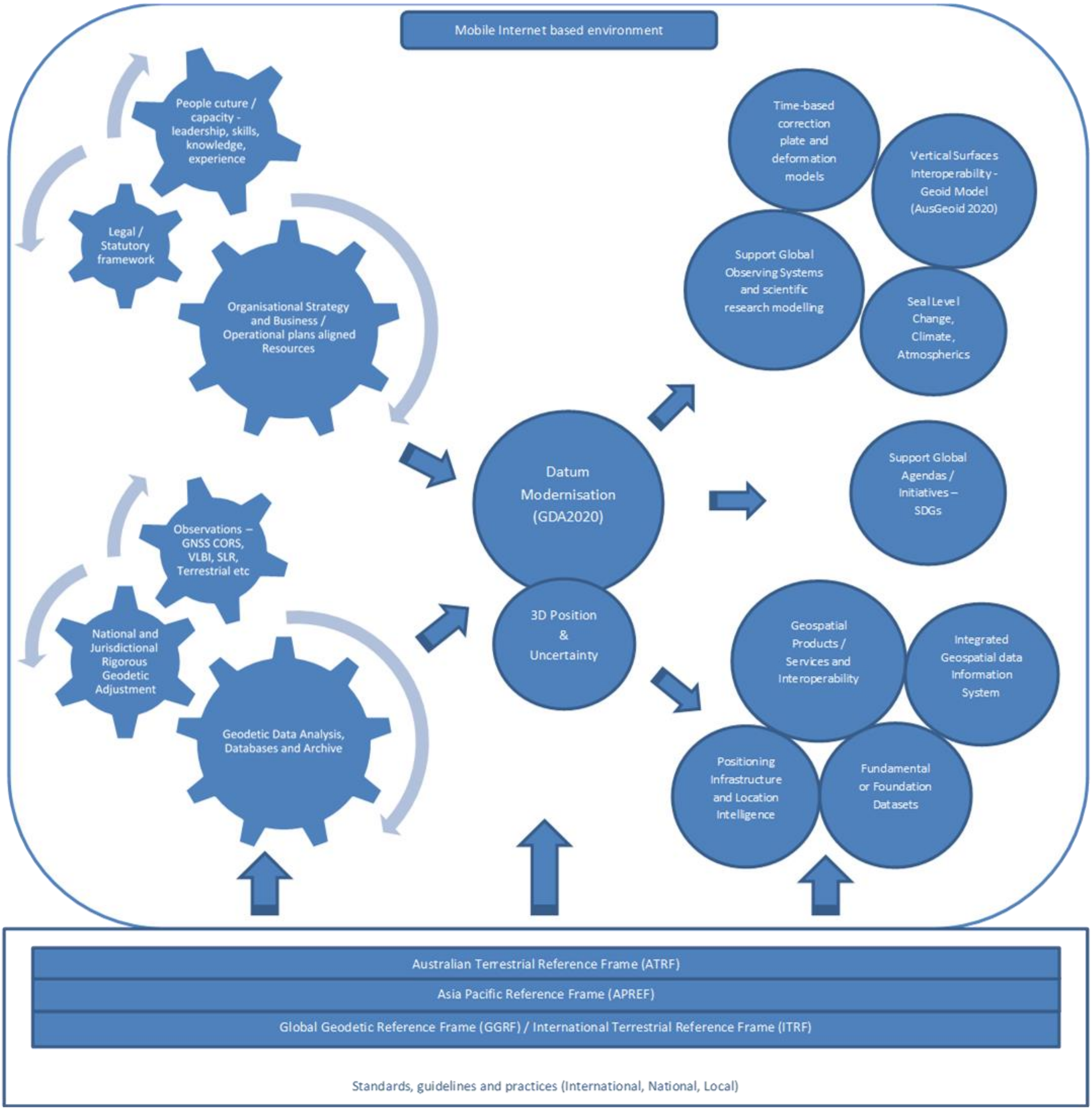

Figure 2.13.1 – Datum Modernisation

3. DATUM MODERNISATION CHALLENGES

The two major challenges identified for the future are as follows –

- Ongoing justification of the value and relevance of the NT GRS and subsequently resourcing.
- Developing and maintaining capability of surveyor's and geospatial scientists.

For the last 5 years the Survey Services GRS or geodetic strategy has not fundamentally changed. The environment however in which the work unit operates can be technically described as being in flux or in management terminology, undergoing continual organisational change. The major spheres of influence which appear to have driven recent organisational change, cannot be solely attributed to fiscal based arguments, it has also been transformed by administrative or political ideologies which have translated to a shift in overall direction, policy, and business priorities. To exacerbate the situation poor understanding and knowledge of geospatial infrastructure and systems, lack of vision, intangible objectives and inadequate advocacy of the potential benefits has led decision makers to misrepresent the importance, relevance, role, and value of the GRS and its infrastructure. As a result the "will and support" for more popular and traditional economic and social activities have received more attention in lieu of GRS activity and / or datum modernisation.

To reverse this apparent trend the stakeholders of the NT GRS need to be more flexible, proactive and progressive in the way they market the *what, how* and *why* proposition. There is a need to articulate and demonstrate how a modernised GRS equates to efficiencies and savings within government; and how an operational GRS is critical infrastructure that facilitates business opportunities and enables innovation to improve productivity and revenue across many sectors. In conjunction with this, realistic examples or case studies and figures, which must be commensurate with NT's economic capability, need to be identified and promoted so as to illustrate a positive return on public investment. Furthermore, it is suggested that a review and examination of its role in geospatial data, systems and infrastructure needs to be conducted so as to create achievable and flexible strategies towards both short and long term goals. Coupled with this, key performance indicators to monitor and measure success are also essential and in the case of the NT they must be intrinsically linked to financial drivers to demonstrate value for money. The abovementioned will be a major challenge for the NT in the current economic and political climate.

Over the last decade, the NT has increasingly found it difficult to attract interested applicants for both cadastral survey or GRS specialist positions. It has also been an ongoing challenge to provide suitable opportunities to enhance and maintain the capability of the existing professional workforce. Although our small economy, remoteness and limited population base are often regarded as "contributing factors", in some respects this situation has sufficed our past business needs as it has cultivated a broader skill-set required for the diverse range of survey work undertaken in such an environment. To further add to the challenge of maintaining and developing capability, the activities of a surveyor or a geospatial scientist, with respect to collection, processing, and delivery of reliable, accurate, interoperable geospatial information are now influenced by disruptive technologies, geospatial trends, and spatial matters relating to environmental, political and social agenda. The surveyor of today is no longer representative of the 'traditional' surveyor, just as the surveyor of tomorrow should again be equipped with different and more contemporary skills.

A valuable step in assessing the current workplace capacity may be in the creation of both an individual and an aggregated matrix across teams to show skill and areas of knowledge and proficiency (including those not directly relevant to roles) and areas of potential developmental focus. The data can be de-identified and used in a shared environment, used as a resource for building project teams and targeted or rapid response. Such a tool may support both the realisation of workplace expertise and the path towards building capacity.

To move forward quickly in this domain will require a paradigm shift, rather than continuing to exist in an environment where we are lagging behind technology and best practice and struggling with diminishing resources. The ultimate outcome would be to redefine the objective, role, and function within the geospatial survey sector, and provide an overall strategic plan identifying the status quo, short-term 3-5 year vision, the roap-map to achieve it and indicators of performance and progress towards it – *"where are we now, where do we want to be in 3-5 years, how are we going to get there, and how will we know when we are there."* In some core aspects of our work, it may be possible to create the future, without realising the present; aspire towards a quantum leap. Essentially, it will require leaders, managers and personnel in both the geospatial and survey related work units to embrace change – creating an environment that supports progressive thinking, agility, and less aversion to risk. This is not naturally characteristic of government as a whole, but has been demonstrated at grass roots in other agencies in the NT and shown to influence wider.

In a unified and collaborative manner, work units need to rationalise operations; realise continuous improvement in, or redefinition of their operations, processes and systems to do things smarter, more effectively and efficiency, with the use of technology and in an environment of innovation, aligned with emerging technologies and trends; and then prove and maintain what they do. A land information agency could ultimately be responsible for managing, storing and disseminating data and related products, ensuring its integrity, reliability and accuracy; setting standards and guidelines; receiving, validating, processing, and analysing and integrating data in an automated environment that accommodates cloud and mobile internet technologies or systems to interact with data providers and users.

4. CONCLUSION

Since the last update 5 years ago, Survey Services work unit has achieved, slowly but surely, significant enhancements to the NT GRS. The completion of milestones or actions has been accomplished largely through the rationalisation and aligning of national and jurisdictional priorities. In many areas, theses priorities together with diminishing resources continue to influence changes to business rules and systems, workflows and processes, and further drive efficiencies in day-to-day operations. A review of essential roles and services within the Survey Services unit together with a strategy to build necessary capacity to achieve the revised objectives remains critical if the unit is to remain competitive in a fiscally constrained environment.

It is the opinion of the authors that delivery and maintenance of the NT GRS is one of the primary functions of Survey Services that must be upheld. The need to ensure the integrity, inter-operability and maintenance of the NT GRS will become critical to decision-makers and stake-holders as they increasingly take advantage of the benefits of a "ubiquitous positioning" era and the access to accurate location intelligence that it provides. The NT GRS must therefore be recognised and supported as critical geospatial infrastructure, and continue to be enhanced, together with other State and Territory jurisdictions and the geospatial industry, in a collaborative and unified manner.

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BIOGRAPHICAL NOTES

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Robert Sarib obtained his degree in Bachelor Applied Science – Survey and Mapping from Curtin University of Technology Western Australia in 1989. He also holds a Graduate Certificate in Public Sector Management received from the Flinders University of South Australia. Rob was registered to practice as a Licensed Surveyor in the Northern Territory, Australia in 1991. Since then he has worked as a cadastral and geodetic surveyor, and a land survey administrator.

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