CORS and a Future Geodetic Framework for Western Australia

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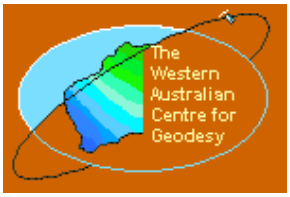

Curtin
University of Technology

Executive Summary

Introduction

The Department of Land Information (DLI) of Western Australia commissioned the technical study 'CORS and a Future Geodetic Framework for Western Australia' with the following Terms of Reference (TOR), in order to develop a future strategy for GPS CORS networks in Western Australia:

1. What CORS options are currently available and how good are they for Western Australia?

2. What are the uses of CORS technology beyond geodetic and survey control?

3. What is the required absolute and relative accuracy for a Western Australian CORS network now and in the future?

4. What is the likely impact of GPS modernisation, Galileo and GLONASS on CORS technology and how would this relate in a Western Australian context?

5. Should DLI wish to proceed with a trial CORS network in the Perth metropolitan area, how should that trial be designed to maximise benefit to DLI in future decision making?

Outcomes in relation to the TOR

TOR 1. What CORS options are currently available and how good are they for Western Australia?

General comments

- A number of CORS networks are currently operating in WA, providing different levels of service to different and often very specific markets and users. These include a small number of geodetic CORS, the AMSA, OMNISTAR and VERIPOS services, and a number of CORS run individually by mining, agricultural or other commercial concerns.

- Today, WA is covered by commercial real-time positioning service down to 10-20cm level. This level of service covers the majority of dynamic applications.

- Below the 10cm accuracy level, existing CORS systems, without upgrade, densification and refinement, are not capable of routinely providing geodetic and survey control accuracy requirements in any operationally practical way, nor over any significant area of Western Australia.

- Below the 10cm accuracy level, the positioning market is specialised and relatively small, being restricted mainly to surveyors, mining companies, agriculture and scientific applications. However, whilst the user base is specialised and small, the purpose of high accuracy applications is often in support of significant economic infrastructure and investment projects such as land development, construction (roads, harbours, bridges, pipelines etc), mine site (including safety) and mineral exploration type activities.

- Although few of the existing CORS could be classed as being of geodetic quality, many could easily be upgraded to a geodetic level if necessary. Many agencies would consider such upgrades if they were to provide a concrete legal link to the Geocentric Datum of Australia (GDA).

- The number of CORS networks and individual CORS within the State is set to steadily increase over the next two to five years.

- The study reviewed possible implementation models for establishing a geodetic CORS network system for the primary purposes of *geodetic datum definition and realisation*:
    - The *'top down model'*, in which CORS networks are established and run by government and scientific agencies. Examples were provided from the United Kingdom and Ireland.

    - The *'bottom up model'* unifies all existing CORS networks in a region into a State or National network, under the umbrella of a single government organisation, a case study was provided from the United States.

Geodetic CORS Networks

- To practically implement a phased transition to direct definition and realisation of GDA94 and AHD71 throughout the populated areas of WA using GPS and AUSPOS would require around 25 optimally placed CORS network stations.

- In addition to routine surveying and geodetic operations, a 25 station state network would also be able to support:
    - an improved State height datum;
    - an independent State set of GDA-ITRF transformation parameters;
    - regionally computed IGS-style products, such as precise orbits and ionospheric models;
    - contribute to continental and global geodesy.

- High precision datum realisation directly through a State-wide CORS network is contingent not only on the installation of optimally placed CORS network stations, but also on technological advances in hardware (GPS modernisation, introduction of Galileo, regeneration of GLONASS, multi-satellite system reception geodetic receivers) and processing software (predominantly the AUSPOS system).

- Given the timeline for relevant technological advances, the phased transition to direct high precision realisation of GDA94 and AHD71 through a State CORS network can be projected to be completed by 2015, assuming the projected GNSS modernisation program timeframes are realised, CORS network installation over a 2007 – 2010 period and a commitment to upgrading CORS receivers to multi-satellite system reception geodetic capability, as necessary. Therefore, notwithstanding the installation of a near-optimal State-wide CORS network, the practical realisation of both horizontal and vertical datums would continue to rely on ground marks in the short to medium term.

Network RTK (NRTK)

- Simulations indicate that with the current GPS constellation and existing technology, 100km NRTK is not a particularly feasible concept. However, with an inter-station spacing of 50km provision of reliable NRTK services are possible with GPS. The introduction of the Galileo satellite navigation system will greatly improve this situation, making NRTK with 100km inter-station spacing possible and greatly improving the reliability of 50km networks.

AUSPOS

- AUSPOS is an automated web-based GPS processing system delivering GDA (and ITRF) high quality datum realisation across the state. It is an important national asset which can already deliver.

- Although other automated web-based processing systems are available from other sources internationally, it is advantageous to the country, and consequently to Western Australia, to maintain its own system, both for legal and developmental reasons and to deliver GDA.

- In the short term, an improved CORS density in WA would improve AUSPOS solutions across the State, so long as data from any additional suitable stations were made available for AUSPOS processing.

- In the longer term, to support a phased transition to direct high precision realisation of GDA94 and AHD71 through a State CORS network, AUSPOS requires re-development and state government organisations should support and assist Geoscience Australia (GA) in this process.

TOR 2. What are the uses of CORS technology beyond geodetic and survey control?

The following applications were identified as having potential State or National benefit and as being currently unsupported by the existing CORS infrastructure within Western Australia:

- Regional real time kinematic positioning services.

- Geohazard monitoring, including crustal monitoring, mean sea level monitoring, tidal loading determinations and atmospheric sounding.

- Post-processed kinematic surveying, particularly for airborne survey work.

- Regional IGS-style products such as precise orbits, atmospheric products and ITRF-GDA transformation parameters, which can be used to provide improved dynamic positioning solutions when supporting services such as OMNISTAR.

- Precision guidance systems, with application in agriculture and engineering, are currently supported in an ad hoc sense by the commercial sector. Availability of services is restricted in some areas of the State by commercial constraints.

TOR 3. What is the required absolute and relative accuracy for a Western Australian CORS network now and in the future?

This Study identified the accuracy requirements that a geodetic CORS Network system would need to achieve to be useful in horizontal and vertical coordinate realisation.

- ***Geodetic applications,*** such as datum maintenance and realisation, crustal monitoring, reference for survey control (support for AUSPOS), and tide gauge monitoring, have an absolute accuracy requirement of better than 1cm (95% confidence) in ITRF.

- ***Survey applications,*** such as transfer of survey control, cadastral surveys, engineering and deformation surveys, including post-processed dynamic applications such as airborne photogrammetry and laser scan surveys, require horizontal and vertical accuracy to 1-5cm (95% confidence), relative to GDA and AHD.

- ***High precision dynamic applications***, such as cadastral pickup, road pick-up, machine guidance, high precision agricultural applications, wave-buoy monitoring, require 1-10cm (95% confidence) horizontal accuracy relative to GDA in real time.

- ***Medium precision navigation applications*** such as precision agriculture, high end vehicle tracking, asset mapping, require horizontal accuracy of 10cm – 1m relative to GDA in real time.

- ***Standard navigation applications,*** such as land, maritime or airborne navigation require horizontal accuracy in the order of 1 – 10m, usually relative to GDA, in real time. Note that for *liability critical* applications, medium and standard navigation applications may have much higher precision requirements.

- ***All other navigation applications*** requiring less than 10m accuracy real time can operate with standalone GPS.

Future accuracy requirements are more difficult to quantify. GA, based on collaboration at an international level and its own understanding of the requirements to meet future needs of its

National Geospatial Reference System has defined three levels of future geodetic CORS-based accuracy. These accuracies are about an order of magnitude more precise than current requirements. The GA-based future accuracy expectations are:

Category	Accuracy Requirement	Application Examples
1	1mm	Reference Frame Development National Datum (GDA, AHD, Gravity Field) Geodetic Science (Neo-tectonics, Sea Level Rise, Isostasy, etc.)
2	10mm at 1σ	Mapping / SDI Precision Agriculture Mining / Construction, Engineering
3	100mm at 5σ	Liability Critical Services Safety of Life Applications

TOR 4. What is the likely impact of GPS modernisation, Galileo and GLONASS on CORS technology and how would this relate in a Western Australian context?

GPS modernisation

- The current Block II GPS modernisation programme commenced in 2000 with selective availability being set to zero (i.e. switched off).

- Upgrade of 12 of the current generation satellites to carry the new civil L2C GPS code achieved. This improves the quality of geodetic static and Real Time Kinematic (RTK) coordinate precision solutions and improves RTK and Virtual Reference Station (VRS) systems over a longer range.

- The next generation of Block II GPS satellites (implementing 2006 – 2010+) will transmit an openly available third civilian frequency signal, known as L5, in addition to L2C. The availability of both L2C and L5 will significantly enhance RTK capabilities, especially in an urban environment.

- Beyond 2013, plans for Block III GPS could only be considered as indicative, with broad goals to increase signal strength (making indoor GPS more of a possibility), greater availability (i.e. more satellites), improved integrity and greater 'survivability' (i.e. less susceptibility to interference).

Galileo

- Currently in the development stage, with the first prototype satellite launched in December 2005. Satellites are designed to transmit up to 4 L-band frequencies, possibly with some only accessible on a 'pay per view' basis. Galileo will comprise a 30 satellite constellation with the full constellation planned to be operational by 2008 (although 2010 or even 2012 look more likely dates).

- With 30 satellites and potentially 4 L-band signals, Galileo may be seen as a direct competitor to GPS in the RTK market.

GLONASS

- By 1997 some 18 GLONASS satellites were operational and with dual GPS/GLONASS receivers and a combined total GPS/GLONASS constellation of over 47 satellites, improved RTK methods demonstrated the powerful potential of expanded GNSS systems over stand-alone GPS.

- Russian support for GLONASS has been variable up until recent times, and as a result the GLONASS system has lost much credibility within the GNSS user community. GLONASS potentially will rapidly be eclipsed by the superior technology offered by the Galileo and modernised GPS systems.

- GLONASS has not been considered in the simulation process. However, it is acknowledged that if an 18+ satellite GLONASS system were to be fully and reliably operational by 2010 or beyond, it could provide useful supplementation to GPS/Galileo.

Combined GPS/Galileo

- The future impact on CORS technology of the GPS modernisation program and the emergence of Galileo is likely to be greater if realised by the combined use of both systems. This will provide improved signal strength and reliability, translating to more rapid, reliable and accurate positioning solutions. In the Western Australian context there will be obvious advantages. The primary remaining issue is the accurate transformation of CORS derived positions into GDA94 and AHD71 coordinates.

In a Western Australian context, even if GPS/Galileo/GLONASS system improvements maintain their publicised timescales, there will be a natural lag of several years before users accept the new technology and go to the expense of trading in their existing for new hardware. Therefore the full impact of GPS modernisations, the introduction of Galileo and GLONASS regeneration will most likely be realised around 2015 rather than earlier.

TOR 5. Potential DLI trial of a CORS network in the Perth metropolitan area to maximise benefit to DLI in future decision making?

This Study identified a number of current proposals for various implementations of CORS networks in WA and indeed across Australia. Rather than proceed to establishing the infrastructure for a trial CORS network in the Perth metropolitan area, designed to maximise benefit to DLI in future decision making, unless of immediate priority, DLI could leverage off the infrastructure being proposed for CORS in WA and Australia.

In this context, a private Perth company is well advanced in its plans to initiate a 5 station CORS Network Real Time Kinematic (NRTK) geodetic quality system in the metropolitan area. DLI has been requested to provide assistance with the CORS network establishment. This assistance includes (i) providing specifications for all the sites and the data processing, (ii) providing the NRTK base station coordinate realisation, (iii) access to its Midland GPS site for data collection and (iv) ongoing network stability monitoring.

This NRTK geodetic quality system proposal within the metropolitan area, or one of the other potential CORS network initiatives, provides a firm basis for DLI trialling a CORS network in the Perth metropolitan area, at very low capital expenditure.

6. Recommendations

Preamble

This Study has found that a CORS-based system is a potentially powerful tool for future datum definition and realisation in Western Australia. Any future geodetic CORS network in WA (or Australia) would be capable of supporting the system of:

i) providing, realising and maintaining a modern integrated geodetic infrastructure system, both horizontally (GDA94) and vertically (AHD71), to meet the spatial infrastructure needs of the State;

ii) the legal traceability requirements as specified under the *National Measurement Act 1960;*

iii) high accuracy scientific applications such sea level monitoring, atmospheric modelling and crustal monitoring.

The ability of such a network to successfully fulfil these roles would be dependent upon projected technological software and hardware developments coming online in the next 5 years.

The introduction of a WA CORS network would represent a policy of phased transition from datum definition and realisation through ground marks to a system of definition and realisation predominantly through the State CORS network. Given current technological limitations, for Western Australia this transition would be likely to take until 2015 and beyond.

Such a transition will be critical to maintain the State's geodetic and navigational infrastructure, in the light of rapid technological developments, throughout the first half of the 21st century.

The following recommendations, drawn from the outcomes of this study, pertain to the role of DLI in datum definition and realisation and in the establishment of a CORS network in the state of Western Australia.

Recommendation 1: DLI to maintain its role of maintaining State standards for datum realisation, legal traceability and support for high accuracy scientific applications such sea level monitoring, atmospheric modelling and crustal monitoring.

Recommendation 2: It would be beneficial to future State development and infrastructure to develop and install a State CORS network capable of high precision geodetic datum definition and realisation.

Recommendation 3: Given the size of Western Australia, the bottom up model for geodetic datum definition and realisation for CORS is financially attractive and facilitates cooperation with industry, rather than competition. Furthermore, since hardware upgrades are market driven, DLI would not be exposed to uncertainties caused by future technological development.

Recommendation 4: DLI to examine the legal framework for all CORS based positioning activities in WA.

Recommendation 5: DLI to lead definition and implementation of unified WA CORS network by initiating contact with CORS operators from all sectors across the State. DLI to clarify role and relationship with GA in any unified state CORS network.

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Recommendation 6: An optimised network of around 25 geodetic CORS will be required to provide basic GPS coverage for high precision geodetic datum definition across the populated areas of the State.

Note that receiver upgrades at CORS sites would need to be undertaken after proven multi-satellite system reception geodetic receiver technology becomes available.

Recommendation 7: DLI to consider installation of a dense CORS network (i.e. 50-100km spacing) in the south-west of the State, for the support of the geodetic datum, the agricultural and resources sectors and geohazard applications.

Recommendation 8: Due to the increasing incompatibility between AHD and GPS derived orthometric heights, DLI must maintain a transformation surface across the State between

AHD and GPS derived orthometric heights. A State CORS network would provide the stable framework upon which this surface can be based and maintained.

Recommendation 9: DLI should develop a new 'scientific' height datum based purely on CORS GPS and the high precision gravimetric geoid in order to maintain a completely GPS compatible height datum for scientific applications and closely monitor the inconsistencies in the AHD.

Recommendation 10: There is an unfulfilled requirement for accurate ITRF-GDA transformation parameters for WA. DLI should use a CORS State network to compute State transformation parameters in conjunction with the GA national solution.

Recommendation 11: Unless there are matters of urgency and priority, any potential trial of a CORS network in the Perth metropolitan area to maximise benefit to DLI in future decision making should be delayed until DLI can leverage off the infrastructure provided by other CORS initiatives in this State.