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# CORSnet-NSW reaches 175 CORS milestone

A testament to LPI's vision to be a world leader in spatial information.



Figure 1: CORSnet-NSW network map as of January 2016.

ORSnet-NSW is Australia's largest state-owned and operated Global Navigation Satellite System (GNSS) Continuously Operating Reference Station (CORS) network. It is built, owned and operated by Land and Property Information (LPI), a division of the NSW Department of Finance, Services and Innovation.

LPI's first CORS was installed in 1992 in Bathurst, using in-house developed programming to support internal survey and aerial photography operations. In 2004, a pilot-project network of seven CORS was installed in the Sydney metropolitan area and made available to the public one year later under the name SydNET.

A renewed effort of expansion to extend the coverage of CORS throughout NSW commenced in 2009 as part of a 5-year, multimillion-dollar Survey Infrastructure Improvement Project, which corresponded with the rebranding of the network as CORSnet-NSW. In only four and a half years, the network grew from 27 stations in late 2009 to 150 CORS in July 2014. This is an extraordinary achievement, considering the technical and resourcing challenges faced and time taken to get approval to build some sites.

In January 2016, the network reached its 175 CORS milestone... and still keeps on growing. This article provides an overview of the current status of CORSnet-NSW and indicates what's in store for the near future.

### **Current status**

Today, CORSnet-NSW (http://www.corsnet. com.au/) is a state-wide network of GNSS CORS providing fundamental positioning infrastructure for New South Wales—and the Australian Capital Territory—that is accurate, reliable and easy to use. It supports the spatial community and provides stimulus for innovative spatial applications and research using satellite positioning technology.

The coordinates of each CORS are determined via the national Regulation 13 process, providing consistent positioning infrastructure that is compatible with other—public and private—CORS operators across the country and offers legal traceability.

Raw data is wholesaled to three premium resellers, SmartNetAus, AllDayRTK and Trimble VRS Now Australia, while CORSnet-NSW subscriptions are currently available through 16 authorised resellers servicing a wide range of applications.

In addition, raw data from all LPI-owned CORSnet-NSW stations support national and local positioning applications via inclusion in the Asia-Pacific Reference Frame (APREF) and Geoscience Australia's free online GPS processing service (AUSPOS), resulting in better performance for users in and around NSW.

As of January 2016, CORSnet-NSW consists of 176 reference stations across the state. Figure 1 illustrates the CORS network coverage, showing stations that are operational (indicated by small triangles) as well as some planned stations (indicated by small circles). A 50 km radius around active stations is shown to illustrate the maximum recommended coverage area for single-base Real Time Kinematic (RTK) operation, while Network RTK (NRTK) coverage is shown as a striped, pink polygon in areas that have sufficient station density to support this technique.

Currently, 75% of the area of NSW (and 99.8% of the population) is covered by the single-base RTK service, while NRTK is available to 56% of the area of NSW (and 98.6% of the population). More than 55% of the state's population is within 10 km of their nearest CORS. The sub-metre Differential GNSS (DGNSS) service is provided across the entire state. Other services include the provision of RINEX and Virtual RINEX data for postprocessing applications (see Position 67, October 2013).

Figure 2 illustrates CORSnet-NSW station redundancy, i.e. the area concurrently covered by two or more CORS. In practice, this means that if the



primary CORS should not be available for any reason, an alternative nearby CORS should ensure nearly the same user experience in regards to accuracy, time-tofix, reliability of ambiguities, etc.

Currently, such backup coverage is available to 39% of the state's area for RTK and 95% for DGNSS. Improving monitoring and climate change research. The tide gauge records available from Fort Denison in Sydney Harbour, which has operated since 1886; and the Pilot Station in Newcastle, since 1925, are two of the longest continuous records in the southern hemisphere (see Position 65, June 2013).

"CORSnet-NSW has established itself as a worldclass, state-of-the-art, state-wide, multi-function CORS network that balances public-good and commercial mandates."

such redundancy to ensure the more effective and efficient delivery of services to our stakeholders is of significant importance to LPI.

## **CORS** monuments

Eleven CORSnet-NSW stations were built to (inter)national geodetic specifications with joint state/federal funding as part of the scientific, national (Tier 2) AuScope CORS network.

Five CORS (Fort Denison, Port Botany, Newcastle East, Port Kembla and Eden) were built specifically to augment long-term tide gauges located along the NSW coast in order to support sea-level Following cross-border arrangements, CORSnet-NSW also incorporates a number of interstate CORS in order to adequately cover areas in the ACT and along the Queensland and Victorian borders. Most stations in NSW are hosted by local councils (the equipment being owned by LPI), and two by private industry. In total, 90% of CORSnet-NSW stations are hosted by LPI's 100+ partners. Examples of typical CORSnet-NSW installations are shown in Figure 3.

In order to provide a legally traceable survey monument that allows the GNSS antenna to be oriented to True North without the need to introduce an antenna

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Figure 3: Typical CORSnet-NSW monumentation and auxiliaries at (a) Tier 2 and (b) Tier 3 sites.

height, the CORSnet-NSW Adjustable Antenna Mount (CAAM) was developed and patented by LPI specifically for use within CORSnet-NSW.

All Tier 3 CORSnet-NSW CORS installations since March 2011 use the CAAM, which has proven to be very effective and particularly invaluable when replacing or upgrading GNSS antennas because a zero antenna height is always maintained. This design is freely available to other CORS operators.

## **CORS equipment**

CORSnet-NSW uses a mix of modern Leica and Trimble GNSS receivers, tracking both GPS and GLONASS satellites. LPI has specifically avoided the exclusive use of only one type of receiver to minimise risks and increase business/ service continuity. Diversification has been limited to two brands in order to simplify fleet management.

The NSW Foundation Spatial Data Framework (FSDF) 2020 Strategy directs CORSnet-NSW to support new GNSS constellations and signals. More than half of all CORS are hardware-ready for (or at least capable of) tracking additional GNSS constellations such as Galileo and BeiDou in the future.

This functionality will be activated by CORSnet-NSW only when each system officially reaches its Initial Operational Capability (IOC), system reliability has been proven and there is sufficient user demand. In the meantime, BeiDou satellites are currently tracked at six Tier 2 CORS and 62 Tier 3 CORS for research and evaluation purposes. This is particularly important given Australia's strategic geographic position on the globe, resulting in a multitude of satellite constellations being available in this region (see Figure 4).

CORSnet-NSW infrastructure has recently been used in proven trials of Precise Point Positioning (PPP) solutions delivered by the Japanese Quasi-Zenith Satellite System (QZSS) for precision agriculture applications in rural NSW.



This was a small but significant first milestone in NSW's desire to introduce satellite-based delivery (through either premium resellers, National Positioning Infrastructure – NPI, international coordination or other mechanisms) to service new and emerging market sectors and realise LPI's aspiration to improve service delivery through new technologies.

CORSnet-NSW uses a mix of highprecision survey antennas (69%) and Dorne Margolin choke ring antennas (31%), generally with radomes installed. LPI intends to have future antennas individually calibrated by Geoscience Australia at its new test facility in Canberra.

The majority of CORS feature dual communications (main and backup, e.g. ADSL and Next G) to ensure the highest possible standard in regards to data availability and data completeness. Installs are equipped with a variety of auxiliary The data centres employ server virtualisation technology to maximise hardware utilisation, flexibility and scalability while at the same time minimising power consumption, space requirements and carbon footprint. Network connectivity and availability is constantly monitored using external service providers. A third, ad-hoc development system is used for internal system testing.

## **Quality control**

Quality control and integrity monitoring of CORS infrastructure is becoming increasingly important for legal traceability of data and measurements as well as for long-term stability studies of station coordinates. CORSnet-NSW operation and performance is monitored by LPI staff in real-time using Trimble's Pivot CORS network management software, which also has the ability to detect abrupt station movement in real-time.

Long-term, multi-year station stability monitoring based on daily 24-hour RINEX files is performed in-house using the scientific Bernese software in an automated process. Station coordinates are calculated with millimetre-level precision, and the resulting time series are made available on the CORSnet-NSW website (see Figure 5 for an example). System performance and station stability are also independently monitored by third

> Figure 4: Number of visible GNSS satellites above 30° elevation expected in 2020 (courtesy Prof. Chris Rizos).



devices such as industrial-strength modems, remote reboot relays, digital cameras with selective motion detection, door alarms, automatic cooling fans, solar power (on selected sites) and Uninterruptible Power Supply (UPS) units that last up to 30 days.

This is complemented by two mirrorimage Network Control Centres (NCCs), located in Sydney and Bathurst, that utilise Commercial-Off-The-Shelf (COTS) CORS management software with full redundancy. ICT architecture allows for immediate failover between the two NCCs to ensure continuous data supply to users. parties, including premium resellers and the APREF analysis centres.

The stability of all Tier 2 CORSnet-NSW pillars is monitored by LPI at suitable intervals through high-precision Reference Mark (RM) surveys. These terrestrial surveys determine the horizontal position of the pillar relative to three surrounding reference marks with an accuracy of better than 1 mm (95% confidence interval) and the vertical position of the pillar plate to within class L2A specifications (maximum misclose  $2\sqrt{d}$  mm - see Position 44, December 2009).



Figure 5: Bernese-derived coordinate time series for BATH as of December 2015.

## **Future plans**

CORSnet-NSW will continue to expand, with additional stations being built on a needs and opportunity basis. The LPI Statement of Business Intent clearly documents the authority's intention to expand the network to at least 200 CORS by the end of the 2016/17 financial year. Additional internal funding submissions aim to boost CORSnet-NSW to 220 stations by the end of the 2017/18 financial year.

The network may grow even further subject to the outcomes of Geoscience Australia's AuScope II federal funding bid. When CORSnet-NSW achieves its next major milestone, its 200th CORS, the majority of the state's users (i.e. urban users) will be within 10 km of their nearest CORS, thereby unlocking the potential of GNSS heighting.

Efforts will also be directed towards the inclusion of GPS modernisation, new emerging GNSS constellations, increased backup redundancy and increased national integration. CORSnet-NSW is providing the backbone of the ongoing efforts for Australian datum modernisation across NSW, which will result in significant improvements for the surveying and spatial information community.

The network's continued expansion and ICT upgrades aim to provide users with even higher quality services, levels of reliability and backup, and to fully support the market's transition from experimentation to acceptance, to full or even sole reliance on CORS-based positioning.

LPI will continue to conduct applied research that informs legislation and provides guidance to the profession. The research achievements to date (e.g. 80 papers in the last 7 years) demonstrate the commitment to promoting LPI as the NSW Government's centre of excellence in spatial information.

### Conclusion

On behalf of the NSW Surveyor General, LPI has a legislative, regulative responsibility to maintain the geodetic control network in NSW. GNSS CORS infrastructure has become essential to cater for the increased demand for accurate, reliable and easily accessible positioning in today's society.

State jurisdictions provide the essential link between national initiatives and academia on the one hand and the profession on the other, e.g. via maintaining geodetic infrastructure and conducting applied research that informs legislation and best practice guidelines. CORSnet-NSW has revolutionised internal and external GNSS operations, not only supporting the surveying and spatial information profession but also making important contributions to national and regional geodesy.

In this context, it is important to remember that geodetic control underpins all spatial data, including water, boundaries, addresses, utilities, transport, elevation, imagery and remote sensing. Furthermore, most revenue and GNSS data consumption will come in the near future from applications such as locationbased services and transport.

By reaching—and indeed surpassing its 175 CORS milestone, CORSnet-NSW has established itself as a world-class, state-of-the-art, state-wide, multi-function CORS network that balances public-good and commercial mandates. It continues to expand in order to further improve positioning infrastructure across the state, ensuring that NSW is very well positioned for the future.

CORSnet-NSW's evolution, operation and continued development is testimony of LPI's vision to be a world leader in spatial information and its mission to develop and maintain products and services to empower commercial and government organisations, tertiary organisations, the public and the community of NSW.

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