House of Representatives Standing Committee on Agriculture and Industry

Inquiry into agricultural innovation

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Summary and Recommendations

This submission contends that there are two critical, generic, impediments to Australian farmers adopting technology and innovation on farms, and hence realising the benefits (efficiency, sustainability and profitability) of emerging technology. These are (i) a lack of a ubiquitous, nationwide, positioning infrastructure with which to guide and monitor farm assets to centimetre precision and (ii) a lack of nationwide 'whole of farm' communications infrastructure and multipoint access models that allow farmers to connect to high speed internet from anywhere on their farms.

Addressing these impediments will not only provide the physical working environment whereby farmers can innovate with, or adopt, emerging technologies including remote monitoring and control of crops, pastures, and even animals, but also farm infrastructure and machinery including the use of robotics and drones.

It is recommended that:

1. A nationwide, centimetre positioning capability to farmers will enable them to reap significant productivity benefits, and that
    a. A ubiquitous centimetre positioning capability requires a Precise Point Positioning (PPP) approach that addresses the market failure associated with every farm requiring their own base station infrastructure, and that
    b. Delivery of this augmentation capability must be enabled by a satellite-based communications infrastructure.
2. Nationwide, reliable on-ground telecommunications, including telecommunications provider interoperability between infrastructure, and concomitant access to high speed internet is crucial to realising e-business and technology opportunities on Australian farms.
    a. Targeting mobile telecommunications blackspots must prioritise those regions that have no coverage whatsoever rather than simply targeting provider-based blackspots.

*with significant contributions from Prof Sue Thomas (UNE), Dr's Peter Woodgate and Phil Collier (CRCSI), Mr Robin Eckermann and Mr Alun Davies (ref 'Acknowledgments' section)

Issue #1: A Nationwide positioning capability for all Australian farms

- **Farm businesses need accurate positioning to realise many economic benefits of precision agriculture.**

The 2010-11 Agricultural Census found that there were 135,000 farm businesses across Australia. The majority of these were involved in specialised beef cattle farming (28%), mixed grain-sheep or grain-beef cattle farming (9%), other grain growing (9%) or specialised sheep farming (8%). The total area of agricultural land in Australia in 2011 amounted to 410 million hectares, 53% of the nation's landmass. Agriculture is a major contributor to the Australian economy. The value of agricultural production in Australia in 2010-11 was $46 billion, with the value added by the agriculture industry accounting for 2.4% of GDP.

Reports by Allen Consulting (2008) and Acil-Allen (2013) forecast significant growth in the economic contribution of the agriculture sector through access to a coordinated national positioning infrastructure. The gross benefit flowing from existing uptake in the agricultural sectors was estimated in 2008 at $829 million per annum (0.08% GDP).

(When combined with co-beneficiaries the mining and construction industries which also realise significant benefits from cm positioning, this increases to $1.4B p.a. or 0.14% GDP).

In 2013 growth was better than expected. Output in the sector was between $298 million and $466 million higher in 2012 as a result of the use and application of augmented GNSS in the grains industry and elsewhere. This represents between 0.9 and 1.5 per cent of the grains and cropping sectors' output. Output is projected to be between $885 million and $2185 million higher by 2020 with further adoption mainly in the grains and livestock industries. This represents around 2.6 per cent and 6.5 per cent of the grains, crops and livestock sectors' output.

- **Delivery of ±2.5 cm accurate positioning in remote and rural parts of Australia is crucial to the widespread adoption and long term productivity of precision agriculture and will support significant innovation in agricultural industries not otherwise associated with, or heavily engaged with, precision agriculture.**

Recent research has shown a range of economic, environmental and social benefits will follow from accurate positioning/guidance of farm implements in the paddock. Controlled traffic farming is a technique that involves constraining the movement of tractors to permanent 'tramlines' or wheel tracks year after year. Precision is achieved by fitting tractors with a ±2.5 cm GNSS guidance system and automated steering. Having designated wheel tracks in paddocks results in higher crop yields (due to less soil compaction) and lower fuel costs. Inter-row sowing is another technique enabled by ±2.5 cm guidance whereby seeds are sown at precise locations, usually in between rows of crops from the harvests of previous years, so as to maximise crop yields. Bowman (2008) and Yule et al., (2013) documents the benefits as follows:

- ✓ Improved safety
- ✓ Improved productivity (more outputs)
- ✓ Improved sustainability (less inputs)
- ✓ Improved profitability

- ✓ Environmental gains/savings (less fuel, less CO_2 emissions)
- ✓ Social benefits (less work, retention of young people, familiarisation with technology)

The Acil-Allen (2013) report confirmed that *"economic benefits in cropping from the application of precision agriculture supported by augmented GNSS are large, enabling recovery of investment rapidly, sometimes within less than two years"*. In controlled traffic farming and inter-row sowing operations, cost savings of between 10 to 50 per cent have been reported (Acil Allen 2013). Adoption rates of precision agriculture in the livestock, horticulture and viticulture sectors have been slow to develop.

The livestock sector needs a 'catalytic' development similar to that experienced by the grains industry in the early nineties. With the advent of low-cost GPS systems for harvesters, the ability to measure and map grain yield launched precision agriculture as we know it today. Armed with the knowledge of spatial variability in crop yield and quality, farmers immediately began to ask 'what if?' in relation to spatially-enabled fertilizer management, sowing, irrigation and soil management. In the livestock industry the ability to track individual animals or herd elements during grazing would offer a similar catalyst, allowing the creation of live-weight gain or wool-production maps for paddocks based on food intake and energy expenditure. 'Precision Livestock management' is expected to spawn new developments in spatially-enabled fertiliser and pasture management (grazing effectively removes nutrients from sections of the paddock and urine and dung deposited during camping re-applies it elsewhere). Moreover given a conservative estimate of 5 million km of farm fencing in Australia (at ~$7,000/km) which equates to ~$35 billion of asset requiring ~ decennial replacement/repair, spatially-enabled livestock management could include opportunities for virtual fencing remotely controlled by knowing the animal's location alone. While not available at present, these technologies are the focus of significant R&D worldwide.

The concept of spatially-enabled agriculture in horticulture emphasises per-plant management and hence seeks to embrace new developments in robotics and autonomous systems (including drones) for weed management, harvesting and soil amelioration activities. Current technological developments are focussing on situational-based positioning (ie where is the device relative to trees or plant beds) rather than external positioning information. The horticulture industry is geographically dispersed and an external positioning capability offers the chance of control integrity/redundancy which are currently all issues precluding the social licence (eg safety) to operate robotics or even drone-based technology.

In the grape and wine industry, there is a lack of appreciation of the need for ~cm positioning in fields already containing accurately located trellising infrastructure. Precision viticulture, like the grain industry before it, kicked off with the introduction of the first grape yield monitors in the late nineties and the industry has since embraced satellite and airborne remote sensing as an adjunct to identifying variability in vine vigour and for guiding per-zone management of vineyard blocks to achieve yield and quality targets. However, segmented harvesting (to segment grapes based on quality) is only currently achievable by pre-mapping the operations. Grape harvesters cannot quantify quality 'on-the-go' and hence the ability to accurately position harvesters along rows would aid in improving the segmentation operations and hence partitioning and marketing fruit to achieve desired wine styles.

Higher adoption rates of precision agriculture, or more correctly 'spatially-enabled agriculture' in its many forms will be assisted by extension of GNSS augmentation services at the 2 cm level of accuracy to all Australian farmers.

- **Delivering a precise positioning across Australia requires first a nationwide precise point positioning methodology (PPP) and a satellite-based delivery infrastructure.**

The use of the global navigational satellite systems (GNSS - or its better known sub-group GPS) to position our machines (or at least the GNSS/GPS receiver on our machines) relies on determining the range (distance) between the receiver and a minimum of four orbiting satellites whose positions are accurately known. Spatial intersection of these distances is used to derive the 3D location of the receiver. This is a challenging process. To put it into perspective, to achieve 2-5 cm positioning accuracy, the distance to each satellite, which is more than 20,000 km away, must be determined to an accuracy of better than 2 cm.

There are numerous sources of error in estimating the distance to GNSS satellites through the upper atmosphere/ionosphere. An effective method of correcting for many of these errors is to use a nearby stationary base station as a reference point relying on the implicit assumption that the base and the rover receivers are subject to similar errors which then cancel out in the differential solution (known as real time kinematic- RTK). This assumption holds when the base and the rover are relatively close together (10-15 km), but begins to break down over larger distances as the common errors de-correlate in spatial terms. In operational terms, this single base (RTK) approach may fail when a base station is servicing the needs of a region rather than a single farm.

A further limitation of the private base-station approach is that the user (e.g. the farmer or the cooperative organisation) assumes the material and financial risks associated with the purchase, maintenance and operation of the base station and the associated communications link that delivers the correction message to the rover.

A solution to the limitations of the single-base (RTK) correction approach is to deploy an array of Continuously Operating Reference Stations (CORS) at known locations and to operate the rover(s) within the confines of the area covered by the network. This approach is known as Network RTK (NRTK) and allows users to be several tens of kilometres from the nearest base station and still achieve centimetre accuracy in real-time. The real-time function of NRTK relies on a stable and reliable communications infrastructure to deliver the correction message from the network analysis centre to the rover. Most commonly, this is done using terrestrial communication channels exploiting the mobile phone network.

While an attractive solution in many circumstances, the main disadvantages of NRTK for farmers is its reliance on a dense (say 70 km spacing) CORS network and reliable access to high speed mobile internet. These requirements inhibit NRTK adoption, particularly in the more remote parts of the country.

An alternative to RTK and NRTK is a positioning methodology known as Precise Point Positioning (PPP). PPP is an enhanced single point (autonomous) positioning technique that, instead of relying on the cancellation of spatially correlated errors using nearby base stations, employs enhanced physical models for the satellite orbits, clocks and other satellite biases, in addition to a complex model for the influence of the ionosphere and troposphere.

While PPP and its many variants dramatically reduce dependence on a CORS network, the practical cost is slowness in solution ‘convergence time’. It can take several tens of minutes and sometimes one to two hours for a PPP solution to achieve accuracies equivalent to NRTK. This slow convergence is a by-product of the external errors. The middle ground is to mix the PPP and NRTK approaches to overcome their respective limitations and capitalise on their advantages. This hybrid approach is known as PPP-RTK. PPP-RTK brings some level of reliance on a CORS network which allows the external error models to be more finely tuned to local needs (e.g. variations in the local atmospheric conditions). The enhanced error modelling allows a faster and more reliable determination of the integer ambiguities, allowing the PPP-RTK solution to converge in a much shorter time compared to conventional PPP. Thus the PPP-RTK approach has the same "look and feel" as NRTK, but is delivered off a much sparser ground infrastructure. Several technical challenges remain in the operational implementation of PPP-RTK, but in a PA context the reduced reliance on a CORS network is an advantage that resonates in remote and regional parts of Australia.

The remaining challenge is delivering the PPP-RTK correction message to remote users, and thereby decoupling them from dependence on the mobile phone network.

Presently only 9% of the country is served by network real-time kinematic positioning (NRTK) services provided by the mobile phone network, leaving remaining users in remote parts of the country to either build, operate and maintain their own ad hoc system or to continue working without the gains and benefits real-time precise positioning can provide.

To overcome the significant barriers to adoption that emerge in a vast and sparsely populated country like Australia, and in particular northern Australia which is the focus of considerable planning and development, an alternative mode of positioning is required and the associated augmentation message must be made uniformly and consistently available.

- **There is a Japanese satellite option available.**

The Quasi-Zenith Satellite System (QZSS) is a three-satellite regional time transfer system and Satellite Based Augmentation System for the Global Positioning System, launched by the Japanese Government. The first satellite 'Michibiki' was launched on 11 September 2010 and is now fully operational. In March 2013, Japan's Cabinet Office announced the expansion of the Quasi-Zenith Satellite System from three satellites to four. The $526 million contract with Mitsubishi Electric for the construction and launch of the three satellites requires will be completed before the end of 2017.

The primary purpose of QZSS is to increase the availability of satellite-based positioning in Japan's numerous urban canyons, where only satellites at very high elevation can be seen. A secondary function is performance enhancement, increasing the accuracy and reliability of global navigation satellite system derived navigation solutions. Compared to standalone GPS, the combined system GPS plus QZSS delivers improved positioning performance via ranging correction data provided through the transmission of sub-metre class performance enhancement signals. It also improves reliability by means of failure monitoring and system health data notifications. QZSS also provides other support data to users to improve GPS satellite acquisition. In this context, the Quasi-Zenith Satellite System (QZSS system) and, in particular the QZSS LEX signal (LEX = L-band experimental channel), emerges as a potential option for providing the correction signals normally available only using terrestrial receiver (eg mobile phone).

- **Due to their orbital characteristics, the QZSS satellites will offer 24-7 coverage of Australia.**

When fully operational, QZSS LEX will offer Australia-wide 24 hour coverage and has been designed specifically to deliver precise point positioning (PPP) augmentation messages to mobile users in real-time. In parallel, a new mode of positioning (PPP-real time kinetic 'PPP-RTK') is emerging. PPP-RTK offers the potential for mobile users to determine accurate (±2cm), real-time positioning using a geographically sparser network of reference stations than is currently possible with the NRTK approach.

This sparse infrastructure requirement is crucial in a country the size of Australia. Coupling QZSS LEX with PPP-RTK could deliver accurate positioning to Australians no matter where they are (outdoors) and this capability is exactly what is needed to speed up the adoption of precision agriculture, and in particular guidance and inter-row crop management systems across Australia.

- **This proposition is built upon a recent trial that demonstrated the technology works!**

During November 2014-March 2015, a research team of 14 institutions, including 6 from Japan and the Australia-New Zealand Cooperative Research Centre for Spatial information (CRCSI) and Rice Research Australia completed an initial demonstration of the QZSS concept (http://www.crcsi.com.au/research/1-positioning/1-20-evaluation-of-qzss-for-precision-agriculture/) at Jerilderie (NSW); demonstrating the ability to provide static and dynamic positioning accuracy down to ±2.5 cm (ie equivalent to the Network RTK (NRTK) positioning solutions currently available for farmers). This was achieved using only a satellite signal (ie no reliance on terrestrial links eg mobile phone to receive correction data).

- **QZSS solution is more than just about guiding tractors- it will underpin ANY future guided technology on farms.**

As part of the 2014-5 'Jerilderie' trial, the team demonstrated the ±2.5 cm positioning accuracy using a fully robotic tractor (ie both static and dynamic accuracy) and this highlighted the second opportunity/need for this system. Ultimately any future robotics or drone systems on farms will require safety measures, including signal integrity/redundancy for safe operation. The QZSS may help break the regulatory impasse presently constraining the future of drones for farming operations.

A nationwide capability also opens up new opportunities to innovate in agriculture. For example Australia's livestock industry, currently not availing itself of positioning technology faces a future whereby every one of its 28 million-head herd could be wearing tracking devices an improvement to the national livestock identification system (NLIS) ear tags that would have a significant multiplier effect on benefits. Future precision livestock management systems that may rely on animal tracking devices for the purposes of measuring feed use or reproductive efficiency, will require NRTK-equivalent positioning accuracy.

Working on the positioning side of the equation (eg QZSS) to provide growers with an alternative to the existing NRTK system which, is constrained by the need to have reliable mobile phone reception, will be an important enabling step towards the uptake of future technology, including large and small autonomous systems by our farmers.

Recommendation 1: A nationwide, centimetre positioning capability to farmers that will enable them to reap significant productivity benefits requires a satellite-delivered Precise Point Positioning (PPP) augmentation system.

Issue #2: A nationwide, farm-wide telecommunications capability supporting multi-point connectivity for single users

- **Mobile 'blackspots' are not real blackspots in terms of supporting farmers wishing to exploit the opportunities for on-farm technology and innovation.**

Increasingly, farm technology and innovation is reliant upon 2-way data transfer enabled by reliable mobile phone coverage and concomitant access to high speed internet, not just in the homestead but also in the paddock where sensors and machinery are deployed. In the last 5 years, advances in wireless sensor networks (WSNs) coupled with low-cost devices capable of sensing soil moisture, in-situ plant biomass and local climate conditions; the so-called 'internet of things' (Taylor et al. 2013), is redefining the meaning of precision agriculture. Agricultural landscapes themselves are set to become sources of high quality, local, yet synoptic, contemporaneous, biophysical data. Add to this the increasing technology options allowing farmers to remotely monitor and even control their machinery on the go (telemetrics). Put simply, on farm technology is increasingly reliant upon a reliable farm-wide communication infrastructure.

Currently Australia's three principal mobile network operators (MNOs) compete vigorously in urban areas where there is a sufficient concentration of customer spending to support multiple carriers, but in regional Australia, the number of carriers drops from 3 to 2 to 1 to zero. Current coverage (across all networks) is around 30-31% of the landmass. Here the distinction is made between covering the landmass and covering premises. The recently announced 499 locations of new towers under the Mobile Black Spot Programme (MBSP) (Commonwealth of Australia, 2015) reiterated the criteria of assessment as being the extent of new coverage provided in square kilometres, the number of premises within the new handheld coverage area, and the length of major transport routes receiving new coverage. It is accepted that area of coverage criterion is dictated by the terrain and tower design and, to all intents and purposes this can be taken as being of equal favour in terms of potential beneficiaries (eg urban or regional locations). However the remaining two criteria weigh heavily towards high population concentration or where the population is on the move on our transportation corridors. Neither of these would emphasise farm land *per se*, where many of the technology and innovations are taking place, and where the telecommunications capability is required for farmers to reap the benefits of the technology and innovation. The notion of a mobile phone 'blackspot' is therefore not particularly relevant to supporting farm innovation in 'open air' operations (eg broad acre or outdoors horticulture farms).

The mismatch between the actual telecommunications needs of Australian farmers and the perceived telecommunications needs of government can only be addressed through abandoning the notion that infrastructure-based competition is the right goal in areas with no current coverage.

The reason that certain farming regions don't currently have coverage is that there is not enough customer traffic to make a good case for commercial investment by any one carrier. Yet in the highest population densities or along major transportation corridors mobile phone coverage by Australia's 3 MNOs can have complete overlap (300% coverage) which rapidly diminishes to 200% coverage (ie two MNOs) then 100% (1 MNO) on the urban fringes and along corridors, then zero coverage moving out into our open farming regions (ref to Fig 1. below).

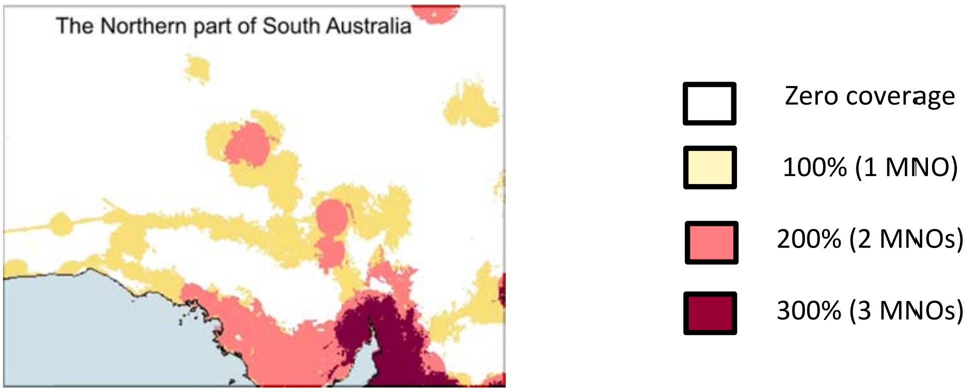

Figure 1. Map of coverage overlap in a segment of South Australia (Courtesy of Robin Eckermann, *Robin Eckermann & Associates*).

A consequence of policies/strategies aiming to induce infrastructure-based competition in mobile telecommunications will lead to economic inefficiency in our farming sector that ultimately the whole market must bear.

- **Provider roaming could significantly improve mobile coverage on farms**

It could be argued that a single MNO with considerable market (and geographic) dominance may resist any notion of roaming- the ability to operate using infrastructure not belonging to the home provider network – owing to the market advantage afforded by that very geographic coverage. However, as programs like the MBSP are introduced to try and improve coverage, the level of taxpayer assistance will increase. It is conceivable offering roaming should be one of the 'strings attached' to public funding.

National Broadband Network products such as mobile backhaul will improve the economics for extending mobile coverage, but this is likely to only work only where the business case was very marginal and a small 'push' gets it over the line. One example is by defining a "non-commercial" area where no mobile operators will likely go because of the sparse population (viz large spaces of open paddocks which are nonetheless agriculturally productive and hence would benefit from access to telecommunications) and allowing NBNCo to offer whole-sale only mobile access in these areas - available to the customers of all three MNOs. NBNCo's fixed wireless solution is fundamentally a mobile network technology, simply nobbled to preclude roaming. It would be the most rational economic outcome - with potential to achieve multiple efficiencies:
1. It would capture the traffic of all three mobile operators;
2. It would combine this with fixed wireless traffic;
3. If coupled with a grant of 700 MHz spectrum (with long reach), then much bigger cells could be created in areas of very low population density (but high agricultural productivity); and
4. By improving mobile coverage, some of the pressure that currently afflicts satellites could be relieved.

Nation-wide, ubiquitous mobile telecommunications coverage is not realistic. Increasing mobile coverage from 30% of the landmass by simply allowing roaming between provide infrastructure would go a long way towards meeting the needs of regional Australia.

- **NBN could be the ultimate solution to nationwide, farm wide telecommunications backbone but it requires the right business models**

There will always be open paddock areas where it makes no sense to extend coverage (for example hill country and rangelands), and in these areas, NBN satellite is a pragmatic option. Accessibility from anywhere in Australia is one defining feature to NBN satellite footprint and it is accepted that the current interim satellite service (ISS) capacity is struggling to meet the larger-than-expected demand from rural and regional Australia. Yet at the same time NBN connectivity afforded through the ISS or the approaching Long Term Satellite Service (LTSS) offers an ideal (overhead) telecommunications backbone for the emerging internet of things (IoT) deployed over our farming land. Examples of connectible devices that could utilise a direct LTSS link includes remote bore monitoring and control systems on extensive agricultural properties (eg single farms larger than the ACT), animal management systems such as walk-over weighing and auto-drafting, telemetrics on large machinery, and, of course, delivery of the CORS or PPP-NRTK supported, nation-wide centimetre positioning augmentation service (as an alternative to satellite delivery systems such as the QZSS proposed in the previous section) .

However utilising the LTSS, or indeed any terrestrial mobile communications infrastructure as the backbone for the emerging farm-wide IoT requires the ability to provide multi-point connectivity without the need for the user to manage individual data plans for each connectible device.

- **University of New England's SMART Farm is showcases reliable, farm-wide internet connectivity in action!**

The University of New England, located ~150 km inland and approximately midway between Sydney and Brisbane on the New England Highway, is transforming 'Kirby-Newholme', a 2,900 ha commercial farm located 10 km north west of the campus, into a SMART Farm (Sustainable Manageable Accessible Rural Technologies Farm) (www.une.edu.au/smartfarm). High-speed and **farm-wide** internet connectivity is facilitated by a combination of fibre and NBN fixed wireless access to buildings (including the award-winning SMART Farm Innovation Centre) and reliable, strong mobile phone reception over the farming land. The predominantly grazing SMART Farm is a national demonstrator site showcasing the latest on-site technologies aimed at improving productivity, environmental sustainability, safety, work flow and social/business support networks on Australian farms. Technologies facilitated by good connectivity include livestock tracking and walk-over weighing, native and invasive animal monitoring systems, quad bike tracking, satellite and drone monitoring of pastures and a network of soil moisture monitoring probes. High speed internet connectivity also allows the SMART Farm team to run virtual field days, advisory sessions and master classes to anyone, anywhere in the world. While 'one-of-a-kind' at present, UNE hopes that one day its SMART Farm will be one of 137,000 SMART farms in Australia.

Recommendation 2: Nationwide, reliable on-ground telecommunications, including telecommunications provider interoperability between infrastructure, multi-point connectivity from across farming operations, and concomitant access to high speed internet is crucial to realising e-business and technology opportunities on Australian farms.

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Robotic tractor guided by QZSS satellite positioning

Acronyms Explained

CORS - Continuously Operating Reference Stations: A network of continuously operating, unmanned receiver stations around Australia whose precisely known locations are used to create regional corrections to GNSS roving receivers.

GNSS – Global Navigation Satellite Systems: The constellation of overhead satellites used to provide a location fix, on the ground, by static and roving receivers. There are also the European Union Galileo positioning system, India's Indian Regional Navigation Satellite System, the U.S. Global Positioning system and the Chinese BeiDou Navigation Satellite System.

GPS – The Global Positioning System: A U.S. run space-based navigation system that provides location and time information in all weather conditions, anywhere on or near the Earth where there is an unobstructed line of sight to four or more GPS satellites.

IoT – Internet of Things: An environment in which objects, animals or people are provided with unique identifiers and the ability to transfer data over a network without requiring human-to-human or human-to-computer interaction.

ISS – Interim Satellite Service (NBNCo): Broadband services provided through two interim satellites while waiting for the dedicated satellites (LTSS) to be launched.

LEX - ‘L’ Band Experimental Channel: QZSS Experimental Signal for delivering high precision (3 cm level) positioning augmentation messages.

LTSS - Long Term Satellite Service: NBN Satellite Service based upon two new satellites to be launched in 2016.

MBSP - Mobile Black Spot Programme: Australian Government-funded investment in telecommunications infrastructure to address mobile black spots in outer metropolitan, regional and remote Australia.

MNO - Mobile Network Operator: Also known as a wireless service provider, wireless carrier, cellular company, or mobile network carrier, is a provider of services wireless communications that owns or controls all the elements necessary to sell and deliver services to an end user including radio spectrum allocation, wireless network infrastructure, back haul infrastructure, billing, customer care, provisioning computer systems and marketing and repair organizations.

NLIS – National Livestock Identification System: Australia's scheme for the identification and tracing of livestock and facilitated by small, button-sized eartags with a unique identification code carried on all livestock.

NRTK - Network Real Time Kinematic: Using a network of base stations to provide a position correction message for roving GNSS receivers.

PPP – Precise Point Positioning: Correction information derived from modelling the ionosphere to improve -ground receiver stations whose accuracy is precisely known and only requires a single roving receiver in operation on the farm.

PPP-RTK- Precise Point Positioning- Network Real Time Kinematic: A hybrid of PPP and NRTK that allows a position correction message to be derived from a sparse combination of CORS stations and provides rapid convergence time to an accurate solution when activated at a roving receiver.

QZSS - Quasi-Zenith Satellite System: Constellation of four GNSS satellites launched by the Japanese government to maintain high- elevation station over Japan and contribute to use of GNSS positioning in high-rise environments (hence high elevation). The figure-of-eight orbital characteristics of these satellites will see them spend considerable time (24-7, between them) over Australia. Importantly these satellites have the capability to transmit PPP-RTK correction messages to on-ground receivers located anywhere in Australia.

RTK – Real Time Kinematic: A real-time correction method of GNSS positioning using a nearby base station that experiences the same degrading effects as the roving receiver. The correction signal is usually transmitted to the rover by radio link.