AUSTRALIAN STRATEGIC PLAN FOR GNSS

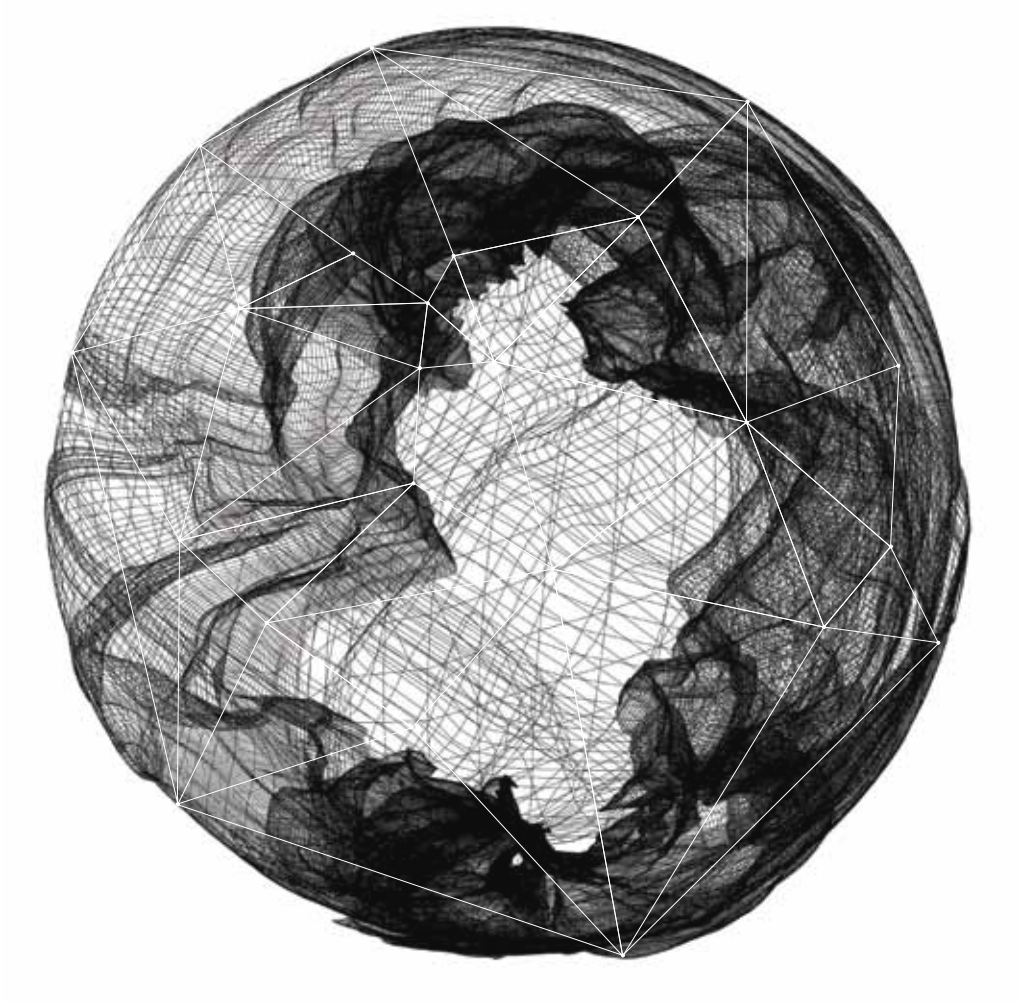
INSIDE:

PREPARING AUSTRALIA FOR THE MULTI-GLOBAL NAVIGATION SATELLITE SYSTEM ERA

AUSTRALIAN SPATIAL CONSORTIUM

PREFACE

THE AUSTRALIAN STRATEGIC PLAN FOR GNSS HAS BEEN PREPARED AT THE REQUEST OF THE AUSTRALIAN SPATIAL CONSORTIUM BY A WORKING GROUP CHAIRED BY PROFESSOR CHRIS RIZOS, UNDER THE DIRECTION OF A STEERING COMMITTEE CHAIRED BY THE HONOURABLE GARY NAIRN.



FRONT COVER IMAGE: ESA - J. HUART

The Plan has been developed in recognition of the fact that Australia, and indeed the world, is on the cusp of a new era in the provision of global and regional navigation satellite systems. In the coming decade, the familiar and widely used Global Positioning System (GPS) will be joined in space by comparable systems from Russia (GLONASS), Europe (Galileo) and China (Beidou), along with regional augmentation systems from Japan (QSZZ), India (IRNSS) and possibly other countries. This proliferation of satellite navigation technologies is set to change the face of position, navigation and time (PNT) determination around the world. New commercial opportunities will emerge and challenging and exciting applications will be developed. The dawning of multi-GNSS will pave the way for the realisation of significant benefits for the nation.

Australia's vast land mass, sparse population, dependence on remote industries and unique geopolitical circumstances demand a unique approach to securing the benefits multi-GNSS promises. We cannot afford to wait for the rest of the world to address our needs. We must act strategically, decisively and proactively to ensure Australia retains its competitive position as a world leader in the adoption and exploitation of emerging PNT technologies and in the development of associated products and services.

This Plan proposes a strategic direction that, if adopted, could see Australia lead the world in the use of multi-GNSS. Resulting benefits will include enhanced productivity, job creation, industry growth, the identification of new export markets, increased competitiveness, improved workplace safety, enhanced national security, strengthened international linkages and a dynamic R&D sector.

Gary Nairn

The Honourable Gary Nairn
Steering Committee Chair

Chris Rizos

Professor Chris Rizos
Working Group Chair

EXECUTIVE SUMMARY

GNSS MUST LIE AT THE HEART OF A NEW COMPONENET OF CRITICAL INFRASTRUCTURE - THE NATIONAL POSITIONING INFRASTRUCTURE

In recognition of the significant economic benefit the Global Positioning System (GPS) has brought to selected industry sectors, the Australian Spatial Consortium (ASC) has commissioned the development of this Strategic Plan. The objective of the Plan is to make recommendations to prepare Australia for the challenges of, and capitalise on the opportunities that will flow from, imminent and far reaching changes in the Global Navigation Satellite System (GNSS) domain.

The term "GNSS" refers to current and future satellite navigation systems deployed by the United States (GPS), Russia (GLONASS), European Union (Galileo), China (Beidou), Japan (QZSS) and India (IRNSS). Individually or combined, these systems currently provide (or will in the coming years provide) reliable position, navigation and timing (PNT) information in real-time, which can be used for a wide range of applications. GNSS receivers in mobile phones and private vehicles cater for low accuracy (metre-level) consumer applications. However, many industrial, scientific, professional and commercial applications depend on high accuracy (centimetre-level) capabilities. It is the needs of this latter group of users that this Plan principally addresses.

Early adoption of GPS in the 1980s has underpinned productivity and safety improvements in many Australian industries such as transport, mining, agriculture and construction. It has spawned the growth of new industries and opportunities in areas such as the provision of location based services (LBS) as well as high accuracy products and services. The launch of new GNSS constellations, and upgrades to existing systems, will bring added benefits and expand technology uptake while increasing dependency on this critical technology. This Plan focuses on the barriers to greater adoption of GNSS for applications such as machine guidance, mapping and precise navigation which are critical to Australia's security, productivity and economic well-being. It is argued therefore that GNSS must lie at the heart of a new component of critical infrastructure – the National Positioning Infrastructure (NPI). The NPI will be capable of providing robust, reliable, fit-for-purpose, real-time services to a vast range of PNT applications.

Although there is strong interest in using high accuracy GNSS in the agriculture, mining and construction sectors, the rate of adoption is still relatively low. GNSS is however a core technology for enabling machine automation in so-called "dull, dirty and dangerous" environments. To secure the consequent economic, social and environmental benefits, Australia needs to implement a strategy to accelerate the rate of uptake of GNSS by these industry sectors. Such automation will ensure the nation maintains its competitive advantage in primary industry production and export. Furthermore, it will drive down fuel costs, improve worker safety, lift productivity and reduce environmental damage and CO_2 emissions.

This Plan acknowledges the benefits of GNSS to a wide array of user communities, identifies the barriers to greater adoption, cautions on the vulnerabilities of space-based PNT systems, advocates action to solve existing coordination issues and urges Australia to capitalise on its unique geopolitical advantage in the Asia-Pacific region for enhanced economic and social gain.

Within a few years the number of available GNSS signals from space will triple. Because of GNSS investments by Japan, India and China, Australia will be fortuitously located in a GNSS "hot spot" where satellite visibility is at a global high. As a consequence, Australia will be amongst the first countries in the world in which critical export industries will be able to take advantage of improved PNT performance and the resulting lowered user application constraints.

In keeping with the opportunities presented by the emerging "multi-GNSS era", four strategic initiatives are recommended in this Plan, accompanied by a number of actions. Against each action, a responsible agency or organisation is identified:

01

Ensure there is leadership for the Australian GNSS community

Australia must take advantage of its unique opportunity to be a first adopter of multi-GNSS technology for critical, high accuracy PNT applications. Leadership in this context requires that the constraints to accelerated adoption of GNSS for machine automation and similar uses be addressed. Ultimately, all users will benefit from a raised awareness of, and increased confidence in the capabilities and benefits of multi-GNSS.

Specific actions under this recommendation include:

- Facilitate the development of relevant government policy (SPU; OSP)
- Ensure effective governance of GNSS related infrastructure and services (GA)
- Increase awareness of GNSS in the broader community (ASC)
- Identify and nurture "champions" across industry and government (OSP; ASC)
- Communicate with stakeholders to build awareness of activity and capability (GA)
- Upgrade fundamental geodetic reference stations to full multi-GNSS status (GA)

02

Adopt a whole-of-nation approach to a sustainable, multi-GNSS-enabled NPI

Coordination amongst stakeholders in the NPI (infrastructure providers, service providers and users) will bring cross-sectoral benefits, reduce duplication and secure efficiency gains.

Specific actions under this recommendation include:

- Identify and coordinate the activities of government and private sector CORS providers (GA)
- Coordinate the deployment and operation of the GNSS component of the NPI (GA)
- Establish uniform CORS operating principles (GA)
- Establish appropriate governance, funding and business models to operate the NPI and deliver NPI-related products and services (GA)
- Coordinate international collaboration in multi-GNSS regional and global initiatives (GA; SPU)

03

Mitigate vulnerabilities in existing and future GNSS infrastructure

As the uptake of GNSS increases, the vulnerability of many sectors to disruption or loss of GNSS services will likewise increase. Action is needed to mitigate the threat to GNSS from interference, in order to increase the resilience of systems to temporary loss of GNSS signals and, where appropriate, to implement backup systems or procedures.

Specific actions under this recommendation include:

- Ensure that the NPI is treated as Critical Infrastructure for the nation (SPU; OSP)
- Establish a Community-of-Interest as part of the Trusted Information Sharing Network (TISN) for Critical Infrastructure Resilience (OSP)
- Investigate the role of an SBAS within the NPI (CASA; GA)
- Protect the GNSS spectrum against interference (ACMA; GA)
- Mitigate GNSS dependency risks (GA; ASC)

04

Capitalise on Australia's unique geopolitical advantage

Australia is uniquely placed (geographically, politically, economically, industrially and scientifically) to secure national (and regional) benefit from the multi-GNSS environment.

Specific actions under this recommendation include:

- Promote the scientific, technical, business and investment opportunities that stem from Australia's unique geopolitical advantage (SPU; GA; ASC)
- Assist neighbouring countries adopt and exploit the benefits of multi-GNSS (ASC; GA)
- Determine capacity needs and skills requirements to service Australia's growing GNSS industry (ASC)
- Grow the education and research sector to service demand for skilled GNSS engineers, scientists and researchers (ASC)

CONTRIBUTORS

WORKING GROUP:

PROFESSOR CHRIS RIZOS (CHAIR)	HEAD OF SCHOOL, SURVEYING AND SPATIAL INFORMATION SYSTEMS, UNIVERSITY OF NSW; PRESIDENT, INTERNATIONAL ASSOCIATION OF GEODESY (IAG); MEMBER OF THE IGNSS ADVISORY COMMITTEE
DR PHIL COLLIER	RESEARCH DIRECTOR, COOPERATIVE RESEARCH CENTRE FOR SPATIAL INFORMATION
MATT HIGGINS	MANAGER, GEODESY AND POSITIONING, DEPARTMENT OF ENVIRONMENT AND RESOURCE MANAGEMENT QLD; CO-CHAIR WORKING GROUP D, UN INTERNATIONAL COMMITTEE ON GNSS; PRESIDENT, IGNSS SOCIETY
GARY JOHNSTON	PROJECT LEADER, NATIONAL GEOSPATIAL REFERENCE SYSTEMS, GEOSCIENCE AUSTRALIA; MEMBER OF THE INTERGOVERNMENTAL COMMITTEE ON SURVEYING AND MAPPING
DIRK NOORDEWIER	AIR TRANSPORT INSPECTOR, AIRSPACE AND AERODROME REGULATION, CIVIL AVIATION SAFETY AUTHORITY
ROB LORIMER	BUSINESS DEVELOPMENT LEADER - ENERGY GROUP AND BUSINESS DIRECTOR - WEALTH FROM OCEANS NATIONAL RESEARCH FLAGSHIP, CSIRO; MEMBER OF THE SPACE INDUSTRY INNOVATION COUNCIL; MEMBER OF THE IGNSS ADVISORY COMMITTEE
MARTIN NIX	CHIEF EXECUTIVE OFFICER, POSITION PARTNERS; MEMBER OF THE IGNSS ADVISORY COMMITTEE
DAN PAULL	CHIEF EXECUTIVE OFFICER, PSMA AUSTRALIA LIMITED
NUNZIO GAMBALE	CHIEF EXECUTIVE OFFICER, LOCATA CORPORATION
KIRK MITCHELL	VICE PRESIDENT, OCEANIA SALES, NAVTEQ
JOHN SPRIVULIS	BUSINESS AREA DIRECTOR, ASIA PACIFIC, OMNISTAR
PROFESSOR RODNEY WALKER	QUEENSLAND UNIVERSITY OF TECHNOLOGY; DIRECTOR OF THE AUSTRALIAN RESEARCH CENTRE FOR AEROSPACE AUTOMATION (ARCAA)
DR TROY BRUGGEMANN	QUEENSLAND UNIVERSITY OF TECHNOLOGY; AUSTRALIAN RESEARCH CENTRE FOR AEROSPACE AUTOMATION (ARCAA)
PROFESSOR PETER TEUNISSEN	ARC FEDERATION FELLOW, GNSS RESEARCH CENTRE, CURTIN UNIVERSITY
PROFESSOR ANDREW DEMPSTER	DIRECTOR OF THE AUSTRALIAN CENTRE FOR SPACE ENGINEERING RESEARCH (ACSER); MEMBER OF THE IGNSS ADVISORY COMMITTEE
DAVID POINTON (FACILITATOR)	FAST MEETINGS CO.
ADRIAN WHITE (RESEARCH ASSISTANT)	LAND AND PROPERTY INFORMATION, DEPARTMENT OF FINANCE AND SERVICES NSW

STEERING COMMITTEE:

THE HON GARY NAIRN (CHAIR)	CHAIRMAN, VEKTA PTY LTD; DIRECTOR, SPATIAL INDUSTRIES BUSINESS ASSOCIATION; CHAIR TASMANIAN SPATIAL INFORMATION COUNCIL (TASSIC)
PROFESSOR CHRIS RIZOS	HEAD OF SCHOOL, SURVEYING AND SPATIAL INFORMATION SYSTEMS, UNIVERSITY OF NSW; PRESIDENT, INTERNATIONAL ASSOCIATION OF GEODESY (IAG); MEMBER OF THE IGNSS ADVISORY COMMITTEE
DR MICHAEL GREEN	GENERAL MANAGER, INNOVATION & SPACE BRANCH, MANUFACTURING DIVISION, DEPARTMENT OF INNOVATION, INDUSTRY, SCIENCE AND RESEARCH
IAN MALLETT	SECTION HEAD, AERODROME AND CNS/ATM SECTION, CIVIL AVIATION SAFETY AUTHORITY
DR CHRISTOPHER BAKER	NAVIGATION WARFARE SCIENCE TEAM LEADER, ELECTRONIC WARFARE AND RADAR DIVISION, DEFENCE SCIENCE AND TECHNOLOGY ORGANISATION
DR CHRIS PIGRAM	CHIEF EXECUTIVE OFFICER, GEOSCIENCE AUSTRALIA; MEMBER OF THE SPACE INDUSTRY INNOVATION COUNCIL
DR RUSSELL PRIEBBENOW	DIRECTOR OF SURVEYS, SPATIAL INFORMATION GROUP, DEPARTMENT OF ENVIRONMENT AND RESOURCE MANAGEMENT, QLD; MEMBER OF THE INTERGOVERNMENTAL COMMITTEE ON SURVEYING AND MAPPING
WARRICK BEACROFT	DIRECTOR, INFORMATION SOURCING, LAND AND PROPERTY INFORMATION, DEPARTMENT OF FINANCE AND SERVICES NSW
BRETT BIDDINGTON	PRINCIPAL, BIDDINGTON RESEARCH PTY LTD; CHAIR, SPACE INDUSTRY ASSOCIATION OF AUSTRALIA; MEMBER OF THE SPACE INDUSTRY INNOVATION COUNCIL
PROFESSOR DON SINNOTT	CONSULTANT; ADJUNCT PROFESSOR, ADELAIDE RADAR RESEARCH CENTRE, THE UNIVERSITY OF ADELAIDE; FORMER CHAIR, AUSTRALIAN GNSS COORDINATION COMMITTEE

AUSTRALIAN SPATIAL CONSORTIUM:

THE HON GARY NAIRN	CHAIRMAN, VEKTA PTY LTD; DIRECTOR, SPATIAL INDUSTRIES BUSINESS ASSOCIATION; CHAIR TASMANIAN SPATIAL INFORMATION COUNCIL (TASSIC)
DR PETER WOODGATE	CHIEF EXECUTIVE OFFICER, COOPERATIVE RESEARCH CENTRE FOR SPATIAL INFORMATION
EMERITUS PROFESSOR MARY O'KANE	CHAIR, COOPERATIVE RESEARCH CENTRE FOR SPATIAL INFORMATION BOARD
OLLIE HEDBERG AM	CHAIR, PSMA AUSTRALIA LIMITED BOARD
GYPSY BHALLA	PAST PRESIDENT, SURVEYING AND SPATIAL SCIENCES INSTITUTE
TONY WHEELER	CHAIRMAN, 43PL
GUS DOMINGUEZ	GEOSPATIAL INFORMATION & TECHNOLOGY ASSOCIATION, AUSTRALIA AND NEW ZEALAND DIVISION

GLOSSARY

ACMA	AUSTRALIAN COMMUNICATIONS AND MEDIA AUTHORITY
ADF	AUSTRALIAN DEFENCE FORCE
AMSA	AUSTRALIAN MARITIME SAFETY AUTHORITY
ANZLIC	AUSTRALIA & NEW ZEALAND LAND INFORMATION COUNCIL
APV	APPROACH WITH VERTICAL GUIDANCE
ASC	AUSTRALIAN SPATIAL CONSORTIUM
BEIDOU	CHINESE GNSS (ALSO KNOWN AS COMPASS)
CASA	CIVIL AVIATION SAFETY AUTHORITY
COMPASS	CHINESE GNSS (ALSO KNOWN AS BEIDOU)
CORS	CONTINUOUSLY OPERATING REFERENCE STATION
DGNSS	DIFFERENTIAL GNSS
DGPS	DIFFERENTIAL GPS
DSTO	DEFENCE SCIENCE AND TECHNOLOGY ORGANISATION
ESA	EUROPEAN SPACE AGENCY
GA	GEOSCIENCE AUSTRALIA
GALILEO	EUROPEAN UNION GNSS
GDA94	GEOCENTRIC DATUM OF AUSTRALIA 1994
GLONASS	RUSSIAN GNSS
GNSS	GLOBAL NAVIGATION SATELLITE SYSTEM
GPS	GLOBAL POSITIONING SYSTEM - US GNSS
ICAO	INTERNATIONAL CIVIL AVIATION ORGANISATION
ICT	INFORMATION & COMMUNICATIONS TECHNOLOGY
IRNSS	INDIAN RNSS
LBS	LOCATION BASED SERVICES
NPI	NATIONAL POSITIONING INFRASTRUCTURE
OSP	OFFICE OF SPATIAL POLICY
PBN	PERFORMANCE BASED NAVIGATION
PNT	POSITION, NAVIGATION AND TIMING
PPD	PRIVACY PROTECTION DEVICE
QZSS	QUASI-ZENITH SATELLITE SYSTEM - JAPANESE AUGMENTATION SATELLITE SYSTEM FOR GPS & GALILEO
RNSS	REGIONAL NAVIGATION SATELLITE SYSTEM
SBAS	SPACE BASED AUGMENTATION SYSTEM - TERM RESERVED FOR AUGMENTATION SYSTEMS FOR AVIATION APPLICATIONS
SIIC	SPACE INDUSTRY INNOVATION COUNCIL
SME	SMALL MEDIUM ENTERPRISE
SPU	SPACE POLICY UNIT
TISN	TRUSTED INFORMATION SHARING NETWORK

CONTENTS

TABLE OF CONTENTS

CHAPTER 1

GPS: SITUATION ANALYSIS

BACKGROUND

DELIVERING THE GPS SIGNALS TO EARTH IS A NETWORK OF APPROXIMATELY 30 SATELLITES

The Global Positioning System (GPS), launched and sustained by the US Government, is an indispensible utility for modern society. GPS comprises a constellation of satellites broadcasting signals that can be tracked by portable devices (receivers). Such receivers are able to deliver continuous, accurate, 3D position, navigation and timing (PNT) solutions worldwide by making simultaneous measurements of distance to a minimum of four satellites[1]. The availability of a universal PNT system has changed the way we live, do business and interact with the world around us. For example, GPS receivers in cars and mobile phones allow us to navigate to places of interest and to access services based on our current location. Similarly, GPS has enabled more efficient and productive farming, the measurement of continental drift and the determination of space weather. GPS supports real-time land, sea and air navigation, underpins telecommunications, validates electronic financial transactions and has improved productivity and safety in mining and construction.

GPS technology adoption and the development of new applications, products and services have increased dramatically in recent years. Continuity of the GPS service is guaranteed (US Government, 2010) and it is provided to users worldwide without restriction and free of charge. GPS devices are nowadays relatively low cost. Their development has underpinned a massive electronics and services industry – they have become smaller (now a single chip within a mobile phone), draw less power, and have substantially more functionality than ever before.

Delivering the GPS signals to earth is a network of approximately 30 satellites (the "space segment") that provide continuous global coverage. A number of ground control and monitoring stations (the "control segment") maintain system performance. Although GPS is operated by the US military, it is the quintessential dual-use (military and civilian) technology. A huge civilian GPS user community now exists with considerable investment already made in augmentation systems to deliver enhanced accuracy, reliability and integrity for certain mission critical and/or professional applications. Collectively these are the so-called "user segment".

GPS has been available to civilians since the early 1980s and is the first example of a Global Navigation Satellite System (GNSS). The generic term GNSS is nowadays preferred to GPS because of progress made in the development of other satellite-based PNT systems. Russia's GLONASS will achieve full operational capability by the end of 2011 or early 2012, while the European Union and China are each establishing their own GNSS[2]. Furthermore, Japan and India are progressing their own regionally focused systems[3]. The introduction of these new GNSSs will fundamentally change the global PNT landscape. This emerging "multi-GNSS era" provides the impetus for this Strategic Plan. The objective is to ready Australia and provide strategic direction for optimal future use of multi-GNSS. Before speculating on this future, we will first review the current state of GNSS usage in Australia.

[1] However, GPS signals are very weak and cannot be used for reliable PNT services when sky-view is limited, including for indoor, dense urban and open-cut mine applications.

[2] The EU's Galileo system is scheduled for initial operational capability (18 satellites) by 2015 and full operational capability by 2020. China's Beidou system is also expected to be fully operational by 2020 (Lemmens, 2011)

[3] The former is in the form of "augmentation" satellites that make possible improved services over those of a standard GNSS, and the latter in the form of a complete regional system that services only a region of the globe.

GPS IN AUSTRALIA

Australia has benefitted from both civilian and military access to GPS since the 1980s and has a highly developed user sector. In 1984 government surveyors upgrading South Australia's survey control network were among the first civilian GPS users. More broadly, Australia is regarded as a lead nation in the adoption and penetration of GPS technology and services. There are a number of examples where manufacturers of GPS equipment have purchased or copied Australian innovations for use in international markets. Australian start-up companies Beeline Technology, Tritronics and KEE Technologies are examples of SMEs that have developed world leading technology in GPS-enabled machine guidance systems for the agriculture and mining sectors in the 1990s. All three now function as research and development centres for large, multi-national corporations (Space Industry Innovation Council, 2010).

GPS is fundamental to Australia's spatial data framework. In the late 1990s Australia moved to a new national geodetic datum – the Geocentric Datum of Australia 1994 (GDA94). GDA94 is based on the Australian Fiducial Network, a network of eight permanent GPS receivers spread across the country (Featherstone, 1996). GDA94 is now the fundamental spatial reference frame for Australia to which location information such as digital maps and other spatial data are related. GPS is critical to the on-going improvement of this reference frame to achieve higher accuracy and to account for the inter- and intra-plate motion of the Australian continent, in order to support the goals of modern geodesy in expanding our knowledge of the dynamic earth (GGOS, 2009).

A less well known application of GPS is in precision timing. GPS is used to provide timing for synchronising telecommunications, electricity grids and data networks as well as time stamping financial transactions in the banking sector (The Royal Academy of Engineering, 2011).

The Australian Defence Force, belonging to a select group of US military alliance partners, secures its access to encrypted precision GPS signals through an agreement with the US Government. The terms of this agreement flow from the stated objectives of the 2009 Defence White Paper (Australian Government, 2009a). Under the agreement, Australia returns value to the US by operating a GPS monitoring station in South Australia which forms part of the critical GPS control segment. In 2010 a Joint Statement on Bilateral Cooperation in the Civil Use of GPS and Civil Space Activities was signed by both nations. Joint research exercises also take place under a bilateral agreement to improve the resilience of GPS, involving both military and civilian participation.

GPS: SITUATION ANALYSIS

A COORDINATED APPROACH THROUGH THE NATIONAL ROLLOUT OF A STANDARDISED REFERENCE STATION NETWORK COULD REAP ADDITIONAL GROSS BENEFITS OF $58 BILLION

GETTING MORE OUT OF GPS

GPS can be considered an enabling technology which can be embedded in other devices or systems for many purposes. No attempt is made to list all applications in this Plan. However, this section provides an insight into the breadth of current GPS use within Australia. For further information, a recent study by The Royal Academy of Engineering provides a more complete summary (The Royal Academy of Engineering, 2011).

Standalone GPS

GPS is designed in such a way that it can support an unlimited number of users. The most basic form of PNT solution can be achieved with a standalone GPS receiver without the need for any other external inputs. The vast majority of consumer-grade devices provide a standalone solution[4], with mobile phones and car navigation systems making up the bulk of this user segment[5]. Such solutions are adequate for many infomobility applications such as vehicle navigation and telematics, and other location based services (LBS).

Standalone GPS and Communications

Through the ability to instantaneously communicate location information, ICT applications can be built to respond to the location or movement of GPS-enabled devices. For example, road-freight vehicles are monitored using GPS to ensure that speed limits, driver rest requirements and route restrictions are adhered to. Corrective Services use GPS to monitor the movement of people who must remain in one location or in a limited geographic area. Parents and aged care facilities use GPS to monitor the location of the young and old. Bushwalking and four wheel driving enthusiasts carry GPS-enabled beacons which allow them to issue a distress signal in an emergency situation which includes their GPS location. The so-called 'E911 mandate' in the US requires all mobile phones to be able to provide location within 50m automatically when emergency calls are made, with embedded GPS chips now increasingly providing this information.

[4] The horizontal positioning accuracy is about 5-10m, the vertical accuracy 2-3 times worse, and the timing accuracy
[5] is of the order of 0.1 microseconds.

These user segments represent an estimated 99.9% of the market for GPS devices.

Enhanced Accuracy GPS

With additional ground or space-based infrastructure it is possible to enhance the accuracy and reliability of GPS. This improvement, or augmentation, of GPS is able to deliver positioning solutions at the sub-metre level using differential GPS (DGPS) methods and even at the centimetre-level with more sophisticated methods. Many professional and scientific applications are now dependent on the provision of enhanced accuracy GPS solutions, for example:

- In recent years, adoption of auto-steer systems in agriculture based on enhanced accuracy GPS has occurred, realising significant economic, social and environmental benefits (The Allen Consulting Group, 2008).
- The construction and mining sectors realise benefits through real-time work progress monitoring and safety systems delivered using enhanced accuracy GPS.
- Underground assets and utilities are protected from damage by excavation because their location is more accurately known and the real-time location of the excavation equipment can be determined with confidence.
- The impact of climate change on sea level rise can be accurately measured by using GPS to monitor the movement of tide gauges and coastal structures (GGOS, 2009).

To support enhanced accuracy GPS applications in Australia, the private sector and government organisations have invested in ground-based infrastructure to support DGPS positioning[6]. This infrastructure ranges from portable reference stations, which farmers, mines, construction companies and others deploy to meet their operational needs, to Continuously Operating Reference Stations (CORS), which are permanently established on very stable structures and allow value-added PNT products and services to be delivered on a commercial basis.

Major infrastructure investments have occurred through Commonwealth and State Government initiatives, such as AuScope[7], GPSnet[8], CORSnet-NSW[9], SunPOZ[10] and AMSA's DGPS service[11]. The private sector has also invested in CORS network infrastructure, such as SmartNet Aus[12], AllDayRTK[13], GPS Network Perth[14] and CheckPoint[15]. Large agricultural system distributors have likewise built reference station infrastructure (e.g. SST-GPS), although these stations tend not to be integrated nor intended for multi-purpose use. Improved accuracies achieved via satellite communications are also available in Australia from Omnistar, owned by Trimble Navigation, and StarFire, operated by John Deere. These both require Australian-based CORS in order to generate GPS correction data.

Most enhanced accuracy applications use Russia's GLONASS system in addition to GPS – hence it is more appropriate to refer to enhanced accuracy differential GNSS (DGNSS) rather than DGPS. While the addition of GLONASS doesn't necessarily improve accuracy, the solution availability is enhanced because more satellites are visible. This is particularly important in environments where sky-view is partially obscured, such as in open-cut mines or when working in steep terrain, and in so-called "urban canyons".

Currently, many users requiring enhanced accuracy, operate their own CORS (or temporary reference station) and communications link. Such an approach is often restricted to a proprietary solution and is therefore not always available, interoperable nor compatible with the requirements of other local users. This ad hoc proliferation of CORS has resulted in duplication of service, dramatic over investment, variable quality control and management practices, and uncertain reference frame realisation. The need for a coordinated approach is evident, especially as we enter the multi-GNSS era.

A report by Lateral Economics estimates that in 2009, the number of private, standalone reference stations in Australia was in the order of 3000. While 3000 stations would in fact be adequate to service the entire Australian continent, the current installations have been inefficiently placed (poor geographic distribution) and not installed to agreed standards, meaning the investment only delivers services to a fraction of the country and a small proportion of potential users. It has been estimated that continued ad hoc investment of this form will support the growing high accuracy GPS positioning industry, generating between AUD$73 Billion and AUD$134 Billion from 2009 to 2030 to the mining, agriculture and construction sectors alone (The Allen Consulting Group, 2008). However, a coordinated approach through the national rollout of a standardised reference station network could reap additional gross benefits of AUD$32 Billion to AUD$58 Billion in the same period (The Allen Consulting Group, 2008). Such a network could form the basis for the CORS element of a NPI, addressing the needs of a wide cross-section of enhanced accuracy users and delivering benefits to all sectors.

[6] Differential GPS (DGPS) techniques determine the position of user devices relative to a "reference station", and therefore require the simultaneous operation of a pair of GPS receivers – the user device whose position is to be determined and the reference station receiver whose location is already known.

[7] Auscope: http://www.auscope.org/content.php/category/id/18

[8] GPSnet: http://gnss.vicpos.com.au/

[9] CORSnet-NSW: http://www.corsnet.com.au

[10] SunPOZ: http://www.derm.qld.gov.au/gnss/pdf/sunpoz_flyer.pdf

[11] AMSA: http://www.amsa.gov.au/Shipping_Safety/Navigation_Safety/

[12] SmartNet Aus: http://smartnetaus.com

[13] AllDayRTK: http://www.alldayrtk.com.au/

[14] GPSNetwork Perth: http://www.gpsnetworkperth.com.au/

[15] Checkpoint: http://www.cors.com.au/

GPS: SITUATION ANALYSIS

AVIATION IS THE PRIMARY APPLICATION FOR ENHANCED INTEGRITY GPS SERVICES

Enhanced Integrity GPS

Some applications of GPS, such as aviation, require a much higher level of guaranteed service (referred to as "integrity") compared to standalone or enhanced accuracy services. A Space Based Augmentation System (SBAS) is an example of a service which, in addition to broadcasting corrections to improve the accuracy of position, delivers GPS integrity information to users, essential for mission critical applications. An SBAS consists of one or more geostationary satellites which transmit position and integrity information to users, derived from a permanent ground-based reference station network. An advantage of an SBAS for aviation users over a system using a terrestrial communications link is that it would provide nation-wide (and possibly regional) coverage.

Aviation is the primary application for enhanced integrity GPS services. This capability is particularly important to support the implementation of Performance Based Navigation (PBN) and Approach with Vertical Guidance (APV) (Australian Government, 2009b). APV is vital in mitigating Controlled Flight Into Terrain (CFIT) incidents such as those which occurred at Lockhart River, Queensland, 2005 (15 fatalities) and Kokoda, Papua New Guinea, 2009 (13 fatalities) (Civil Aviation Safety Authority, 2010). APV approaches, such as those enabled by SBAS, are some eight times safer than non-APV approaches. Australia has supported an International Civil Aviation Organisation (ICAO) resolution that commits the nation to adoption of APV by 2016. To date no firm plans exist to build and operate an Australian or regional SBAS, though discussions are taking place within the Civil Aviation Safety Authority (CASA).

Precise Timing from GPS

GPS makes possible the dissemination of time at the sub-microsecond level, effectively synchronising all devices attached to a GPS timing receiver. Such synchronisation is vital for telecommunications, computer/data networks (upon which much of the banking sector rely), and the efficient operation of electricity distribution grids.

Military Use of GPS

Military systems which use GPS provide the Australian Defence Force (ADF) with a powerful strategic and tactical technology to assist in maintaining Australia's national security. Under the conditions of Australia's alliance with the US the ADF is granted privileged access to encrypted GPS signals that are not available for civilian use. These signals are more resistant to jamming and provide improved positioning accuracy for standalone GPS devices. It should be noted that many military applications mirror those in the civilian sector.

CASE STUDY

GPS IN AGRICULTURE:

Securing real economic and environmental benefits for Australia

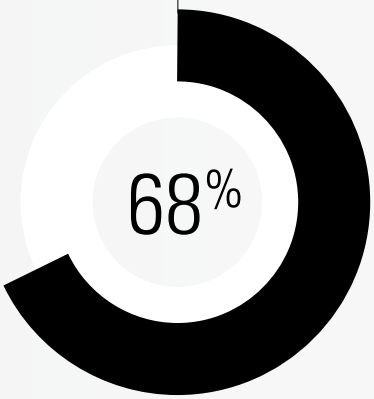
THE EUROPEAN GNSS AGENCY ESTIMATED THAT THE GNSS MARKET WILL GROW AT A COMPOUND AVERAGE GROWTH RATE OF 11%

In 2008, Kim Bowman, an Agribusiness consultant from Queensland, undertook a study of the economic and environmental impacts of controlled traffic farming (CTF) adoption on the Darling Downs (Bowman, 2008). CTF employs high accuracy GPS positioning to guide farm machinery so that the wheels of such machinery always follow the same path through a paddock, regardless of the operation being undertaken. Sometimes these wheel tracks are known as "tram lines" to reflect the fact that the machinery never diverts from them. The use of CTF results in less soil compaction which in turn yields substantial benefits. Bowman's objective was to quantify those benefits.

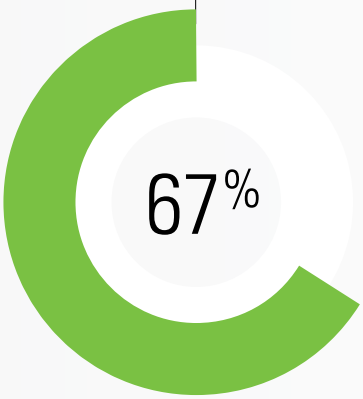
The benefits of CTF can only be realised through machine guidance, typically accomplished by using high accuracy (±2cm) GPS technology.

The key benefits documented in Bowman's study included:

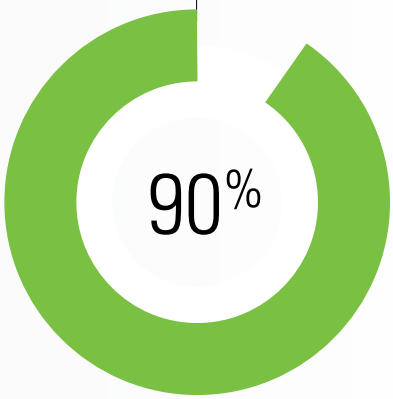
- 68% increase in farm gross margin
- 67% reduction in farm labour costs
- 90% reduction in soil erosion
- 93% reduction in Nitrogen loss through runoff
- 52% reduction in CO_2 emissions
- 52% reduction in diesel use
- 45% reduction in repair and maintenance costs



INCREASE IN FARM GROSS MARGIN



REDUCTION IN FARM LABOUR COSTS



REDUCTION IN SOIL EROSION

ECONOMIC BENEFITS OF GPS/GNSS

Several studies have been carried out on the economic benefits of GNSS. The European GNSS Agency estimated that the GNSS market will grow at a compound average growth rate (CAGR) of 11% from €58 Billion in 2010 to €165 Billion in 2020. The total GNSS-enabled market in Europe would be valued at €244 Billion in 2020 (European GNSS Agency, 2010).

Worldwide the global value of enhanced accuracy GPS products and services, a subset of the total GPS market, was estimated at US$3 Billion in 2009 and was predicted to grow to between US$6-8 Billion by 2012 (a CAGR of 19-23%) (Position One Consulting, 2010). GNSS also provides many societal and environmental benefits. For example The Allen Consulting Group (2008) highlight that improved farming practices using GNSS would reduce input, reduce soil compaction, increase yield, reduce water run-off and soil erosion, reduce impact on water quality, lower carbon dioxide emissions, reduce fuel usage and reduce stress to farmers. The side-bar "GPS in Agriculture" elaborates further on the benefits to agriculture that can be secured through high accuracy GPS-based machine guidance.

DEPENDENCE AND VULNERABILITY

A concern with the current level of utilisation of GPS in Australia (and elsewhere) is whether or not suitable back-up systems are in place. System failure, signal loss due to intentional or unintentional interference, signal jamming, or malicious spoofing can all render the system unusable, inaccessible or unreliable (The Royal Academy of Engineering, 2011; National PNT Advisory Board, 2010).

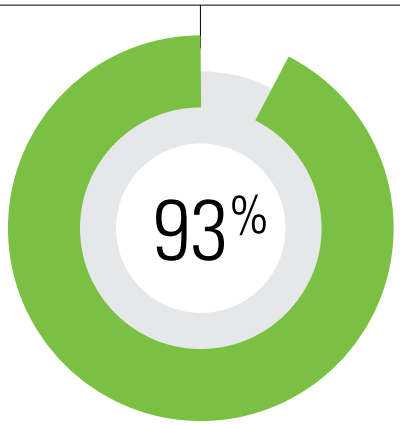
The transmission power of GPS signals is very weak[16]. Signal reception is readily interrupted by obstructions such as man-made structures, terrain, vegetation and sources of radio interference. Hence satisfactory performance of GPS requires both a clear sky-view (so that a minimum of four satellites can be simultaneously "seen" by a user device), and a "clean" radio frequency environment (free of competing signal transmitters that would overwhelm the GPS signals).

In some cases, procedures can be employed to identify and manage the impacts of signal obstruction and/or interference. For mass market applications temporary unavailability of service would mostly be an inconvenience. However, in machine guidance, mission critical navigation tasks, safety-of-life and some timing applications, the implications of these vulnerabilities could be dramatic, if not catastrophic.

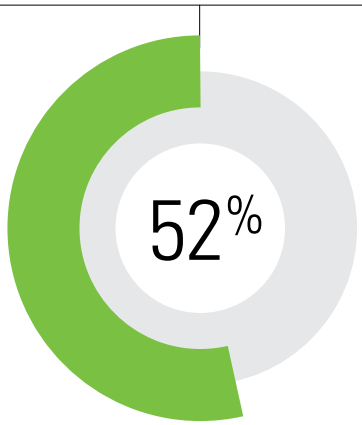
Recent studies have drawn attention to the vulnerability of GPS and the significant impact that would result should a loss of service occur.

For example, the European Commission estimated that 6-7% of the EU economy is now dependent on satellite navigation applications. This dependency is expected to grow (European Commission, 2011). Similar studies have been conducted in the US yielding comparable results (National Transportation Systems Center, 2001; National Security Telecommunications Advisory Committee, 2008). The Australian economy is likewise dependent on GPS and subject to the negative impacts of system failure or service denial.

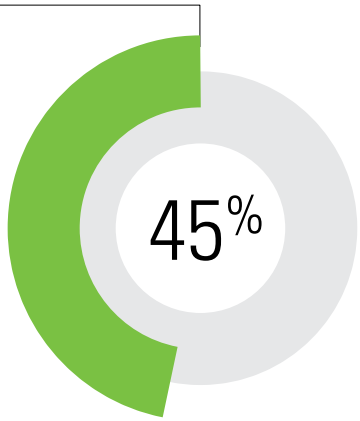
Though illegal in Australia, devices designed to deliberately interfere with the reception of GPS signals – known as Privacy Protection Devices (PPDs) – can be readily purchased on the internet for less than $30. A low-power PPD can jam GNSS signals over areas of several kilometres. In late 2009, a PPD operating in a truck caused havoc to a newly installed GPS-based landing system at the Newark Airport in the US (see side-bar "GPS Jamming"). Such incidents will increase as PPDs become more common. Examples such as this demonstrate the need to recognise the critical importance of ensuring continued access to GNSS signals, protecting users against the impacts of intentional and unintentional interference and jamming, and considering options for alternative PNT systems.



REDUCTION IN NITROGEN LOSS THROUGH RUNOFF



REDUCTION IN CO_2 EMISSIONS REDUCTION IN DIESEL USE



REDUCTION IN REPAIR AND MAINTENANCE COSTS

[16] The transmission power of the GPS signals is approximately equivalent to a 50 Watt domestic light bulb.

CASE STUDY

GPS JAMMING:

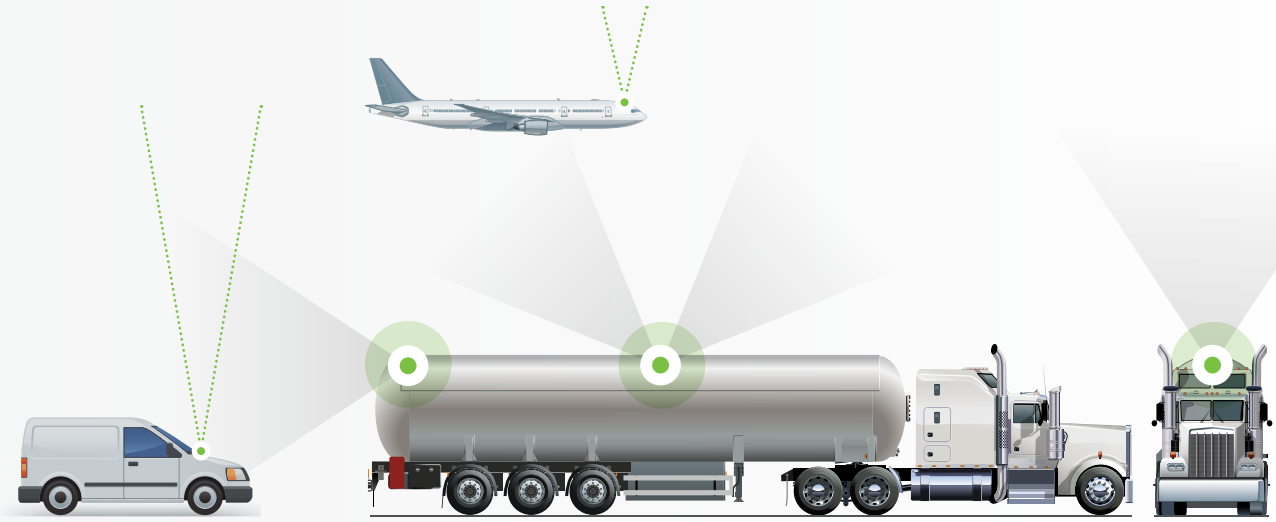
As the uses of satellite-positioning technology continue to grow, what can be done to stop deliberate and dangerous jamming of the signals?

No aeroplanes fell out of the sky and no one died. But in late 2009 engineers noticed that satellite-positioning receivers for a new navigation aid at Newark Airport in New Jersey (US) were suffering brief daily breaks in reception. Something was interfering with the signals from GPS satellites. It took two months for investigators from the Federal Aviation Authority to track down the problem: a driver who passed by on the nearby New Jersey Turnpike each day had a cheap GPS jammer in his truck.

Such devices are illegal to sell or use, but they have become popular with commercial drivers who object to their employers tracking their every move. A jammer prevents a tracking device in the vehicle from determining (and then reporting) its location and speed—but it also disrupts GPS signals for all other users nearby.

Extracted from The Economist, March 10, 2011 (www.economist.com/node/18304246)

These dependencies on and vulnerabilities of GNSS in general[17] have boosted interest in the development of alternative PNT technologies, particularly for mission- and time-critical applications. For example, inertial sensor systems can be used to augment GPS-derived positions for short periods of signal outage. Further, the Locata technology, a terrestrial positioning system developed in Australia[18], provides a useful complement or alternative to GNSS in circumstances where access to satellite signals is restricted or unavailable, including for indoor and open-cut mine applications (Rizos et al, 2011).



[17] All other GNSS, RNSS or SBAS have the same vulnerability as they all transmit very low power signals in the microwave portion of the electromagnetic radiation spectrum.

[18] Locata Corporation: http://www.locatacorp.com/.

Image: ESA - J. Huart

CHAPTER 2

MULTI-GNSS OUTLOOK AND OPPORTUNITIES

THE MAIN ADVANTAGES OF MULTI-GNSS ARE IMPROVED CONTINUITY, ACCURACY, EFFICIENCY, AVAILABILITY AND RELIABILITY

OVERVIEW

GPS adoption has increased substantially across many industries. This is expected to continue and in many cases accelerate. By the end of 2011, almost 80% of new mobile phones are expected to incorporate GPS functionality (iSuppli, 2010). Furthermore, it is forecast that by 2021 between 66% and 80% of agricultural land used for cropping in Australia will be managed, for such things as tractor guidance and auto-steer, utilising GNSS (The Allen Consulting Group, 2008).

As GNSS adoption increases, the world will transition from being reliant on GPS alone, to operating in the multi-GNSS era. Assuming appropriate compatibility between systems, user equipment will access various configurations of satellites and signals and associated ground- and space-based infrastructure to secure enhanced accuracy and integrity. The main advantages of the multi-GNSS era over a single system solution include improved continuity, accuracy, efficiency, availability and reliability (Rizos, 2008).

The imminent change in the GNSS landscape will have implications for value-added service industries, receiver manufacturers, users, signal providers, standards bodies and research institutions. In this respect, Australia has an opportunity to adopt a strategic approach to the transition to the next generation of multi-GNSS technology and services. Adopting such an approach promises to secure significant and accelerated benefits for the nation.

EXPLOITING AUSTRALIA'S ADVANTAGE

Over the coming decade the European Union, China, Japan and India will launch dozens of new global and regional navigation satellites. At the same time, Russia and the US will modernise their respective systems – thereby realising the multi-GNSS era. Given its geographic location, its political, economic and industrial environment and its research and development strengths, Australia is well placed to be at the forefront of multi-GNSS

Geographic Advantage

The South East Asian region will have access to all GNSS and RNSS systems – an advantage not enjoyed by any other region of the world. The launch of new constellations will triple the number of navigation satellites, and these new satellites will provide significantly more signals than are currently available. Figure 1 illustrates that, in terms of the number of satellites viewable at any time, a GNSS "hot spot" will advantageously sit over South East Asia.

The benefits that flow from having access to more signals, satellites and constellations include:

- Faster and more accurate position determination
- Improved reliability and integrity of positioning
- Better coverage, particularly in obstructed environments
- Reduced vulnerability to single system failure
- The ability to undertake real-time positioning over greater distances
- Reduced ground infrastructure needs (and therefore costs)
- The opportunity to develop new applications and service offerings

Average Combined GNSS visibility over 24 hours (15 degree mask)

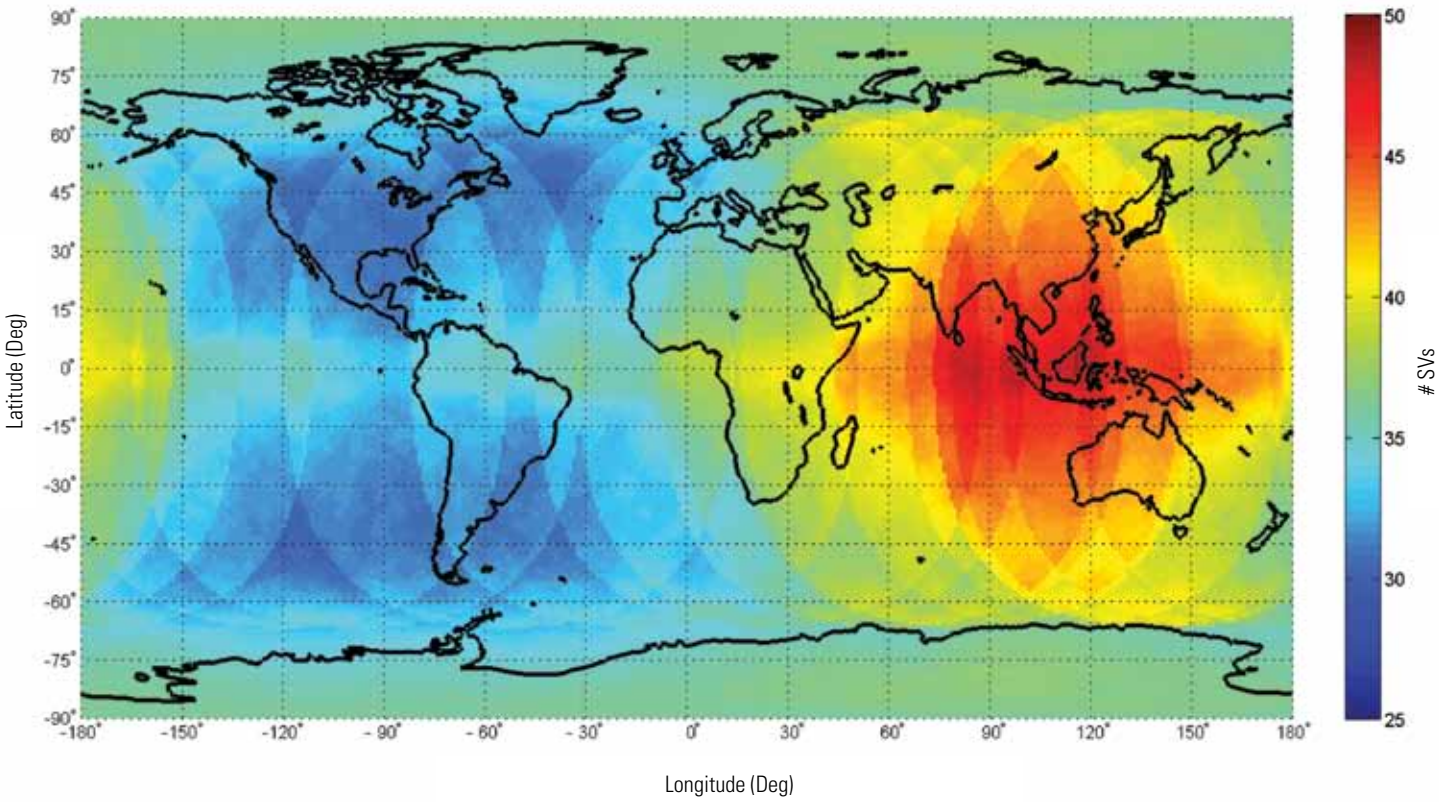


Figure 1 - The multi-GNSS "hot spot" over South East Asia (University of NSW, 2011)

MULTI-GNSS OUTLOOK AND OPPORTUNITIES

AUSTRALIA IS AN IDEAL CHOICE FOR GNSS SYSTEM PROVIDERS CONSIDERING THE HOSTING OF CRITICAL GROUND-BASED TRACKING AND MONITORING FACILITIES

Political Advantage

Australia offers a stable and dependable political environment that is attractive from the perspective of international engagement and investment. This reality, coupled with the fact that Australia is a large, geographically stable, southern hemisphere land mass that falls within the GNSS "hot spot", means that Australia is an ideal choice for GNSS system providers considering the hosting of critical, ground-based tracking and monitoring facilities. A large and widely distributed network of ground stations is essential to reliably model satellite orbit and clock corrections, to provide communication and upload links and to allow global monitoring of system performance. Australia therefore has an opportunity to develop long term partnerships with the world's most significant space powers. Hosting of ground monitor stations of the different GNSS control segments has the potential to lead to direct benefits for industry, researchers and ultimately the user community.

Australia has already exploited its geographic and political advantage to some degree. Australia currently hosts a GPS monitor station in South Australia. The European Space Agency (ESA) operates a ground station in Western Australia as part of the Galileo test phase. The establishment of a second Galileo station in north eastern Australia is currently being considered. A monitor station for Japan's QZSS has been installed in the ACT. Both Russia and China have initiated discussions with the Australian Government and potential Australian host organisations for installing test equipment. Opportunities for more formal engagement with GNSS system providers should be aggressively pursued in order to build collaborative relationships.

Economic and Industrial Advantage

Australia is well placed from a national wealth perspective to take advantage of the opportunities offered by the multi-GNSS era. Australian businesses have demonstrated capacity to exploit the opportunities multi-GNSS offers. Historically, the private sector has shown a willingness to invest in GNSS augmentation systems[19] as well as pursuing innovative product development. The emergence of multi-GNSS will create new opportunities, leading to job creation and export potential. In addition, early adoption of multi-GNSS products and services by user communities has the potential to create competitive advantage for key industries like agriculture, mining and construction.

Scientific Advantage

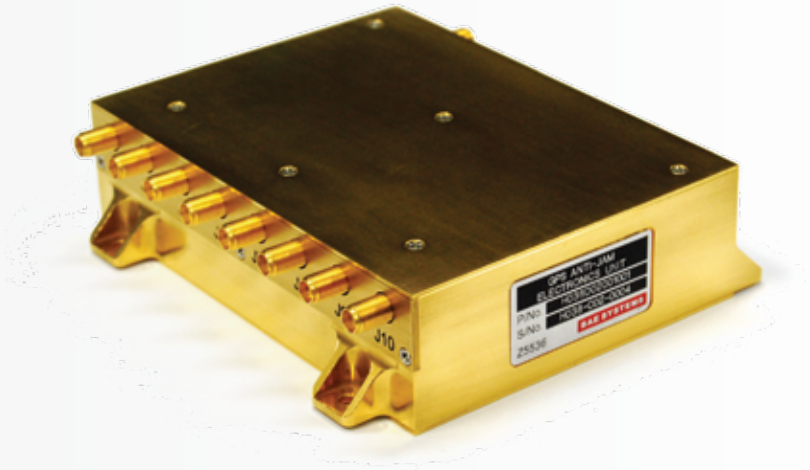
In the GNSS field, the Australian research community is active and internationally regarded. Our R&D strengths coupled with the existence of the GNSS "hot spot" will create unique opportunities to undertake research into multi-GNSS measurement processing strategies, new receiver design architectures, the development of new products and services, as well as identifying and validating new applications. Australia could become a unique global test bed for multi-GNSS experimentation, creating opportunities for collaborative international research partnerships. The side-bar "Development of an Australian Miniature GPS Anti-jamming System" describes a collaborative R&D project that has developed an innovative, miniature anti-jamming device, demonstrating the capacity of Australian scientists and engineers in the GNSS domain.

[19] In the form of Continuously Operating Reference Station (CORS) networks.

CASE STUDY

BAE SYSTEMS / UOA GPS ANTI-JAM SYSTEM

Recently developed under a Capability Technology Demonstrator, the GPS Anti-Jam unit performs interference cancellation and direction finding.



Development of an Australian Miniature GPS Anti-jamming System

Source: Michael Vaughan, BAE Systems, Mawson Lakes, South Australia.

A miniature GPS anti-jamming system that protects GPS navigation and timing receivers and can geo-locate the jamming source has been developed as a joint undertaking between the University of Adelaide and BAE Systems. The project was funded under DSTO's Capability Technology Demonstrator Program. The anti-jamming device has been designed and built specifically to support and protect military use of GPS for navigation, precision weapons delivery, precision timing and the future "digital battlefield".

Of particular interest is the use of the system in unmanned aerial vehicles (UAVs) which utilise GPS for precision navigation, but have restricted payload capabilities. In October 2010, the system underwent successful demonstration for DSTO. Opportunities for commercialisation and use beyond military applications are now being considered.

MULTI-GNSS OUTLOOK AND OPPORTUNITIES

SPECTRUM PROTECTION

As adoption of GNSS technology in Australia expands, both reliance on GNSS availability and vulnerability to loss of service increase. Even with international agreements in place to ensure Australia's access to the new GNSS signals, there is still a very real possibility of intentional or unintentional interference. Avoiding or mitigating such problems requires a robust approach to radio spectrum protection in the relevant signal frequencies. Given the rapid development of wireless technologies for telecommunications, the risk of interference could emerge at any time. For example, in the US there is currently significant public debate about the potential for a new 4G mobile broadband services (called LightSquared[20]) to interfere with GPS signals and thereby deny PNT capability to a wide range of users operating near wireless base stations. Responsibility for spectrum protection in Australia resides with the Australian Communications and Media Authority (ACMA). It is vital that ACMA monitors international GNSS developments closely and voices any Australian concerns in regard to GNSS service degradation. In this context it should be noted that Australia is one of only a few countries in the world with legislation specifically aimed at outlawing the possession of GNSS signal jamming equipment (PPDs).

PNT INFRASTRUCTURE

In a recent report, the Australian Space Industry Innovation Council (SIIC) identified GNSS-based PNT capabilities as a strategic priority for space industry development in Australia. The report highlighted two main components of critical infrastructure which are required to augment GNSS usage in Australia and thereby enhance its versatility, value and availability. The two recommended elements were the CORS component of a NPI and an SBAS.

The Australian and New Zealand Land Information Council (ANZLIC) has recently released its "National Positioning Infrastructure (NPI) Policy" (ANZLIC, 2011). In this document, the NPI is seen to be an amalgam of different positioning technologies and facilities, serving a variety of purposes and meeting a diverse range of user needs. Figure 2 illustrates ANZLIC's concept of the NPI. It can be seen that GNSS technology, and the related augmentation systems, make a substantial and essential contribution to the NPI. With regard to the CORS component the typical ground configuration consists of a relatively dense (50-100km spacing) network of permanent and stable CORS. The GNSS data acquired at these stations is sent via high speed data link to one or more Network Control Centres where a series of complex computations are performed and measurement correction messages are generated. The correction signal is transmitted to suitably equipped GNSS users (via the internet or some other data link) to achieve real-time positioning accuracies of approximately ±2cm. The focus is on delivering highly accurate, real-time positioning. Guaranteed levels of availability, robustness of service and solution integrity become secondary considerations when accuracy is the key driver. To achieve consistently high accuracy this component of the NPI must be based on the measurement of the carrier signals broadcast by the GNSS satellites. This requirement adds significant technical complexity, reduces the robustness of the solution, imposes a significant cost burden on user receiver equipment ($10k+) and demands a high density of ground stations.

[20] LightSquared has applied to build a 4G terrestrial wireless communications network in the US. Recent research has confirmed that LightSquared transmissons will interfere with GPS signals. This threat to GPS services has aroused a significant reaction from industry and the general public (www.saveourGPS.com).

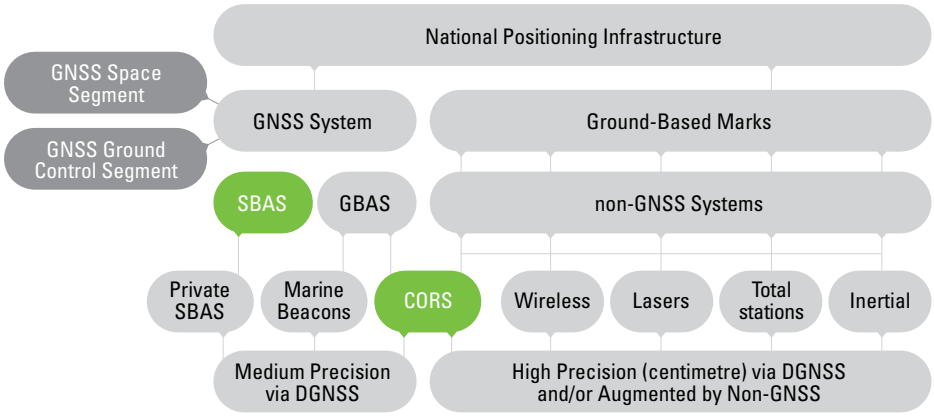


Figure 2 - The NPI Concept (ANZLIC, 2011)

The SBAS component is the second element of the NPI that is relevant in the context of Australia's GNSS strategic planning. The "ground segment" of an SBAS consists of a relatively sparse ground reference station network (approximately 20-30 would be required across Australia) and at least two Master Control Stations (MCS). Using dedicated communications links, the MCS acquires and combines the data from the reference stations and uses these data to compute and model signal errors and to verify the integrity of the real-time position solution. Communications with users is via two or more geostationary (GEO) satellites (the "space segment") to which the computed signal corrections and integrity message are uploaded and then re-broadcast. The GEO satellites and the dedicated ground communications infrastructure are the distinguishing features of an SBAS. They provide the guaranteed levels of availability and system redundancy needed for safety-of-life and mission critical applications such as aviation. In contrast to the CORS component of the NPI, the main focus of an SBAS is not positioning accuracy, but rather the availability and reliability of the augmented GNSS signals. SBAS systems do not use the GNSS carrier signals, but rather the binary codes to achieve accuracies in the range of ±1-2m. SBAS-capable user receivers are relatively cheap, costing around $300 per unit. Currently Australia has neither an SBAS nor a national real-time CORS network. From an NPI perspective, there are only small areas of the country where real-time, ±2cm accurate positioning is available. The Victorian Government, for example, offers a state-wide service, driven largely by the needs of precision agriculture and other machine guidance applications. Similar networks of smaller scale do exist, established by government and private sector operators, but true national coverage and consistency of operation is not available.

While targeting a different user sector, an SBAS provides an intermediate step toward realising the NPI. The accuracy offered by SBAS is not sufficient for applications such as precision agriculture, machine guidance, mining, construction and surveying, however it will enable applications and stimulate advances in many other domains such as marine navigation, road transport and emergency services. The truly ubiquitous nature of an SBAS coupled with the high reliability of the service will further promote and encourage adoption, bringing accelerated benefits to many users.[21]

OUTLOOK

Augmentation systems such as CORS networks and SBAS provide benefits which cannot be realised with standalone GNSS services. Unlike many other countries, Australia's large land mass and sparse population make delivery of the needed infrastructure technically challenging and potentially costly. This situation is evident when considering the current ad hoc approach to the roll-out of CORS networks. To keep pace with other nations, Australia must coordinate its approach to NPI and must target future NPI developments to optimally realise the benefits offered by multi-GNSS. One such benefit is anticipated to be reduced station density (and therefore cost) compared to what is required under the present GPS-only scenario.

[21] CASA is considering various options for an SBAS, including possible cooperation with Japan and/or India on the design of a regional SBAS.

CHAPTER 3

FINDINGS AND RECOMMENDATIONS

LESS THAN 20% OF COMPANIES IN THE MINING, AGRICULTURE AND CONSTRUCTION SECTORS HAVE THUS FAR INVESTED IN GNSS-BASED MACHINE AUTOMATION SYSTEMS

FINDINGS

Several economically significant Australian industries rely on and benefit from satellite-based PNT for their day-to-day operations. However, the rate of adoption is relatively low. For example, it is estimated that less than 20% of companies in the mining, agriculture and construction sectors have thus far invested in GNSS-based machine automation systems. Further economic and social benefits can be secured by these and other industries through a national GNSS strategy that aims to overcome barriers to adoption, and facilitate innovation and the development of new applications across a broad range of industries.

As new GNSS constellations become available, now is the time to address Australia's future use of GNSS. Maximum national benefit will be secured by providing coordination, a policy framework, the underpinning infrastructure and appropriate augmentation services to support the PNT needs of every user, anywhere in Australia. The result will be improved productivity and workforce safety, maintenance of Australia's comparative global economic advantage in key industries, increased export income, improved environmental monitoring, lowered CO_2 emissions, and an enhanced reputation as a nation of innovators.

Australia's geographic location, middle-power status, stable politics and robust economy mean that Australia can occupy a unique position in the global GNSS community. Formal and high level engagement with GNSS system providers and the coordinated roll-out and operation of a GNSS component of the NPI are considered pre-conditions for these benefits to be fully realised.

THE KEY FINDINGS IDENTIFIED IN THE PREPARATION OF THIS PLAN ARE

With regard to the present:

1.
Australia has no investment in the space segments (i.e. satellites) of any of the current or future GNSS.

2.
Australia hosts one GPS monitor station in South Australia and one QZSS ground station at Mt Stromlo (ACT). Discussions are underway to host ground monitor stations for other GNSS system providers.

3.
Australia has a growing dependence on GPS, and to a lesser extent GLONASS, across a wide range of industry sectors.

4.
Exploitation of GNSS brings substantial economic and public good benefits to the nation, estimated to be of the order of several billions of dollars per annum.

5.
High accuracy GNSS contributes significantly to Australia's economic well-being, through productivity gains in the agriculture, mining and construction sectors in particular.

6.
There is a healthy level of basic and applied GNSS R&D being undertaken by universities, government agencies and the private sector.

7.
There is a niche Australian industry sector developing and exporting GNSS products for the machine automation market.

8.
Australian participation in international scientific and political forums concerned with GNSS is at an impressively high level.

9.
Dependence on a single GNSS (e.g. GPS) results in an increasing, and potentially unacceptable, level of national vulnerability.

10.
The current ad hoc proliferation of CORS networks across Australia may unintentionally restrict the benefits realisable under a multi-GNSS environment.

11.
Australia has a number of unique geopolitical advantages when it comes to GNSS technology and applications which can be exploited to the benefit of industry, the community and the environment.

With regard to the future:

12.
The potential benefits to Australia of multi-GNSS are more significant than those currently enjoyed under GPS alone, principally due to the expected increased uptake of GNSS for machine automation, and the development of new innovative user applications.

13.
These additional benefits will flow from the improved performance of multi-GNSS.

14.
Benefits will also flow from increased system interoperability, resulting in reduced complexity and the lowered cost of multi-GNSS receivers and operations.

15.
Australia is well positioned geographically, politically, scientifically, industrially and economically to exploit these benefits.

16.
Australia is located in the GNSS South East Asian "hot spot".

17.
The level of benefits secured for the nation will depend on factors over which Australia has influence, such as investment in appropriate national CORS infrastructure, increased coordination of GNSS facilities and operations, improved governance, investment in R&D, and education and leadership in general.

18.
Full exploitation of the capabilities of multi-GNSS requires the facilitation of a GNSS component of the NPI that will yield improved accuracy and reliability, and secure enhanced integrity, not only through coordination of the establishment of CORS networks but through mechanisms for monitoring and ensuring service quality and maintaining the national spatial reference frame.

19.
The NPI must be regarded as Critical Infrastructure for the nation and be designed, built and operated in a manner commensurate with its fundamental importance.

20.
With appropriate support, Australian industry, along with the research and education sector, could be up-skilled and grown to exploit the opportunities that will emerge during the multi-GNSS era.

FINDINGS AND RECOMMENDATIONS

FOUR STRATEGIC RECOMMENDATIONS ARE IDENTIFIED HERE

RECOMMENDATIONS

The Australian Spatial Consortium will lead in the implementation of the recommendations of this Plan, aided in an operational sense by Geoscience Australia (GA), the Office of Spatial Policy (OSP), the Space Policy Unit (SPU), the Australian Communications and Media Authority (ACMA), and other national agencies as appropriate. It must be emphasised that this Plan was prepared with the civilian users and the general community in mind. Coordination of some of the recommended actions with military agencies may also be required.

Four strategic recommendations are identified here. Each recommendation is accompanied by a number of discrete actions, and a responsible agency is identified for each action.

01

ENSURE THERE IS LEADERSHIP FOR THE AUSTRALIAN GNSS COMMUNITY

1.1
Facilitate policy development for international engagement on GNSS-related issues, such as hosting of ground monitor stations, the establishment of international GNSS test beds in Australia and participation at international GNSS forums. (SPU; OSP)

1.2
Ensure appropriate and effective governance to coordinate government and private sector investment in enhanced GNSS infrastructure, and products and services dependent upon it. (GA)

1.3
Increase awareness and promote the benefits of GNSS to the broader community via an interactive narrative of advocacy and education. (ASC)

1.4
Encourage industry "champions" by creating opportunities for government agencies and private sector organisations to exercise leadership and responsibility in keeping with the directions of this Plan. (OSP; ASC)

1.5
Communicate with all sectors of the GNSS community on implementation issues and progress. (GA)

1.6
Advocate for the need to upgrade the fundamental reference station network to support multi-GNSS tracking, to invest in the development of a new geodetic datum, and to coordinate the activities of federal and state government agencies and the private sector. (GA)

02

ADOPT A WHOLE-OF-NATION APPROACH TO A SUSTAINABLE, MULTI-GNSS-ENABLED NPI

2.1
Identify existing NPI-related activities of government and private sector CORS providers. (GA)

2.2
Identify and mitigate investment risks by analysing and resolving duplication, fragmentation, consistency, timeliness and funding issues, with a view to ensuring a coordinated roll-out of the GNSS component of the NPI. (GA)

2.3
Coordinate the deployment of the GNSS component of the NPI based on capability to meet the above principles efficiently and effectively, to ensure that the NPI is built on hierarchical principles, and is strongly linked to the fundamental global GNSS reference station network and geodetic datum. (GA)

2.4
Establish and enforce consistent technical and commercial operating principles so that high accuracy and high integrity users are assured of the quality of enhanced GNSS by all service providers. (GA)

2.5
Establish appropriate governance, funding and business models to operate the NPI and deliver NPI-related products and services. (GA)

2.6
Coordinate international collaboration in multi-GNSS regional and global initiatives, campaigns and tests. (GA; SPU)

03

MITIGATE VULNERABILITIES IN EXISTING AND FUTURE GNSS INFRASTRUCTURE

3.1
Ensure the NPI is formally identified as Critical Infrastructure and that it is resourced, managed and protected accordingly. (SPU; OSP)

3.2
Form a Community-of-Interest as part of the Trusted Information Sharing Network (TISN) for Critical Infrastructure Resilience. (OSP)

3.3
Investigate the role of an SBAS within an NPI, what form it should take, what its functionality must be, and the partnership arrangements for its deployment and operation. (CASA; GA)

3.4
Protect the GNSS spectrum against RF interference through an appropriate regulatory framework. (ACMA; GA)

3.5
Mitigate GNSS dependency risks by:

3.5.1
Ensuring broad adoption of multi-GNSS, thereby eliminating single system dependence. (ASC; GA)

3.5.2
Promoting the appropriate use of non-GNSS back-up and augmentation technologies. (ASC)

3.5.3
Encouraging the development and deployment of alternative PNT systems where GNSS cannot operate effectively. (ASC)

3.5.4
Address issues of vulnerability. (GA)

04

CAPITALISE ON AUSTRALIA'S UNIQUE GEOPOLITICAL ADVANTAGE

4.1
Promote the unique benefits and opportunities that stem from Australia's geopolitical status as a politically stable, middle-power, with advanced infrastructure, an educated workforce, an active industry sector and a world class R&D capability

4.1.1
Encourage GNSS system providers to locate and operate ground monitor stations in Australia. (SPU; GA)

4.1.2
Encourage GNSS receiver manufacturers and application developers to engage with Australian companies and research organisations to develop, test, validate and demonstrate innovative GNSS products and services in Australia. (ASC)

4.2
Attract overseas investment in Australian-based GNSS businesses and research organisations. (ASC)

4.3
Assist neighbouring countries with GNSS infrastructure development, technical advice, education and skills development. (ASC, GA

4.4
Determine capacity needs and skills requirements to service Australia's growing GNSS industry. (ASC)

4.5
Grow the education and research sector to service demand for skilled GNSS engineers, scientists and researchers. (ASC)

REFERENCES

ANZLIC (2011) National Positioning Infrastructure Policy. ANZLIC – The Spatial Information Council. 11 pages.

Australian Government (2009a) Defence White Paper 2009 – Defending Australia in the Asia Pacific Century: Force 2030. May 2009. 140 pages.

Australian Government (2009b) National Aviation Policy White Paper – Flight Path to the Future. December 2009. 238 pages.

Bowman K. (2008). Economic and Environmental Analysis of Converting to Controlled Traffic Farming. Proc 6th Australian Controlled Traffic Farming Conference, Dubbo, NSW. p.61-69. ACTFA.

Civil Aviation Safety Authority (2010) Performance Based Navigation Implementation Plan: Australia. March 2010. 32 pages.

European Commission (2011) Report from the Commission to the European Parliament and the Council: Mid-term Review of the European Satellite Radio Navigation Programmes. January 2011. 28 pages.

European GNSS Agency (2010) GNSS Market Report. October 2010. 34 pages.

Featherstone W.E. (1996) An Updated Explanation of the Geocentric Datum of Australia (GDA) and its Effects Upon Future Mapping, *The Australian Surveyor*, 41(2), 121-130.

Global Geodetic Observing System: Meeting the Requirements of a Global Society on a Changing Planet in 2020, H.-P. Plag & M. Pearlman (eds.), Springer, Heidelberg, ISBN 978-3-642-02686-7, 332pp, 2009.

iSuppli (2010) Press Release: Four Out of Five Cell Phones to Integrate GPS by End of 2011. July 2010.

Lateral Economics (2009) Nation Building for the Information Age: The Economic Case for Governments Leading the Development of a National High Accuracy Positioning Network. January 2009.

Lemmens M. (2011) A Hundred-Plus Signals. *GIM International*, 25(6), June 2011. Available on line from http://www.gim-international.com/issues/articles/id1734-A_Hundredplus_Signals.html

National PNT Advisory Board (2010) Jamming the Global Positioning System - A National Security Threat: Recent Events and Potential Cures. November 2010. 10 pages.

National Security Telecommunications Advisory Committee (2008) NSTAC Report to the President on Commercial Reliance on the Global Positioning System. February 2008. 39 pages.

National Transportation Systems Center (2001) Vulnerability Assessment of the Transportation Infrastructure Relying on the Global Positioning System. August 2001. 113 pages.

Position One Consulting (2010) The Global Market for GPS/GNSS in GIS Mapping 2009-2013. Robert Lorimer and Eric Gakstatter. April 2010. 144 pages.

Rizos, C., Li, Y., Politi, N., Barnes, J., Gambale, N., (2011) Locata: A New Constellation for High Accuracy Outdoor and Indoor Positioning. *FIG Working Week "Bridging the Gap Between Cultures"*, Marrakech, Morocco, 18-22 May, paper 4917, http://www.fig.net/pub/fig2011/index.htm.

Rizos C. (2008) Multi-constellation GNSS/RNSS from the Perspective of High Accuracy Users in Australia. *Journal of Spatial Science*, 53(2), 29-63.

Space Industry Innovation Council (2010). Report prepared by the Space Industry Innovation Council PNT Working Group.

The Allen Consulting Group (2008) The Economic Benefits of High Resolution Positioning Services. Prepared for the Victorian Department of Sustainability and Environment and the Cooperative Research Centre for Spatial Information. November 2008. 51 pages.

The Royal Academy of Engineering (2011) Global Navigation Satellite Systems: Reliance and Vulnerabilities. March 2011. 45 pages.

US Government (2010) National Space Policy of the United States of America. June 2010. 18 pages.

DESIGN:
SYNSATION.COM.AU

HTTP://
SPATIALCONSORTIUM.ORG.AU

Image: ESA - J. Huart

AUSTRALIAN
SPATIAL
CONSORTIUM