



Australian Government

Geoscience Australia

Cnr Jerrabomberra Avenue
and Hindmarsh Drive,
Symonston ACT 2609

GPO Box 378,
Canberra, ACT 2601 Australia

Phone: +61 2 6249 9111
Facsimile: +61 2 6249 9999

Email: first.lastname@ga.gov.au

Web: www.ga.gov.au

ABN 80 091 799 039

Spectrum Management Review
Department of Communications
GPO Box 2154
CANBERRA ACT 2601

Geoscience Australia Submission to the Spectrum Management Review

To the Project Manager,

Geoscience Australia (GA) is pleased to make this submission to the Australian Government review of the Spectrum Management Framework.

GA's mission is to apply geoscience to Australia's most important challenges, promoting access to the geoscience information and knowledge the nation needs to engage with important economic, social and environmental issues.

This submission focusses on spectrum management for Position, Navigation and Timing (PNT) and Earth Observations from Space (EOS).

Yours sincerely,

A handwritten signature in black ink, appearing to read 'John Dawson', with a small dot at the end.

Dr John Dawson
A/g Group Leader
Geodesy and Seismic Monitoring

**Geoscience Australia Submission to the Australian Government Review of the
Spectrum Management Framework**

September 2014

Introduction

Geoscience Australia (GA) is pleased to make this submission to the Australian Government's review of the Spectrum Management Framework. GA's mission is to apply geoscience to Australia's most important challenges, promoting access to the geoscience information and knowledge the nation needs to engage with important economic, social and environmental issues. GA typically provides its data, products and information free to the community, under Creative Commons licenses, as a 'public good'. A recent strategic review of the agency by the Department of Finance found that all aspects of the agency's work were highly valued across the community.

GA is particularly pleased to note the emphasis in the Terms of Reference on considering the concept of 'public good' in a broader and more strategic sense. As noted above, GA provides a range of products on a public good basis and they translate directly into:

- a safer community, for example through bushfire monitoring and location awareness;
- more efficient industries, for example through enhanced, quality assured positioning and navigation;
- more effective and efficient mechanisms for managing the environment, for example through water and land monitoring;
- increased productivity, for example through identification of new mineral and petroleum exploration opportunities and open access to spatial data products.

GA's ability to deliver these public good products and services depend heavily on the spectrum management framework, making it clear that the ability of that framework to support GA's work has significant implications on GA's ability to serve the public good.

GA has chosen to focus its submission on two key business lines where the spectrum management framework has the most significant impact, and to flag issues to be considered. The two business lines are:

- Position, Navigation and Timing (PNT)
- Earth Observations from Space (EOS)

Both of these key business lines are identified in *Australia's Satellite Utilisation Policy* as 'space applications of national significance', further reflecting their importance to the nation and to the functions of GA.

Position, Navigation & Timing (PNT)

Introduction

This Section reviews current spectrum management arrangements for Position, Navigation and Timing (PNT) resources and services on the Australian mainland and within its maritime jurisdictions. The submission primarily focuses on radiofrequencies specified within the Radionavigation-Satellite Service (RNSS¹) allocation for receiving Global Navigation Satellite System (GNSS) services. The need for satellite and terrestrial communications (radio and broadband) to distribute raw and augmented data from current and emerging GNSS services is also acknowledged, along with the ongoing development of non-GNSS PNT technologies.

The eight Terms of Reference (TOR) identified by the Department of Communications in their '*Spectrum Review - Issues Paper*' are reviewed in a PNT context below. New and emerging GNSS services, public interest spectrum issues, and a whole-of-government and whole-of-economy approach to spectrum allocation, valuation and licensing for PNT applications are key themes emphasised throughout this submission. Given the current spectrum management framework has been in place since 1992, and was last reviewed in 2002, Geoscience Australia highlights the timeliness of this review for two primary reasons:

a) To address PNT developments since 1992/2002:

- **Globally** - The US Global Positioning System (GPS) is not the only GNSS. Russia's GLONASS² system is fully operational and, like GPS, is undergoing a long-term modernisation program. Europe has launched four GNSS satellites since 2005 for its Galileo system, and China reached 14 operational satellites in 2012 (first launching in 2000) for its Beidou system.
- **Regionally** – Japan's first regional satellite was deployed in 2010, and two regional satellites have been deployed by India since 2013.

Each of these countries will continue deploying global and regional satellites for the next 5-10 years (at least) to reach Full Operational Capability (FOC) and to modernise their constellations. Billions of dollars have been spent by these foreign nations to develop space-based PNT capabilities that remain freely accessible worldwide, bringing billions of dollars of benefit to countries such as Australia (Allen Consulting Group, 2008, GSA, 2013).

- **Collectively** – Recognising the growing value that multi-GNSS PNT information contributes to the Australian economy, planning is required by the Australian Government to facilitate and protect access to the RNSS allocation. The extent to which GPS is now integrated in our everyday phones and other devices reflects the value and growing dependence that society places on utilising satellite positioning technology. Indeed, the transition to multi-GNSS offers dramatic improvements in the accuracy, consistency, integrity, repeatability, sustainability, and resilience of these everyday PNT products and services. Not surprisingly, most commercial devices are already multi-GNSS enabled.

Furthermore, GPS has become increasingly embedded in the nation's underlying physical and information infrastructure (critical and otherwise) – an evolution that is permeating all facets of the Australian economy, and will bring greater efficiency, redundancy and capability through the transition to a multi-GNSS economy. The benefits of this transition should be identified and recognised within Australia's spectrum management framework.

¹ Defined in Subsection 3(1) (Part 1) of the Australian Radiofrequency Spectrum Plan (2013), RNSS: (a) means a radiodetermination-satellite service (e.g. GPS and other GNSS) used for radionavigation; and (b) includes any feeder link necessary for the operation of the service.

Radio frequencies for each GNSS can be identified as allocations to the RNSS, meaning the term 'RNSS allocation' (referred to herein) represents the combined frequencies of all GNSS identified in this document.

² Global'naya Navigatsionnaya Sputnikovaya Sistema (GLONASS).

b) To address PNT developments from 2014 onwards:

A multi-GNSS future offers unprecedented opportunities for Australia. The country's unique geographic location provides full visibility to all new constellations, including regional augmentations across the Asia-Pacific. Through collaborative partnerships with providers of these systems, Geoscience Australia leads and coordinates PNT activities aimed at enhancing access to these systems, to support and promote downstream scientific, commercial and public good applications. Whole-of-government planning through Geoscience Australia is contributing greater awareness and understanding on the societal and economic returns that derive from protecting the multi-GNSS spectrum resource. Long-term planning will ensure RNSS spectrum is protected in ways that maximise Australia's operational and competitive opportunities.

Geoscience Australia will strengthen engagement with Commonwealth, State and Territory Governments, in cooperation with industry and the research community, to build interoperability, redundancy, integrity, capacity, sustainability, efficiency and transparency in the country's National Positioning Infrastructure (NPI). Communicating with clarity and certainty requires confidence and understanding on how and why the RNSS spectrum resource is shared and protected for PNT. This submission facilitates this understanding.

Key Messages:

- *Billions of dollars have been spent by foreign nations to develop GNSS capabilities that support the delivery of Australian Government and business services every day, and everywhere. Australia is uniquely located to develop, host and benefit from unprecedented expansion in multi-GNSS technologies, meaning reliable and sustainable access to spectrum is critical.*
- *The spectrum framework needs to be simplified and communicated in a manner that allows all users and service providers to understand their rights and restrictions for accessing and investing in new and improved multi-GNSS technologies.*
- *Australia's spectrum framework should recognise the whole-of-government value generated by multi-GNSS PNT technologies, reflecting the embeddedness of these technologies in the Australian economy, to maintain alignment with international RNSS standards and planning.*

Recommendations:

- i. Reduce complexity in existing legislative and policy instruments to identify and communicate rights and restrictions for transmitting and receiving all GNSS services within the RNSS allocation (TOR-1).*
- ii. Ensure the spectrum framework accommodates access and protection requirements for new and emerging GNSS services in ways that maximise efficiency within the existing RNSS allocation to support public interest use and commercial growth in PNT industries (TOR-2 and -3).*
- ii. Ensure spectrum legislation and technical regulations have transparency, consistency and flexibility, to accommodate current and future multi-GNSS PNT requirements across multiple sectors of the economy (TOR-5).*
- iii. Consider options for an all-encompassing license sponsored by whole-of-government in Australia to accommodate current and future public interest use of RNSS spectrum (TOR-6, -7 and -8).*

The remainder of this submission details existing spectrum management arrangements for PNT activities in Australia to identify future considerations for each TOR.

TOR 1 – Simplify the framework to reduce its complexity and impact on spectrum users and administrators, and eliminate unnecessary and excessive regulatory provisions

- Information on existing legislation and regulatory provisions for GNSS allocations in Australia has been sourced from:

<i>Australian Communications and Media Authority Five-Year Spectrum Outlook 2013 – 2017</i>
<i>Australian Radiofrequency Spectrum Plan (2013)</i>
<i>International Telecommunication Union (ITU), Radio Regulations (Edition of 2012)</i>
<i>Australian Communications and Media Authority Act 2005 (ACMA Act 2005)</i>
<i>Radiocommunications (Prohibited Device) (RNSS Jamming Devices) Declaration 2004</i>
<i>Radiocommunications License Condition (Apparatus License) Determination 2003</i>
<i>Radiocommunications (Foreign Space Objects) Determination 2000</i>
<i>Radiocommunications (Communication with Space Object) Class License 1998</i>
<i>Radiocommunications Act 1992 ('the Act')</i>

- The mixture of provisions listed above is a multi-layered network of legislative and regulatory instruments and policy that is difficult to navigate. This 'framework' primarily addresses GPS requirements within the RNSS allocation, leaving incomplete, and in some cases ambiguous information on other GNSS radiofrequencies that can or cannot be transmitted or received in Australia. Multi-GNSS technology is already available commercially and has been used in Australia for at least the past decade through Russia's GLONASS system.
- From a Government and user perspective, it is difficult to identify which licenses are held and by whom; what these licences protect and what remedies are available in case of breach; which GNSS systems and radiofrequencies are not licensed and the implications of using non-licensed GNSS radio transmissions; and whether current licensing mechanisms address and account for the broader public interests that GPS, and emerging GNSS will deliver.
- Despite this complexity, the current spectrum framework has not impacted access to or the utility of GNSS constellations other than GPS to support Geoscience Australia's functions, and the broader PNT operations the agency enables. Updating the existing spectrum management framework to reflect this current 'state-of-play' is viewed by Geoscience Australia as a logical, whole-of-government opportunity to recognise, protect, champion and formalise a resource allocation that is essentially 'reserved' by the Australian Government already, albeit with some ambiguity administering its use.

Recommendation (TOR-1):

- Reduce complexity in existing legislative and policy instruments to identify and communicate rights and restrictions for transmitting and receiving all GNSS services within the RNSS allocation.*

TOR 2 – Improve the flexibility of the framework and its ability to facilitate new and emerging services including advancements that offer greater potential for efficient spectrum use, while continuing to manage interference and providing certainty for incumbents

- Long-term spectrum planning requires flexibility and foresight to accommodate new and emerging GNSS radiofrequencies, and to investigate spectrum options for non-GNSS PNT technologies that function as a complement, backup and by-product of GNSS services. Developing a sustainable spectrum framework with the flexibility to respond immediately to domestic and international research and investment

opportunities will ensure Australian infrastructure, technology, governments and industry remain competitive in a multi-GNSS future.

Recommendations – See TOR-5, -6, -7 and -8.

- Assigning clear and informed access and protection rights will ultimately reduce barriers to spectrum sharing/co-existence where, for example, identical frequencies from different space systems (e.g. GPS, Galileo, QZSS³, IRNSS⁴ – see Table 1 in Appendix A) already fall within frequency ranges covered by existing licences. Similarly, GNSS radiofrequencies (e.g. GLONASS, Galileo, Beidou, QZSS) that are within the RNSS allocation specified in the *Australian Radiofrequency Spectrum Plan (2013)*, but not held under existing space apparatus licences, should be examined for the public interest value they contribute alongside existing licenses. This establishes a whole-of-government, whole-of-economy approach to GNSS spectrum management in Australia (see TOR-6). The outcomes of this approach will assure service providers and users of their rights during this pivotal transition to a multi-GNSS future.
- Regarding intentional and unintentional interference to GNSS services within the RNSS allocation, an early response by the Australian Government was to recognise, address and protect the increased use of GNSS services to prohibit by law⁵ the use of RNSS jamming devices in Australia. This review brings the opportunity to update the spectrum management framework to account for provisions set out in the *Radiocommunications (Prohibited Device) (RNSS Jamming Devices) Declaration 2004*, with a view to planning future requirements for protecting multi-GNSS services. Further consideration should be given to protecting terrestrial PNT technologies that are emerging as a backup and complement to GNSS (e.g. for safety-of-life transport applications and emergency management systems).
- No immediate threats from ‘disruptive’ technologies have been identified that potentially interfere with the RNSS allocation in Australia. The current framework allows complaints and concerns to be raised with the ACMA for investigation, the outcome of which may vary depending on the GNSS affected.

Recommendation – See TOR-3.

- In the context of facilitating access to new and emerging systems, it is noteworthy that the US military is also moving towards using signals from constellations other than GPS to ensure continued access, and to thwart potential spoofing. Partnerships with other nations that provide these systems are being explored⁶.

TOR 3 – Ensure efficient allocation, ongoing use and management of spectrum, and incentivise its efficient use by all commercial, public and community spectrum users

- At present, radiofrequency bands associated with all existing and emerging GNSS constellations are recognised in the RNSS allocation specified within the *Australian Radiofrequency Spectrum Plan (2013)*. However, only three space apparatus (transmit) licenses are held by the Department of Defence in Australia to protect three GPS frequencies L1, L2 and L5. Whilst the *Radiocommunications (Communication with Space Object) Class License 1998* specifies a broader frequency range for receiving signals on Earth, the class license is only valid for Earth stations that receive space apparatus licensed signals (GPS), and GPS is the only space object specified in the legislation⁷. Inefficiencies arise where radiofrequencies transmitted by emerging GNSS, such as Japan’s QZSS, Europe’s Galileo and India’s IRNSS, are identical to those transmitted on GPS frequencies that are already licensed.

³ Japan’s Quasi-Zenith Satellite System (QZSS)

⁴ Indian Regional Navigation Satellite System (IRNSS)

⁵ *Radiocommunications (Prohibited Device) (RNSS Jamming Devices) Declaration 2004*.

⁶ <http://www.insidegnss.com/node/3991>

⁷ *Radiocommunications (Foreign Space Objects) Determination 2000*

- There is significant scope for improving technical efficiency (doing more with what we have) and dynamic efficiency (ensuring spectrum is allocated and used efficiently over time) at no additional cost to existing license holders. Indeed, there is scope to review options for licensing GNSS spectrum on whole-of-government public interest grounds with regard to multi-sector use and dependence on multi-GNSS information for public safety and business-as-usual service provision (see TOR-6 and -7). The prevailing situation in Australia, where an abundance of multi-GNSS enabled smart devices are already used despite potential inconsistencies with the current spectrum framework, suggests existing legislative and regulatory provisions require updating, whilst ensuring the framework's fundamental objectives to provide efficient allocation and use of spectrum (to maximise overall public benefit) remain valid.

Recommendation (TOR-2 and -3):

- iii. *Ensure the spectrum framework accommodates access and protection requirements for new and emerging GNSS services in ways that maximise efficiency within the existing RNSS allocation to support public interest use and commercial growth in PNT industries.*

TOR 4 – Consider institutional arrangements and ensure an appropriate level of Ministerial oversight of spectrum policy and management, by identifying appropriate roles for the Minister, the Australian Communications and Media Authority, the Department of Communications and others involved in spectrum management

- Existing institutional arrangements for Ministerial oversight and departmental roles are appropriate under the Radiocommunications Act and ACMA Act.

No Recommendations.

TOR 5 – Promote consistency across legislation and sectors, including in relation to compliance mechanisms, technical regulation and the planning and licensing of spectrum

- In light of TOR-1, -2 and -3, multi-GNSS is expanding the utility of GNSS infrastructure in the national interest (see TOR-6, -7 and -8) for applications such as transport (road, rail, aviation and maritime), agriculture, engineering, mining, finance, mapping, hydrography, asset management, Earth sciences (crustal monitoring, sea-level rise), meteorology, emergency management and national security.
- Geoscience Australia recognises that individual sectors have different PNT infrastructure and performance specifications (e.g. safety-of-life services), varying levels of regulatory oversight and PNT compliance (e.g. aviation standards, heavy vehicle compliance), and varying mechanisms by which these requirements are developed, implemented and monitored. However, each sector that uses multi-GNSS PNT technology requires access to the same RNSS spectrum, meaning each sector seeks clarity and agreement on how the RNSS spectrum resource is allocated and protected. The spectrum framework should therefore articulate with clarity and certainty the rights and restrictions of GNSS users from all sectors of the Australian economy, to ensure legislation and regulations are transparent, consistent and enforceable across all jurisdictions. Maximising access to multi-GNSS capabilities, without diminishing the protection offered through legislative and regulatory provisions is essential to implementing good governance, with the structure and flexibility to respond to future opportunities.
- Also noteworthy are recent discussions held between the US Federal Communications Commission (FCC) and the GNSS/PNT community regarding collaboration to protect GPS spectrum, and to use this spectrum as efficiently as possible as demand in adjacent bands continues to increase. Key topics discussed at the

forum focussed on critical GPS/GNSS applications, including the need to provide accurate location for emergency calls, setting tighter limits on out-of-band emissions affecting GNSS frequencies, and the use of GPS timing in the power grid, financial markets, and for telecommunications, all of which are highly relevant to the Australian economy. According to FCC Chairman Tom Wheeler:

- *“Today is about federal and non-federal leaders coming together to discuss successful industry-driven collaborations and GPS receiver performance. These are not abstract issues ... But let me also be specific about what today is not. It is not about FCC-mandated receiver standards. Rather it is about the best way to protect GPS operations in the context of evolving technology and adjacent spectrum activities.”*

Recommendation (TOR-5):

- iii. *Ensure spectrum legislation and technical regulations have transparency, consistency and flexibility, to accommodate current and future multi-GNSS PNT requirements across multiple sectors of the economy.*

TOR 6 – Develop an appropriate framework to consider public interest spectrum issues

- The need for a comprehensive whole-of-government framework for planning, allocating, using and managing spectrum for public interest use has been expressed throughout this submission. The definition of ‘public or community services’ in Section 10 of the *Radiocommunications Act 1992*, and the meaning of the term ‘adequate provision’ in Section 3(b), reflect Geoscience Australia’s intended government outcome to provide multi-GNSS PNT information for public-interest purposes:
 - *Informed government, industry and community decisions on the economic, social and environmental management of the nation’s natural resources through enabling access to geoscientific and spatial information.*
- Current methods of pricing spectrum do not necessarily reflect the public interest value enabled by multi-GNSS PNT information. Pricing on a per megahertz, per year basis for individual radiofrequencies from individual constellations can limit incentive to license additional multi-GNSS signals that bring integrity, redundancy, availability, accuracy, reliability, interoperability and compatibility for public and community services.
- In its current form, the spectrum management framework encourages and facilitates cross-sector use of GPS through licenses held by the Department of Defence (i.e. open access for civilian users). Without these licences, another entity would need to license this spectrum (per megahertz, per year under existing licensing arrangements) to ‘authorise’ the transmission of GPS signals in Australia. The resulting licensing conditions may differ from those currently implemented in the national interest by the Department of Defence. A more suitable approach, particularly as more GNSS signals become active within the RNSS allocation, would be an all-encompassing licence sponsored by whole-of-government in Australia. Whole-of-government might refer to an individual agency sponsoring a multi-GNSS licence on behalf of all users (e.g. the ‘Defence’ scenario currently adopted), or multi-agency agreement and sponsorship recognising the public interest value multi-GNSS creates for government and business services nationally. ‘Sponsorship’ in this context could include direct licensing fees from single or multi-agency appropriations, or using other sources of government revenue to allocate spectrum on public good grounds. From a whole-of-government perspective, market-based incentive auctions for allocating spectrum do not seem

appropriate in this public interest context, given maximum efficiency and equity is sought to protect the multi-GNSS spectrum asset in the national interest (refer to FCC example described in TOR-6).

- To highlight the delicacy of GPS (and future multi-GNSS) spectrum in this context, and the sensitivity of its broad user base, a clear example was recently observed in the US:
 - Substantial concerns were raised by Governments and industry in the US in response to a national terrestrial broadband proposal submitted by the company Lightsquared to the US FCC. The proposed network was designed to transmit high-powered signals on frequencies adjacent to GPS spectrum. Extensive testing demonstrated the unprecedented interference this would cause for GPS/GNSS devices and infrastructure nationally across the US, primarily through the Lightsquared signal drowning out very weak GPS signals. The proposal was ultimately rejected on public interest grounds.

Recommendation – see TOR-8.

TOR 7 – Develop a whole-of-government approach to spectrum policy

- In the short-term, recognising that existing licences can be expanded to accommodate non-GPS signals from other GNSS is a first step towards more efficient use of the spectrum resource. In the longer-term, ensuring an appropriate spectrum planning framework is in place to support reception of multi-GNSS transmissions as new signals come online will ensure the full public benefits are immediately made available to Australian users.
- A whole-of-government, whole-of-economy licensing approach that authorises and protects existing and future RNSS allocations on social and economic grounds, at no charge to service providers and users, seems a logical and natural step to support public and community services in Australia. The fact that limited information is available regarding the existing spectrum ‘market’ (for users to make informed decisions about availability, use, sharing, leasing, sale or purchasing of spectrum), suggests a whole-of-government sponsorship approach justified on social and economic grounds would only formalise what is the prevailing view and approach by service providers, legislators, regulators.

Recommendation – see TOR-8.

TOR 8 – Develop a whole-of-economy approach to valuation of spectrum that includes consideration of the broader economic and social benefits

- With reference to TOR-2 and -6, there is no explicit competition for RNSS spectrum in Australia that would raise the need for incentive auctions and other market-based pricing mechanisms. However, lessons learned from the Lightsquared proposal (TOR-6), combined with knowledge of the growing embeddedness of multi-GNSS in critical and other infrastructure across Australia, suggests the value of RNSS spectrum to the Australian economy is not well understood. For example, new research can generate new positioning techniques, such as those being developed by the Cooperative Research Centre for Spatial Information (CRCSI), leading to increased productivity and cost efficiencies (e.g., reduced inputs for establishing positioning infrastructure) for essential public and community services. Spill-overs from facilitating the production of fundamental spatial datasets using PNT technologies include a more informed community, which facilitates better decision-making.
- Geoscience Australia’s mandate to support public and community services requires continuous measurement of the size and shape of the Australian landmass to detect and monitor natural hazards such as crustal motion. These functions serve to improve public safety and community planning to prevent damage to critical assets, such as power and transport networks. As the network of users who connect to

the reference frame increases, the value of the reference frame itself increases given more users can communicate and apply authoritative position information in a standardised reference system.

- Other benefits of multi-GNSS services include improvements in conventional and space weather forecasting; rapid detection of hazardous events such as earthquakes and tsunamis; assisting neighbouring countries to exploit GNSS technology and benefit from regional hazard monitoring applications; and improving performance monitoring of GNSS constellations to mitigate against vulnerabilities such as signal jamming and interference. The contribution of spectrum to enabling these social and economic benefits should be recognised in the spectrum management framework to justify whole-of-government sponsorship of RNSS licences, thereby enabling access to multi-GNSS signals, and protecting against any interference that potentially disrupts, disturbs or devalues these outcomes.

Recommendation (TOR-6, -7 and -8):

- iv. Consider options for an all-encompassing license sponsored by whole-of-government in Australia to accommodate current and future public interest use of RNSS spectrum.*

APPENDIX A (PNT) – GNSS SPACE SYSTEMS & RADIO SIGNALS:

Country (Owner)	Space System	Global or Regional Coverage	Central Radio Signal (Carrier) Frequencies (MHz)
United States	Global Positioning System (GPS) <i>- Fully Operational</i>	Global	L1: 1575.420 L2: 1227.600 L5: 1176.450
Russia	Global'naya Navigatsionnaya Sputnikovaya Sistema (GLONASS*) <i>- Fully Operational</i>	Global	L1: 1598.0625 – 1609.3125 L2: 1242.9375 – 1248.625 L3: 1202.025
European Union	Galileo <i>- Under Development</i>	Global	(E2-L1-E1): 1575.420 E6: 1278.750 E5a: 1176.450 E5b: 1207.140
China	Beidou (also known as Compass) <i>- Under Development</i>	Global	B1: 1561.098 B2: 1268.520 B3: 1207.140
Japan	Quasi-Zenith Satellite System (QZSS) <i>- Under Development</i>	Regional	L1: 1575.420 L2: 1227.600 L5: 1176.450 QZSS-LEX: 1278.750
India	Indian Regional Navigation Satellites System (IRNSS) <i>- Under Development</i>	Regional	L5: 1176.450 (S-Band): 2492.08

Table 1. GNSS systems and their radio signal frequencies.

**Using the Frequency Division Multiple Access (FDMA) technique, each GLONASS satellite transmits navigation data on a different frequency within the frequency ranges specified for GLONASS L1 and L2. GLONASS L3 uses the Code Division Multiple Access (CDMA) technique to transmit unique ranging codes on the same L3 frequency from each satellite; the standard method used by other GNSS.*

From Table 1, GNSS radio signals (highlighted bold) that are transmitted within frequencies specified in existing space apparatus licences (italicised) are:

- *1164.45 – 1188.45 MHz (GPS-L5; Galileo-E5a, QZSS-L5; IRNSS-L5)*
- *1215.60 – 1239.60 MHz (GPS-L2; QZSS-L2)*
- *1563.42 – 1587.42 MHz (GPS-L1; Galileo E2-L1-E1; QZSS-L1)*

From Table 1, GNSS radio signals (highlighted bold) that are within frequencies ranges specified in the *Radiocommunications (Communication with Space Object) Class Licence 1998* (italicised) are:

- *1164 to 1215 MHz (GPS-L5; GLONASS-L3; Galileo-E5a, E5b; Beidou-B3; QZSS-L5; IRNSS-L5)*
- *1215 to 1260 MHz (GPS-L2; GLONASS-L2; QZSS-L2)*
- *1559 to 1610 MHz (GPS-L1; GLONASS-L1; Galileo E2-L1-E1; Beidou-B1; QZSS-L1)*
- *2483.5 to 2500 MHz (IRNSS S-Band frequency)*

Earth Observations from Space (EOS)

Background

Earth Observations from Space (EOS) are observations of the Earth made by scientific instruments carried on-board satellites. EOS provide a unique perspective of the Earth. They enable us to build up a comprehensive and comparable understanding of the whole continent over long-term periods, and they give us access to new data on a regular basis. This combination of attributes, coverage, longevity and currency, are unique to EOS. Although complementary, other platforms, such as ground-based observatories and airborne surveys, simply cannot realistically meet these criteria.

The richness of this data, in which tens of billions of dollars are invested, presents considerable opportunities for Australia. Effective application of this data will boost productivity and innovation, increase the efficiency of government administration and regulation, create new opportunities for new businesses to compete in the digital economy, and enable Australia to develop products and services that are highly transferrable to international markets.

EOS already contribute \$3.3 billion to the Australian economy annually and underpin over 100 government programs⁸. EOS is already being used to improve agricultural productivity and competitiveness, to support our management of natural hazard risk, to discover new minerals, and to help reduce red-tape associated with environmental management and approvals. EOS already offers fantastic Return-on-Investment for Australia. In effect, Australia spends approximately \$105 million a year on EOS activity, leveraging access to data in which other nations have invested tens of billions of dollars to build and operate satellites, to deliver \$3.3 billion of value to the economy.

However, EOS in Australia is at a critical transition point. Many applications are on the brink of moving from 'research' into full implementation, including by the private sector. And with the right conditions, EOS is expected to be ubiquitous in the same way that Global Navigation Satellite System (GNSS) technologies, such as GPS, are becoming ubiquitous and boosting productivity across all areas of the economy.

But Australia does not operate a single EOS satellite, and relies entirely on data from satellites operated by other nations (similar to the GNSS situation). Australia has typically adopted a 'take what we can get' approach. This approach has worked well in the past, and has enabled us to reach the current point where the potential value of EOS is clear.

However, this approach will not continue to work into the future for three primary reasons:

- Australia needs more certainty about future data supply. Investments in the development of new products and services based on EOS will only be made if people, including value-adding business, have certainty about what data they will be getting, and confidence that plans are in place to ensure continuity of supply into the future.
- Australia wants influence over future satellite design, to ensure new infrastructure meets Australian requirements. Certain requirements can be more important to Australia than to the nations investing in the satellites.
- Australia wants access to data on the lowest-cost and most open basis possible, to ensure the benefits are realised as widely as possible across the economy. Satellite operators are often under pressure to recoup costs, and unless Australia is seen as a valued contributor to their programs, rather than a 'freeloader', they will reasonably expect us to pay for data.

⁸ (ACIL Tasman, 2010)

Accordingly, Australia seeks to move from a ‘take what we can get’ approach to a proactive requirements-driven approach, where we engage with satellite operators to secure access to the most important datasets for Australia, and where we make valued contributions to their programs in areas where Australia has niche strengths.

Management of spectrum has a very real and significant impact on Australia’s ability to do this. Spectrum management approaches are central to success, because:

- Spectrum facilitates communication between satellites and ground stations to:
 - Download data directly from satellites;
 - Communicate with satellites to monitor their state of health and issue commands.
- Spectrum interference impacts on the observations that can be made:
 - Key natural phenomena are inherently only detectable in very specific parts of the spectrum. Interference with these parts of the spectrum (e.g. the ‘Fingerprints of Nature’) diminishes the potential value of the data collected by the satellites.
 - Data acquired by active instruments, such as those using RADAR technology to ‘bounce’ signals off objects on the ground like ships, can be denuded if there is interference in the relevant spectrum bands.

Moreover, spectrum management has disproportionate impacts on EOS, compared to many other potentially competing uses, because:

- **The use of particular parts of the spectrum is unavoidable** - The need to use them is driven by fundamental mission requirements and physical constraints. For example, there is no possibility to use a different part of the spectrum to observe the ‘Fingerprints of Nature’. If there is interference, the data simply cannot be acquired. Similar to communicating with satellites from the ground, only certain parts of the spectrum can ever possibly work.
- **Long-term certainty of spectrum is critical** - The lead-times for any activity relating to space are considerable, often in the order of decades, with key decisions (such as where data will be downlinked) locked-in many years out from launch. Satellite and ground station operators need to know they will have spectrum certainty for many years after a satellite is launched, potentially decades. Once investment commitments are made, it is very difficult to adapt, meaning spectrum certainty encourages substantial long-term investment. Satellites often cannot be feasibly adapted to, for example, a change from downlinking in Australia to Africa.

The current approach to spectrum management, in the context of the framework itself, and how it is implemented, do not position Australia well to realise the full benefits of EOS. They do not enable adequate and complete consideration to be given to the current and potential value of EOS to Australia, such as:

- If EOS is not available to support environmental monitoring, what will the impacts be on the trillion dollars of ‘ecosystem services’ provided by our natural environment, such as pollination?
- If Australia cannot secure access to EOS on suitable terms, what are the costs of comparable data acquisition programs such as airborne surveys as an alternative?

As such, the questions that should be posed for any future spectrum management framework should be:

1. Does the framework enable Australia to ensure it can reliably ‘get what it needs’, e.g. by directly assuring access to data about Australia, for use in committed missions?

2. Does the framework position Australia to make valued contributions to the international satellite operator community, to support the case that these operators should continue to provide us with access to that data on favourable terms?

The following sections explore the key spectrum issues in this context.

Downlink and uplink

The ability to downlink data to ground stations in Australia, for Australian purposes, will continue to be important. Changes in technology that enable satellites to store more data on board, and to download that data in locations far removed from the area over which it has been acquired, are often cited as reasons why Australia may not require its own ground stations. Although these changes will influence what ground infrastructure we deploy, and where, they do not change the fact that Australia will require ground infrastructure into the foreseeable future because:

- Not all the satellites that are important to Australia will operate on this model;
- For time-sensitive applications, such as community safety, waiting for the satellite to 'return home' to download data is not acceptable. Given internet links are then required to get the data from the 'home' station back to Australia, the supply chain becomes more complex and the likelihood of outages also increases;
- Storage on satellites is inherently limited, but where supplementary ground stations are available in particular geographical areas, the satellite operators can acquire additional data in those areas. As such, ground stations in Australia make it more likely that more data will be acquired over Australia.

Despite the importance of these ground stations, Australian Government agencies have found it very difficult to secure long-term access to the required spectrum. It has been proposed that consolidation of ground station facilities in 'space parks' would help address spectrum management issues by making it easier to secure appropriate spectrum protection, both in terms of uplink and downlink. While desirable on the surface, such an approach has significant issues:

- The cost of consolidating infrastructure into such locations would be considerable, and not supported in the foreseeable future;
- For certain satellites and certain programmes, such as meteorological programs, there are significant limitations on where ground stations can be located;
- Consolidation can reduce the resilience of the national network of ground stations by, effectively, putting 'too many eggs in one basket'. Leaving aside the obvious issue of an malicious attack on such a consolidated facility, should assurances about spectrum not actually be followed through, Australia would be highly exposed.

This is not to say that 'space parks' will not develop. However, the use of 'space parks' should be driven by a better fit for mission requirements, and for sustaining maintenance and operational costs, rather than by any argument around it being the only way to guarantee spectrum.

These issues are exacerbated when considering the potential opportunities to support the international community, both in providing locations for them to host equipment, and operating equipment that meets their operational requirements (similar to the GNSS scenario).

Australia is well positioned geographically to host ground infrastructure of value to satellite operators. For some applications, they have limited choice about where to locate their infrastructure. In terms of communicating with the satellites through uplink to support command and control, Australia has the potential to carve out a niche as the location of the 'core' ground stations upon which satellite operators rely to protect their billion dollar investments.

These investments have significant potential to create economic activity and jobs in regional areas, whether paid for by the satellite operator directly, or funded by the Australia Government as a form of ‘co-contribution’ to the satellite operator’s program.

However, recent experiences with the current spectrum management regime have made operators, and Australian Government agencies, nervous about making these investments. For example, one very large space agency was encouraged to move ground infrastructure into a particular area as a way of ensuring they could support decade-long programs, but were subsequently given conflicting messages about how ‘secure’ their spectrum was. This has made them very wary about future engagement with Australia.

These experiences have also raised questions about how holistic and strategic current assessments are. In the example cited above, it appeared that less value was given to the use of spectrum at that particular facility because it was related to ‘research’ rather than direct economic activity. However, this consideration ignored the facts that:

- the agency in question also operates a range of EOS satellites that do offer considerable direct benefit to Australia, and for which we may have secured favourable access in return for securing access to spectrum for a facility in which they have invested significant sums;
- although primarily used to facilitate ‘research’, the facilities are **also** used during the critical launch phase for new EOS satellites, including those operated by **other** satellite operators who have EOS satellites of significant potential value to Australia.

As noted above, there are physical limitations on the spectrum that can be used in an EOS context, and the nature of EOS programs necessitates very long-term certainty about spectrum access. However, it has been observed that the current framework can be ‘short-sighted’ and support ‘high-value’ competing uses for these key areas of spectrum, despite the fact that:

- such uses are likely to move to other parts of the spectrum within relatively short periods (3-5 years);
- the practical reality being that assured co-existence is often perfectly achievable.

Observations

As noted above, spectrum management is important not just for ensuring data that has been acquired can be reliably transmitted to the ground; it is critical to ensuring that the data required to support important applications can be acquired in the first place.

EOS are either made ‘passively’, by listening to signals emanating from the ground as a result of natural processes, or ‘actively’, as the result of issuing a stimulus (such as a RADAR signal) and monitoring the response. Spectrum interference can have significant impacts on both.

In the case of ‘active’ observations, where such interference is predictable well in advance, some accommodation may be possible by designing instruments to use different parts of the spectrum. However, there is only so much flexibility. In certain cases, particular applications are particularly sensitive on quite narrow parts of the spectrum. For example, L-Band Synthetic Aperture RADAR observations are best suited for certain important agricultural productivity applications, and there is limited flexibility to adapt. The physical properties to be observed just do not lend themselves to, for example, using C-Band signals.

Where interference is unpredictable, or only becomes apparent after the launch of a satellite, there is a real potential that data from that satellite over Australia may be unusable. A number of studies have been undertaken to explore the extent to which certain types of interference affect ‘active’ observations, but there is still considerable uncertainty. This is an area that merits careful attention.

In the case of passively acquired EOS, there is much less flexibility and the impacts of poor spectrum management policy have considerable flow-on effects across a very wide number of areas. Understanding key characteristics of the Earth system, and how they are changing over time, is critical to our ability to engage with important issues including natural disaster mitigation, drought, climate change and water resource management. The ability to observe these 'Fingerprints of Nature' reliably, and over necessarily long periods, is made more challenging by the fact the natural signal levels involved are very low-level and simply cannot tolerate interference. As such, an effective spectrum management regime must ensure they are protected for the long-term.

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