12 APRIL 2021

SPACE & SPATIAL ROADMAP 2030

CONSULTATION PAPER - A CALL FOR VIEWS

Authorised By:
The Steering Committee of the 2030 Space and Spatial Industry Growth Roadmap

FOREWORD

The space and spatial industries have never been more important for the future of Australia. They both have a fundamental role to play in helping Australia navigate the response to catastrophic bushfires, the impacts of climate change, and the development of recovery plans for the economy following the global pandemic and its impact on our society and the economy. The growth of these two sunrise industries will have a profound effect on the well-being of Australia over the next decade and beyond.

The combination of space and spatial working together adds enormous value. In many ways these two industries are co-dependent and synergistic. The space industry sets up critical elements of the communications supply chain (through satellite communications (SATCOM)) together with vital content from Global Navigation Satellite Systems (GNSS) and Earth Observation (EO) sensors). The spatial industry provides the vast bulk of the subsequent data infrastructure, value-added content and analytics, and the ‘last yard’ delivery channels to customers and end users for most industries and across global societies.

Optimising this combined ecosystem over the next decade will create a premium competitive advantage for Australia; greatly strengthen our sovereignty, defence and security; and play a key role in managing our environment and improving our well-being.

But the nation faces a major challenge in growing its emerging and fragmented space community so that it can reach the critical mass required of a modern space-capable nation.

The purpose of this consultation paper is to specifically seek the advice of key stakeholders in the space and spatial ecosystems on actions that can be taken over the coming decade to accelerate the growth of the space and spatial industries working together.

This input will then be used to develop the 2030 Space and Spatial Industries Growth RoadMap which will be completed later in 2021.

Your input and feedback is warmly welcomed.

Dr Peter Woodgate

Chair of the Steering Committee of the 2030 Space and Spatial Industry Growth RoadMap

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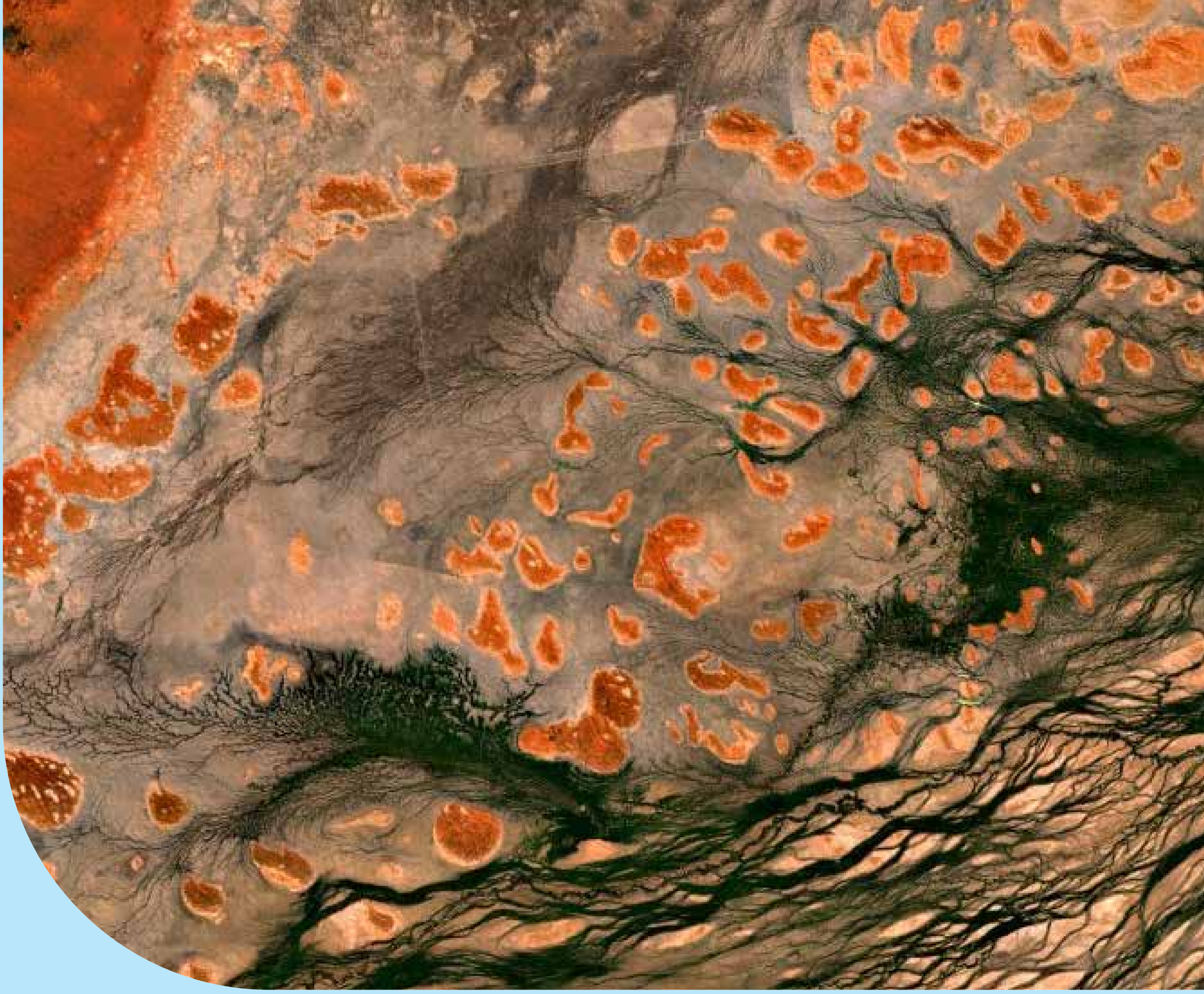


EXECUTIVE SUMMARY

In this information age, economic success, societal well-being and national security pivots around our ability to collect, disseminate and exploit complex data in a timely and effective manner. Space and spatial capabilities are central to achieving this, providing essential data and services to support areas of national importance such as land and water security, emergency management, and, increasingly, autonomous systems and smart cities management.

The Australian space and spatial industries are poised for great growth. By systematically and strategically working together, these two closely allied industries will realise enormous benefits that would otherwise not be possible.

The Space and Spatial Growth RoadMap is being developed to:

1) highlight the strategic importance of a strong Australian space and spatial capability,

2) identify the critical characteristics of such a capability, and

3) outline the steps required to realise an integrated space and spatial ecosystem that will be a key national asset.

This paper sets out a series of issues that are designed to elicit feedback through a comprehensive process of consultation. The desired outcome from the consultation process will be a growth RoadMap focused on the most important areas where space and spatial can work together and a set of actions to optimise the accelerated growth of these two industries looking out to 2030.

The paper focusses on those issues that have not yet been factored into the many existing strategies and plans of the agencies, organisations and companies that have contributed to the paper. The priority for this paper is on the growth potential for earth-oriented applications, recognising that the outward looking space will warrant similar attention in the future. The issues raised here are therefore those that should be considered in addition to existing planning arrangements which are shown in Figure 1 below:

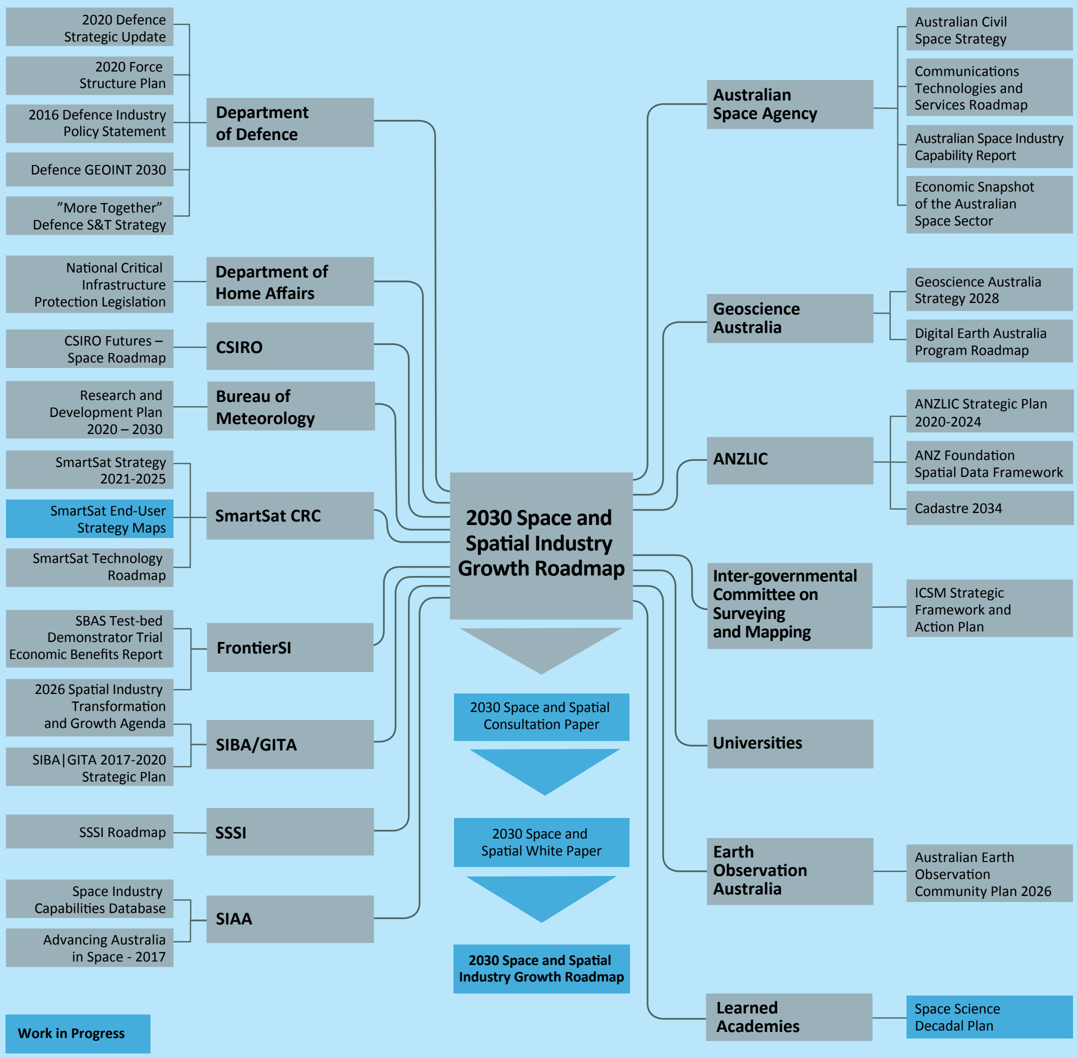
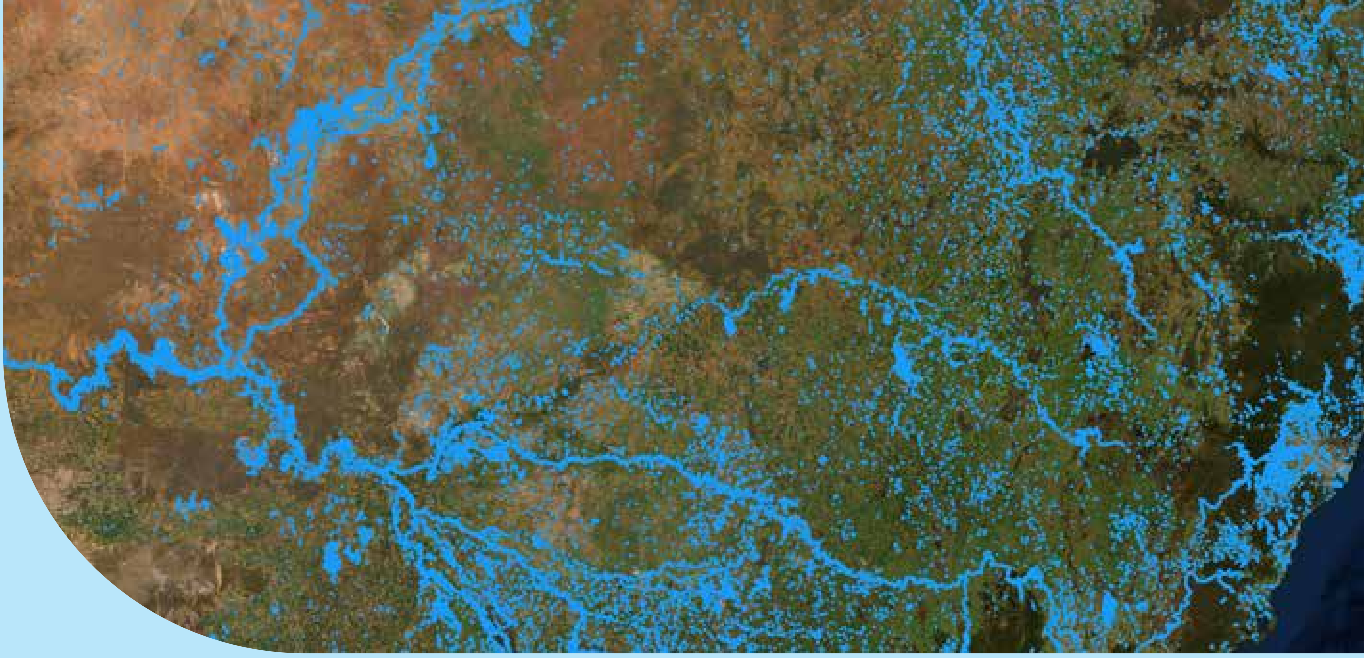


Figure ES1: A summary of the current strategies and plans in the space and spatial industries in Australia

We are seeking your feedback on the issues highlighted in this Executive Summary and the more detailed Consultation Paper:

- Do these issues represent the right priorities for Australia?
- What issues are missing, understated or overstated?
- What are the must-have capabilities that Australia needs to integrate into the nation's space and spatial ecosystem to optimise growth and build national resilience over the next decade that are not yet part of any published and intended plans?

Mainstreaming integration of the space and spatial sectors has the potential to achieve direct, indirect and cumulative impact across almost all areas of Australia's society and economy.



Benefits of the Integration of Space and Spatial

Australia's space industry, although small, has well recognised world class expertise in certain areas from which we can build. By contrast, Australia's spatial community is much more dominant by world standards but still exhibits strong growth potential. Operating in tandem, these competitive advantages serve as a strong basis from which both industries can grow.

Space and spatial are making an increasingly critical contribution to digital transformation. Global spending on the digital transformation is expected to reach $2.3 trillion by 2023, a five year compound annual growth rate of 17.1% for the period 2019 - 2023. The space industry has been estimated to be worth US$350 billion in 2019 with potential to grow to over $US1.1 trillion by 2040. The Australian space sector was estimated to be around $3.9 billion in size in 2019 and forecast to grow at 7.1% pa over the five years to 2024.

The total direct economic benefits from the use and application of earth observation from space data alone was found to be worth A$496 million to the Australian economy in 2015, and predicted to reach A$1,694 million by 2025. In 2016, geospatial services were conservatively estimated to generate US$400 billion per year globally. However, the total economic contribution was predicted to be several times higher, through approximately US$550 billion derived from consumer benefits; the creation of approximately 4 million direct and 8 million indirect jobs; and improvements of revenues and costs of sectors that contribute 75% of global GDP.

The global markets for big data from satellites alone is growing rapidly (see Figure 2).

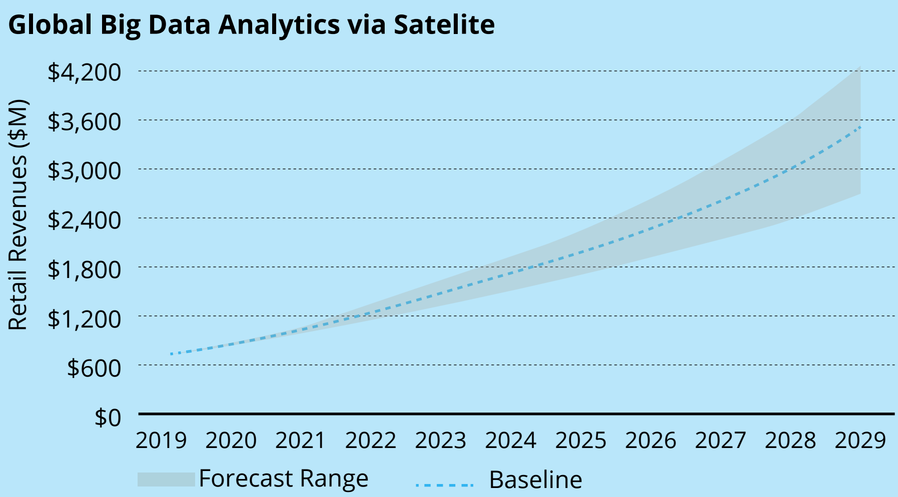


Figure ES2: Forecast Global Revenues for Spatial Data Analytics, 2020 (Source: NSR 2020)

Most industries require spatial data analytics as illustrated in Figure 3:

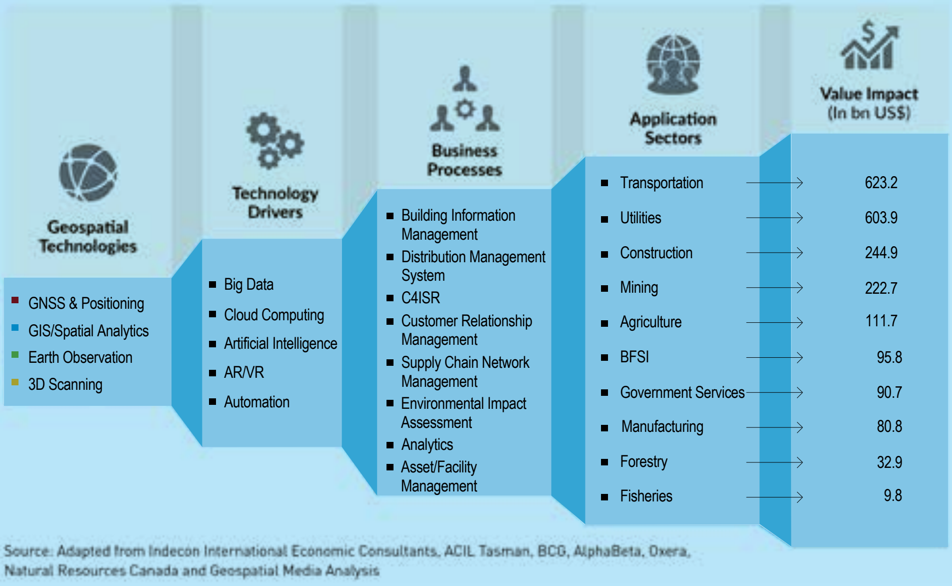


Figure ES3: Value Impact from Geospatial Technologies (Source: GeoBuiz 2018)

A coordinated, strategic approach to integration of Australia's space and spatial sectors could:

1. Increase productivity in key Australian sectors including agriculture (food, fibre and carbon), mining, transport, construction and energy through improved coordination between the end users and technology/data providers developing solution-based products and services.
2. Support the delivery of public good services including defence, national security (and in particular cyber security), disaster response, emergency management, environmental monitoring, urban planning, sustainable cities and digital twins to name a few.
3. Grow the domestic space and spatial industries, achieving an internationally competitive advantage in high value-add areas including:
    a. advanced instrumentation;
    b. advanced geospatial analytics;
    c. location intelligence services; and
    d. telecommunications.
4. Accelerate the maturation of Australia's space and spatial industries, by leveraging the successes of the Australian Space Agency (ASA), SmartSat CRC, Frontier SI, Digital Earth Australia (DEA) and the National Positioning Infrastructure (NPIC) of Geoscience Australia (GA), and CSIRO, amongst other programs.
5. Better align academic programs with industry needs, including by producing industry-ready graduates who meet the skills demanded by this industry growth.
6. Increase Australian participation in the global space and spatial industries.
7. Increase the commercialisation and utilisation of research in the space-spatial sectors.
8. Increase surety of access for Australia's vital information supply chains.
9. Establish the nexus of an enduring space-spatial integration in Australia.
10. Address the challenges and opportunities presented by open data, open technology and the introduction of modern telecommunications (including fibre and 5G).
11. Reduce duplication and increase efficiency in the delivery of state and government geospatial services.

Focus Areas Driving National Benefit

There are already many applications dependent on the contribution of space and spatial services. The key premise of this consultation paper, and the intended space-spatial industries growth RoadMap that will follow, is that much more can be done to build and accelerate Australia's capabilities, and that such action will lead to improved national outcomes and sustainable economic growth.

In the following summary, issues are grouped under the three broad areas where space and spatial technologies and services can benefit Australia:

1. National Security
2. Economy Development
3. Societal/Environmental.

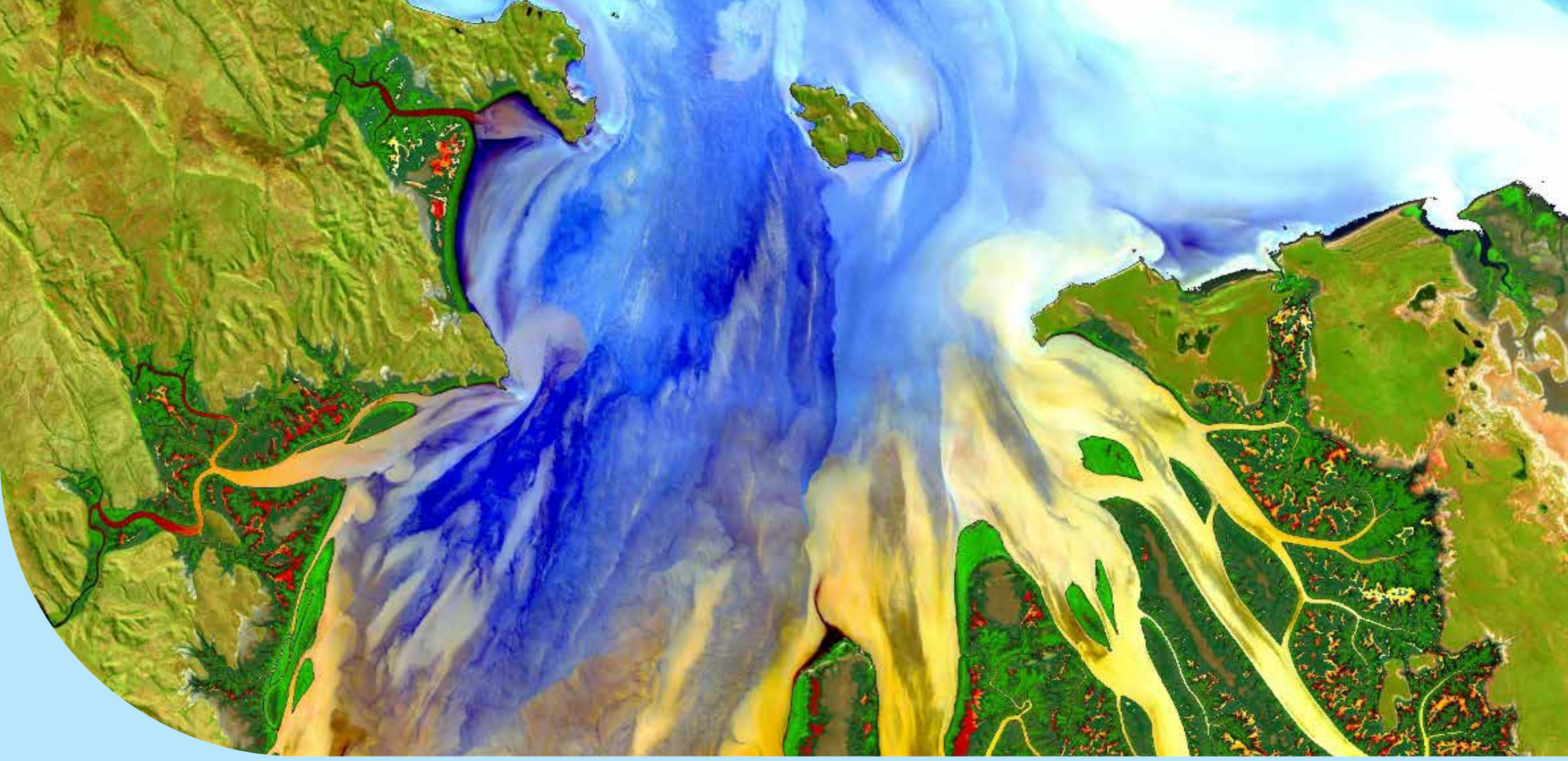
National Security

Establishing Critical National Space and Spatial Systems

Australia has a small space industry and relies heavily on the goodwill and cooperation of the world's spacefaring nations for access to vital space-based assets, products and services. *For Australia to take its place as a modern space nation capable of managing its own space needs, rapid and very substantial growth in our space industry is required.* What are the must-have capabilities that Australia will need to integrate into the nation's space and spatial ecosystem to optimise growth and build national resilience over the next decade that are not yet part of any published and intended plans? What additional steps need to be taken to ensure assured access to the full range of space and spatial related capabilities needed by this nation?

Australia's capacity to design and manufacture critical elements of space systems is increasing but from a much lower base than many countries with equivalent economies. Key issues for growth include the level of desired sovereign capability and the balance of sourcing from domestic markets and international markets, the right size for Australia's space manufacturing and testing capability and answering the question of how to sustain this capability in a globally competitive and often distorted market. Other countries use offsets to 'protect' national capabilities, but Australia moved away from that policy some time ago. What mechanisms can be brought to bear to ensure Australian manufacturers can compete in international markets? Should a level of Australian content be mandated? Which areas of the space supply chain should not be developed in Australia but should still be sourced from overseas? What underlying capabilities will deliver the most sustainable and enduring space and spatial industries?

The ability to connect space services and spatial information products with end-users is vital to the growth of the Australian space and spatial sectors. Without sufficient spectrum and the capacity to downlink large amounts of data, many of the emerging growth areas in the space and spatial domain will be constrained. The challenges of accommodating more satellite systems within existing spectrum allocations as well as finding spectrum for the increasing amounts of data to be downlinked is driving significant development activity. Australia has world class capability in ground infrastructure and has opportunities as a location for ground networks for high volume data downlinks. There are a number of activities that Australia could undertake. They include Australia playing an active role in international fora to preserve key spectrum for space and spatial activities including in higher spectrum bands and for optical links. An information campaign could raise awareness across all government agencies of the critical strategic importance of satellite spectrum for the space and spatial industry and how erosion of satellite spectrum will reduce the availability of space and spatial services; exploring all opportunities for Australia to provide high speed data downlink sites for space and spatial data particularly for high data downlinks from Asian, European and American satellites. The Australian development of waveforms and spectrum sharing techniques could be encouraged and supported as well as on-board processing techniques to optimise the downlinking of essential data. Focusing research on emerging technologies such as Australian development of optical communications capabilities and infrastructure as well as exploration of higher Radio Frequency bands to reduce interference and increase capacity of satellite communications could create global market opportunities for Australian industry.



Finally, Australia's growing security dependence on space and the increasing vulnerability of national security space capabilities has created the need to rethink the scope and scale of Defence space capabilities. The 2020 Defence Strategic Update states the intent for sovereign space capabilities in both satellite communication and satellite imaging capabilities and the recognition of space as a military operating domain. This increased focus on space capabilities, with a corresponding increase in future funding, for our national security creates new opportunities for Australian industry to develop and deliver space-based capabilities to government, both directly and in partnership with international allies.

Economic Development

Accelerating Growth of Australian Space and Spatial Businesses

The COVID-19 global pandemic has brought into sharp relief the importance of high growth industries in helping rebuild the national economy, stimulating creation of new jobs and supporting business development. Space and spatial are critical sunrise industries in the digital world that offer great potential for Australia.

From a nascent ecosystem just three years ago Australia now has over 60 space start-ups. In order to grow into a large and sustainable ecosystem four key questions will need to be answered: How can we grow the funnel of the start-ups (per million people) in Australia? How can we increase the start-up success rate? How can we maximise the economic value-add to Australia? What impediments do we need to identify and address? Consideration should be given to development of a formal national plan of action for space and spatial start-ups.

Whilst Australia has hundreds of SMEs in both the space and spatial industries, very few have grown to become billion-dollar multi-nationals. It is important that we understand the barriers to this growth and consider appropriate corporate incentives without resorting to inefficient subsidies. How might Australia respond to this challenge?

Governments, and particularly Defence Departments, are playing a key role around the world in fostering vibrant and large national space and spatial sectors. A coordinated national approach for defence and the civilian sectors would see investments made in companies as part of a strategic design that seeks to optimise an enduring space and spatial ecosystem with a vibrant private sector at its core.

Governments across Australia are increasingly recognising the value of a whole-of-government, whole-of-jurisdictional, enterprise-wide approach to procurement. Given the need to get this right across all of Australia's tiers of government and across the defence and civilian divide, advice is sought on how best to develop a national approach to procurement of space and spatial services and capabilities that operates in the national interest.

Enhanced decision-making through Critical Spatial Data and Systems

Australia possesses many significant spatial data stores within government agencies and research organisations (eg GA's DEA, the National Computational Infrastructure, jurisdictional agency systems, and NCRIS facilities to name a few) which have been created fit for a specific purpose. These have been or are in the process of being migrated to cloud environments, mostly owned and operated by multi-national private sector providers, some of which are located offshore. It is timely to examine the risks to these national spatial data stores, their infrastructure, systems and analytics, including the physical location of the systems on-shore and off-shore. Of the potential to create and manage datastores on-board in space, which elements are considered high priority? How big an impediment to growth is the cost of data?

Consideration could be given to redefining and expanding the existing list of Foundation Spatial Data Framework (FSDF) themes and the systems that support their creation and use. These data need to be optimized for the three and four dimensional needs of a future sensor and information world powered by artificial intelligence. Another key task could be to map the needs of sectors and organisations that service Australia's critical infrastructure and systems of national significance (as defined by the Department of Home Affairs) against what the FSDF can provide in its current and in future forms.

Spatial digital twins are an advanced spatially accurate digital representation of the real world and are emerging as a powerful tool to help people improve their understanding of our physical environment and make better-informed decisions. The use of digital twins should lead to improved outcomes and benefits, build predictive capability, and offer just-in-time analytics and products. Digital twins vastly improve the value of data through aggregation and shared access, leading to better decision making. Spatial digital twins are an essential component of the overall digital transformation agenda across government and industry and are advancing rapidly. It is essential that Australia collaborate with the local and global initiatives to develop the use of this technology. These organisations include Open Geospatial Consortium (OGC), International Standards Organisation (ISO), the US based Digital Twin Consortium and The Smart Cities Council. The Australia and New Zealand chapter of The Smart Cities Council is stewarding the development of a Digital Twin Strategy for Australia and New Zealand. Their goal is to create the conditions for a thriving digital twin marketplace in the region. OGC is working closely with ISO on standards development with active working groups. The Digital Twin Consortium even though still in its formational stage, has, given its membership, the potential to have a powerful influence on the way forward.

Trusted, Precise Global Navigation Satellite Systems (GNSS)

To capitalise on the rapidly growing demands for Position, Navigation and Timing (PNT) systems which are accessible, accurate and available for all Australian sectors, a major challenge will be developing an indigenous capability that provides assured access to PNT across the nation by improving its resilience, robustness, precision and trustworthiness over the long-term. Australia is ready to update its current GNSS Strategic Plan for Promoting Enhanced PNT Capabilities. The update could consider setting out strategic and industry-aligned incentive mechanisms to facilitate development of high-tech GNSS-related products, services and workforce by local companies and organisations, and making these new PNT capabilities available across the nation. In Australia, leadership of this strategy development will require disciplined coordination across government, Defence, industry and education.

Societal/Environmental Wellbeing

Optimising the Workforce: STEM and Diversity

There is a significant opportunity for the space and spatial industries to work more closely with Australia's strong educational and vocational training systems. The need to attract, train and retain people with advanced Science, Technology, Engineering and Mathematics (STEM) skills to support long-term and sustainable growth across the sector has been identified by many reviews. A key task will be to review and extend the current analysis of the skills gap being undertaken by the Australian Space Agency and SmartSat CRC to ensure that it identifies both space and spatial skills that are not adequately meeting these industry's current and future needs.

For the space and spatial sectors to be able to sustainably grow, innovate and deliver leading and useful research in the coming years, a diverse and inclusive workforce will be needed. It is proposed that the Space, Surveying and Spatial Diversity Leadership Network (SSS-DLN) continue to leverage, amplify and expand existing successful D&I initiatives and actions plans at sector level and that peak bodies take a leadership role in advancing efforts to improve the diversity of our sector. A key outcome should be to benchmark, monitor and report on the state of D&I in the sector on a regular basis. Best practice outcomes from this network can be applied more broadly across the space and spatial sectors.

At the Commonwealth Government level, the Thodey report into the Australian Public Service pointed to the need for urgent improvements so that Australia can leverage the full potential of digital systems and data analytics facilitated by suitably skilled people. This observation is particularly prescient for space and spatial. One option is the development and implementation of a space and spatial awareness program for the public services operating at all layers of government. This program could be aimed at enhanced understanding of policy, technological and regulatory implications of space and spatial systems and services across Australia's society and economy as a formal part of the implementation of the Thodey review. Case studies of existing best practice would inform the awareness program.

Essential Systems for Climate Resilience

Increasing bushfires, floods and other natural and human-induced disasters are sharpening the focus on the responsibilities of Federal and State Governments to improve coordination and response to larger scale natural disasters. This has come under close scrutiny in recent years. The 2019-20 fire season has brought this issue to the fore. Many inquiries, especially the Royal Commission into National Natural Disaster Arrangements, have examined these issues from a national and regional perspective. What more can be done, that has not already been identified, to deploy space and spatial capabilities to greater effect in the effort to deal with natural disasters?

The current paradigm for earth observation systems supporting broader economic and environmental objectives involves data collection to monitor ecological/environment systems with data analysis informing decision makers on actions that may deliver certain outcomes. Moving to a management-focused approach requires access to a wider range of data with better data governance, coupled with advanced analytics/machine learning techniques and greater use of spatial digital twins. The key is to develop phenomena-specific systems purposely designed to respond to societal, environmental and economic pressures to produce the highly valuable information products that end users need, rather than just creating more low value data.

Ongoing and cross-agency collaboration across industry and governments is key to improving spatial information capability and datasets to inform decision-making across the environment portfolios of governments. In addition, next generation data governance and clearly defining accountability for data collection, storage, management and integration across agencies could provide a systematic approach to ensure high quality data capture to empower analytic methods including artificial intelligence and machine learning. It is important that end users of spatial technology are regularly informed of megatrends in spatial technologies so current information and understanding can be applied to their land and environmental monitoring, management and decision-making processes and diminish the barriers to adopting new technologies for sustainable environment management.

Executive Summary – Key Questions for Readers

We are seeking your feedback on the Focus Areas highlighted in this Executive Summary and Key Issues outlined in Section 5 of the detailed Consultation Paper:

1. **Are the three Focus Areas, National Security, Economic Growth and Societal/Environment Benefit, the right lens to view opportunities for Space and Spatial sectors?**
2. **Do the key issues outlined in Section 5 represent the right priorities for Australia?**
3. **What issues are missing, understated or overstated?**

Furthermore, your responses to the following questions or other views raised in this consultation paper would be appreciated.

4. What are the must-have capabilities that Australia needs to integrate into the nation's space and spatial ecosystem to optimise growth and build national resilience over the next decade that are not yet part of any published and intended plans?
5. What additional steps need to be taken to ensure assured access to the full range of space and spatial related capabilities needed by this nation?
6. What mechanisms can be brought to bear to ensure Australian manufacturers can compete in international markets?
7. Should a level of Australian content in Critical National Space and Spatial Systems be mandated?
8. Which areas of the space supply chain should not be developed in Australia but should still be sourced from overseas?
9. What underlying capabilities will deliver the most sustainable and enduring space and spatial industries?
10. How can we grow the funnel of the start-ups in Australia in order to drive innovation?
11. How can we increase the start-up success rate?
12. How can we maximise the economic value-add to Australia from the Space and Spatial sectors?
13. What impediments do we need to identify and address?
14. Looking at the potential to create and manage datastores in space, which elements are considered high priority?
15. How big an impediment to economic growth is the cost of data?
16. What more can be done, that has not already been identified, to deploy space and spatial capabilities to greater effect in the effort to deal with natural disasters?

We want your opinion - please visit https://2030spaceandspatial.com/feedback/.

1. SPACE AND SPATIAL: A NEW ERA FOR AUSTRALIA

1.1. Purpose

The purpose of this consultation paper is to specifically seek the advice of key stakeholders in the space and spatial industry sectors regarding actions that can be taken over the coming decade to accelerate the growth of the space and spatial industries.

The feedback from this consultation process will be used to develop the 2030 Space and Spatial Industries Growth RoadMap which will be completed later in 2021. The RoadMap will identify the most pressing issues for action at a national level that will contribute to sustainable growth in the two sectors and also deliver national benefits to Australia's society, its economy and national security through better and more widespread access to space and spatial systems and services.

1.2. Introduction

There is a great deal of activity currently underway that will undoubtedly contribute to the growth of the space and spatial industries. However, this activity is fragmented and, by world standards, falls well short of positioning Australia as a fully-fledged space-faring nation. Rapid growth is essential.

This paper is intended to seek to identify the new and additional actions and investments that can build on this activity through comprehensive consultation with key stakeholders, including stakeholders within the space and industries and those who are users, beneficiaries or contributors to the space and spatial industries. The outcomes of this consultation will 'stand on the shoulders' of the work already announced and underway and will help form a key part of the 2030 RoadMap itself. Actions that will be included in the RoadMap will be those that have a champion together with identified sources of resourcing.

This paper sets out an initial set of issues assembled by the Steering Committee for the 2030 Space and Spatial Growth RoadMap . Australia's space science community, although small, has well recognised world class expertise in certain areas from which we can build. By contrast Australia's spatial community reputation and track record is much more dominant by world standards and operating in tandem with the space community can serve as strong basis on which both can grow.

These issues set out in this paper are not exhaustive, and it is expected that consultation will lead to the identification of new issues and actions and changes to those already included herein.

Two additional pieces of companion work are already underway. The first is the development of a 'Space and Spatial Ecosystem Map'. Currently a work-in-progress, this map sets out the major elements of the system that the 2030 Steering Committee considers will comprise the optimal ecosystem by 2030. It forms a view about elements that need to be established or further developed, which ones should have a strong Australian base and which ones can be sourced by overseas providers. The 2030 Steering Committee is oversighting the development of this map.

The second piece of work is an analysis of the risks faced by all areas of Australia's society, economy and critical infrastructure through their reliance and dependence on space assets and systems, including satellite telecommunications, PNT from GNSS, and earth observation by satellite. This work will include consideration of the vital role played by spatial information and spatial infrastructure. This work is taking a supply chain view of these risks and dependencies using a formal approach based on ISO 31000:2018 Risk Management Standard. It is being conducted under the auspices of the Department of Home Affairs with the secretariat provided by the Australian Space Agency. The outcomes of this work will be made available to the 2030 Steering Committee for inclusion, where relevant, in the 2030 RoadMap.

1.3. The Power of Space and Spatial

Spatial data and space services are ubiquitous to our modern and digitally connected lives. The power of where, enabled through space and spatial, is the record of what we do, when and where we do it, and in what environment—because everything happens somewhere. Nations can use location to connect data and workflows for government, industry, researchers and the community to make decisions that improve the economic, environmental and social outcomes for Australia.

> ***"By taking location information and applying geospatial capabilities to analyse and visualise the content, government policy and service delivery can become more relevant, targeted and efficient, both during emergencies and in business as usual." (Geoscience Australia)***

Over the past 18 months Australia has been subjected to a series of disasters that have had wide ranging impacts across the nation, including the Queensland floods, the national drought, the national bushfire crisis and currently COVID-19. A critical aspect in supporting response and recovery has been understanding the geographic extent of these disasters, the nature of the community and businesses affected, and the social, physical and environmental infrastructure and assets impacted. Space technologies play a vital role in collecting data and information (through PNT and through remote sensing by earth observation), disseminating existing and new data and information (through tele-communications).

Location provides a unifying factor for much of the data that is available, as well as a powerful tool to understand and communicate the data, information and stories the data contains. By taking location information and applying geospatial capabilities to analyse and visualise the content, government policy and service delivery can become more relevant, targeted and efficient, both during emergencies and in business as usual, and industry can function and grow.

Various studies into the space and spatial sector highlight the significant and growing contribution to local, national, regional and global economies, now and into the future (Table 1).

Report	Geospatial capability	Country/region	Value (Million; Billion; Trillion)
ACIL Allen, 2015	Earth observations (EO from space)	Australia	To the Australian economy: • A$496M in 2015 • A$1,694M by 2025
AlphaBeta, 2016	GIS/Spatial Analytics (location intelligence)	World-wide	In 2016: • US$400B globally in (direct benefits only) • US$550B globally (including consumer derived benefits, via productivity gains and efficiencies) • Creation of 4 million direct and 8 million jobs
Australian Space Agency	Australian space sector		Estimated to be $3.9 billion in 2019 with around 10,000 jobs.
Frontier SI, 2019	Geospatial infrastructure (accurate positioning technology)	Australia, New Zealand	To the Australian and New Zealand economies: • improved positioning technology forecast to deliver $A7.6B over 30 years (based on 27 demonstrator projects across 10 sectors)
Geospatial Industry Outlook and Readiness Index (2019 Edition)	Geospatial services (location intelligence)	World-wide	Location intelligence market value: • $US9B in 2014 • $US22B in 2018
IBISWorld	Australian Space sector		Expected to grow at 7.1% pa from 2019 – 2024.
Morgan Stanley	Space industry	World-wide	In 2019 the Global Space industry was estimated to be worth US$350 billion with forecast growth to over US$1.1 trillion by 2040.
Nous Group, 2019	Earth observations (EO from space and marine observations)	Asia Pacific (21 economies)	To the regional economy: • $US372B in 2019 • $US1.35T by 2030 (business as usual scenario) • $US1.48T by 2030 (through enhanced cooperation)
UK Cabinet Office economic study, 2018	GIS/Spatial Analytics (location intelligence)	UK	To the UK economy: • £4 billion per year to the UK's economy

Table 1: Summary of selected studies into the value of space and spatial sectors (refer to footnotes for full citations).

The space industry has been estimated to be worth US$350 billion in 2019 with potential to grow to over $US1.1 trillion by 2040. The Australian space sector is estimated to be around $3.9 billion in size in 2019 and forecast to grow at 7.1% pa over the five years to 2024.

The total direct economic benefits from the use and application of earth observation from space data alone was found to be worth A$496 million to the Australian economy in 2015 , and predicted to reach A$1,694 million by 2025. In 2016, geospatial services were conservatively estimated to generate US$400 billion per year globally . However, the total economic contribution was predicted to be several times higher, through approximately US$550 billion derived from consumer benefits; the creation of approximately 4 million direct and 8 million indirect jobs; and improvements of revenues and costs of sectors that contribute 75% of global GDP.

According to analysis from the leading satellite service market research company NSR, the emerging market for data analytics services on earth observation and satellite communication enabled sensor data is likely to grow rapidly as shown in Figure 1. NSR make the following observation:

> ***While the mainstay of the satellite "data" industry focused primarily on data feeds, the value of insights derived from pixels and bits has gained more importance over the years. Cloud computing has eased barriers to entry in this market, and customer adoption has increased. Leveraging services from cloud service providers and other major tech platforms for automation and machine learning tools combined with geospatial know-how has led to the growth of a highly fragmented downstream analytics market.***

By comparison, a number of organisation work to capture global impact and value from the space and spatial markets. Two widely referenced works are shown in Figure 2 and Figure 3.

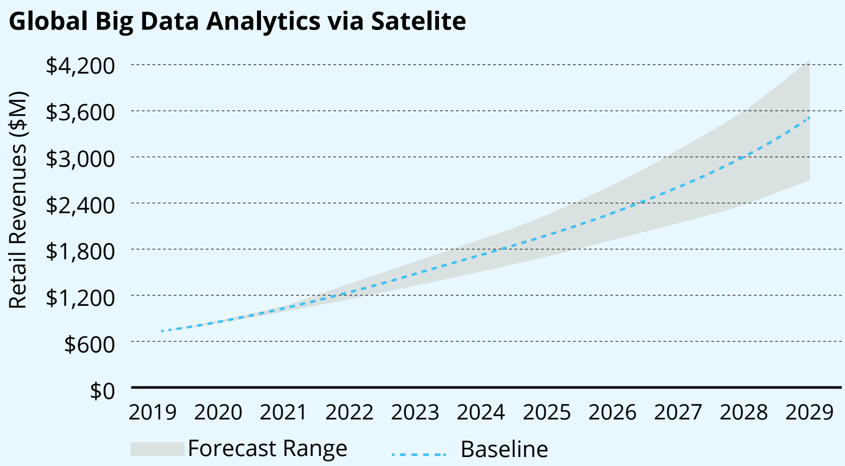


Figure 1: Forecast Global Revenues for Space Data Analytics (Source: NSR 2020)

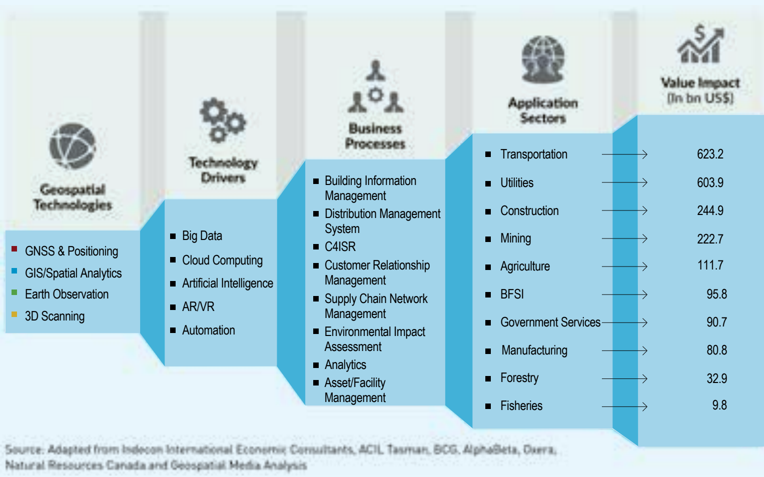


Figure 2: Value Impact from Geospatial Technologies (Source: GeoBuiz 2018)

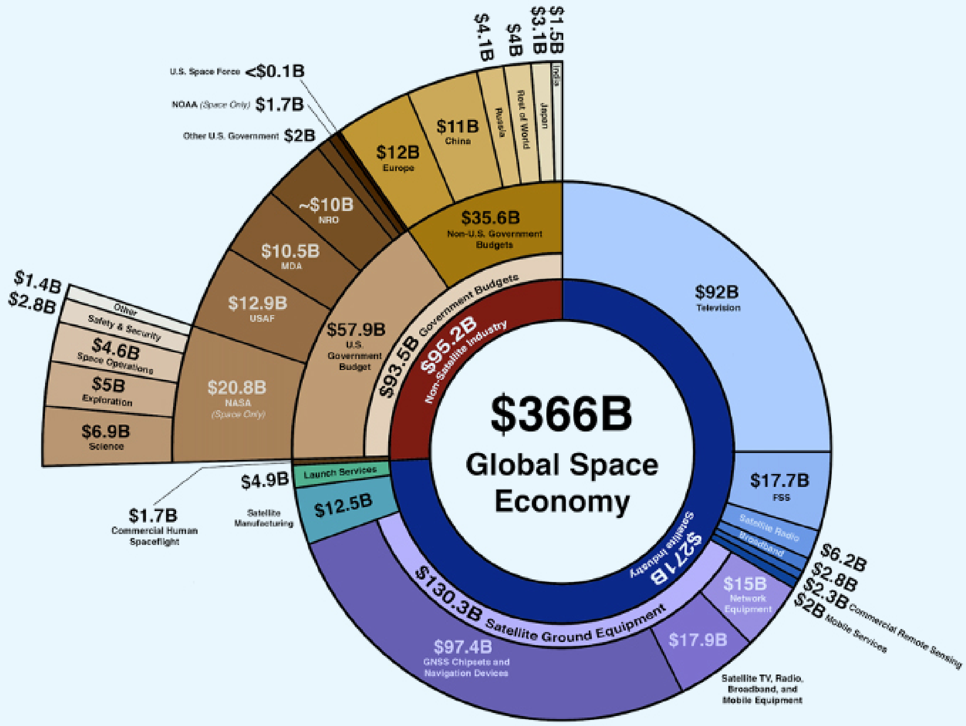


Figure 3: Scale of Global Space Economy (Source: Bryce 2019 Global Space Economy at a Glance)

According to a 2018 UK Cabinet Office economic analysis, more accessible and better-quality location data in infrastructure and construction could be worth over £4 billion per year to the UK's economy . In 2019, the value of Earth and Marine Observations to the 21 economies of the Asia Pacific Economic Cooperation was conservatively estimated to be US$372 billion. Under a business-as-usual model, the total estimated value of Earth observations to the Asia-Pacific is expected to reach US$1.35 trillion by 2030, or through enhanced cooperation, to exceed US$1.48 trillion . And, the Location Intelligence industry market size has grown from nearly US$ 9 billion in 2014 to around US $22 billion in 2018 . The economic drivers for space and spatial are clear.

The power of the integration of space and spatial for social, environmental and economic benefits are numerous and can provide benefits across the supply chain. Think about your next cup of coffee – go all the way back to where it begins. Imagine the farm of the future … where livestock are fitted with location and health sensors that detect not just where they are but how they are coping during times of drought – all enabled through a suite of low-cost, internet connected IoT sensors. Consider that farmers are using fenceless technologies and advanced AI to develop and implement an automated sustainable grazing plan for the property that leverages where the water and feed are today and environmental forecasts to predict where it will be in the future. The milk from the cattle is associated with a sustainable farming certification through an automated farm practice monitoring and certification service based on long-term satellite data. The milk is transported from the farm to the processing factory to the café using a fleet of autonomous trucks whose routes are determined through a network analysis applied to data from a rich network of sensors from other vehicles, sensors in roads, and all enabled by highly accurate positioning, earth observations and spatial data.

From autonomous vehicles on mine sites to spatially enabled canes assisting the visually impaired to navigate smart cities, the case for the power of space and spatial integration is clear. Nations can use location to connect data and supply chains in a way that improves the safety, health, economy, and sustainability of their communities—ultimately making them more liveable and resulting in benefits to society, the economy, and the environment.

1.4. Drivers for 2030 RoadMap

The following principal drivers have been identified as having a major impact on the development of the 2030 space and spatial growth RoadMap:

COVID-19 Recovery: As the nation prepares for the recovery phase of its battle with COVID-19 the timing of the road-mapping represents an ideal opportunity to develop a deep and well considered contribution to the national planning, especially its ability to engender confidence and hope for a challenged private sector.

National Space Growth Objectives: The Australian Government is committed to achieving two key objectives for the space industry by 2030: 1) 20,000 additional jobs and, 2) triple the size of the space economy to a $12 billion contribution to GDP. The current size of the Australian space industry is around $3.9 billion. The Roadmap will specifically address these key national goals.

The Australian Space Agency (ASA): Established in June 2018, ensures Australia has a peak agency for space responsible for achieving the economic growth targets. The ASA developed the Australian Civil Space Strategy to advance this vision and provide a long-term plan for the space sector.

The Spatial Industry: Has critical capabilities that leverages space technologies, both for earth observation and positioning, providing high value information products and services to almost every part of the Australian economy. This critical capability is set for significant growth over the next decade, delivering whole new application capabilities and service areas.

Value of the spatial industry: Australia's spatial industry currently contributes at least $12 billion to GDP. The Spatial Industry is growing at around 10% globally and is set to make a major contribution to the achievement of the ASA's space industry growth objectives.

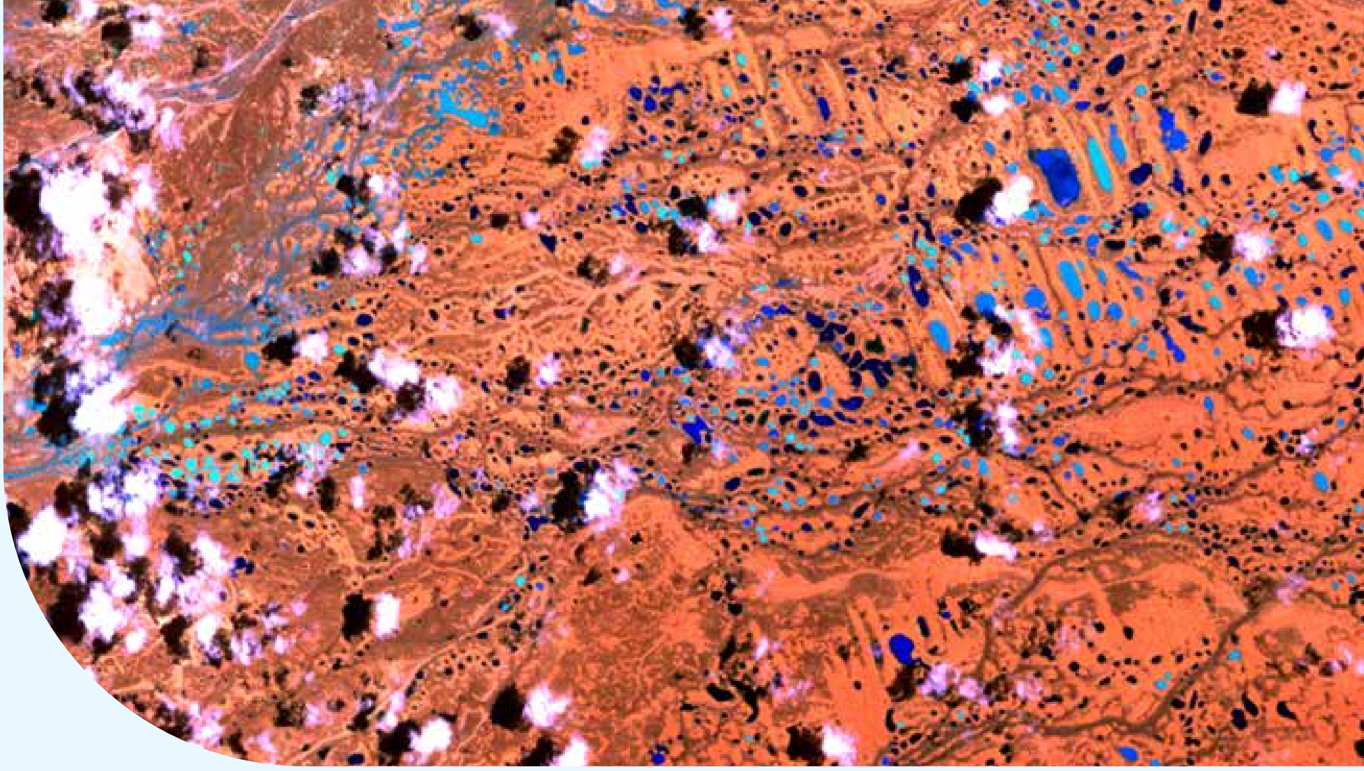
The recently created SmartSatCRC: Is set to invest $245 million in space technologies over the next seven years through its 100 plus partnering organisations which include 70 companies, 20 universities and the CSIRO, and the Department of Defence through DST. The SmartSatCRC's strategic plan will benefit greatly if it can be nested in the context of the proposed 2030 RoadMap.

ANZLIC – the peak spatial data policy Council for Government in Australia and New Zealand: Faces a threshold point on harnessing the spatial digital twin as the next step-change in spatial data infrastructure (SDI) thinking and practice. In March 2020, ANZLIC published its Strategic Plan 2020-24 and is poised to participate in the 2030 RoadMap.

The Department of Defence: The July publication of 2020 Defence Strategic Update and Force Structure Plan commits Defence to $7B of space investment and foreshadows up to $13.4B in the longer term. It is perfect timing now to marry this with the road-mapping of the civilian sector and recognise a key objective of the Department of Defence which is to improve Australia's defence resilience and develop a competitive and sustainable Defence industrial base.

Geoscience Australia (GA): Is leading the development of high-accuracy Positioning, Navigation and Timing (PNT) infrastructure for Australia with a $225M investment from the Australian Government in the 2018 budget. GA is also pioneering the use of satellite imagery data through the DEA capability, with an initial investment of $37m and a further ongoing investment of approximately $12M per year, providing a powerful capability for harnessing the enormous data stores of satellite imager

CSIRO: Is growing its capability in space, building on its long history in spacecraft tracking and earth observation. The Space Technology Future Science Platform funds technology development across all of CSIRO's business areas, including advanced manufacturing, agriculture and biosciences. CSIRO has also purchased 10% of time on the NovaSAR earth observation satellite, which will be available to Australian researchers as a national facility.



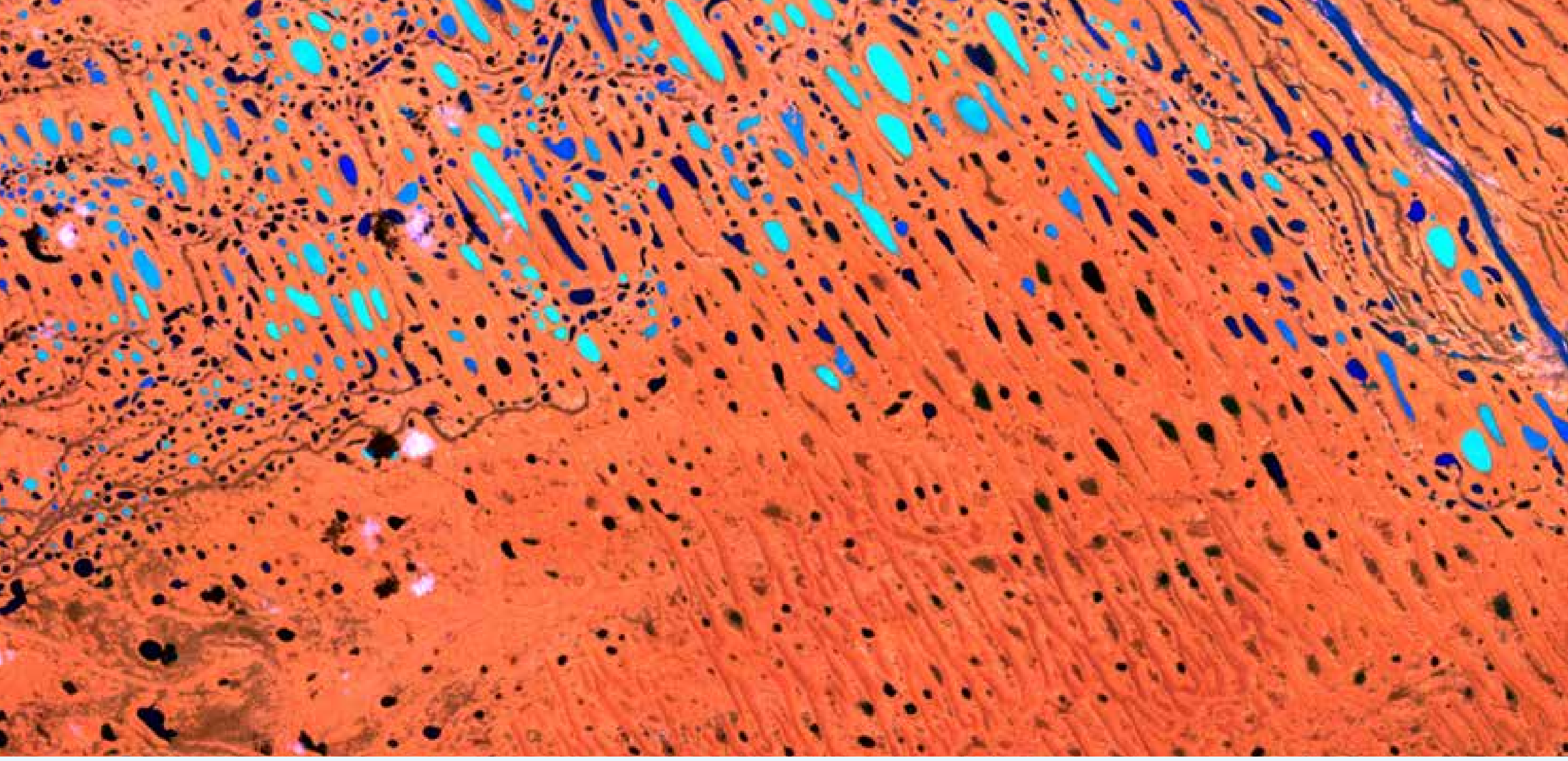
Earth Observation Australia (EOA) Inc: Is Australia's peak body representing industry, all levels of government, research and education, that collect and transform earth observation data into essential products and services for government, defence and industry. EOA conducted an extensive national consultation in 2015-16 and developed the "Australian Earth Observation Community Plan 2026" with five priority actions and projects to deliver high-quality earth observation information, infrastructure, and services that are used widely by government, industry, research and the community in Australia and internationally. Implementation of this plan continues to assist with 2026 Spatial Industry Transformation and Growth Agenda and the Australian Space Agency's EO Priority. EOA's focus is on integrating effectively across research – government – and industry, which is essential to make the space-spatial linkage work.

Peak Industry Bodies: Australia's peak space industry body, the Space Industry Association of Australia (SIAA), and peak spatial industry body, the Spatial Industries Business Association and Geospatial Information & Technology Association ANZ (collectively known as SIBA|GITA) have a nascent collaboration at present. The 2030 RoadMap will provide the mechanism for formalising a new era of close cooperation between the two industry peak bodies.

Open Geospatial Consortium in Australia. Many members of OGC come from Australia. Multiple OGC international meetings have been hosted by Australia. Australian members have led or contributed to the establishment of several OGC Standards. The Australia and New Zealand Forum provides a community for discussing issues particular to the region.

Sovereignty: One of the fundamental motivations for the reinvigoration of Australia's space policy and space industry has been the recognition that Australia needs far more sovereign equity in and assured access to vital space assets and space-derived services. Achieving of this objective will be greatly aided by the RoadMap which will collectively steward harmonised policy, planning and investment for Australian partnership in and ownership of space assets and spatial data and services.

NASA: In September the Prime Minister announced a $150M contribution to support Australian involvement in NASA's Moon and Mars shots (the Lunar Gateway and Project Artemis). This investment will support Australian businesses contribute to NASA's critical pipeline of work. Australia was also an early signatory of the NASA sponsored Artemis Accord which define a set of principles guiding the exploration of outer space. The Artemis Accords are based on the 1967 Outer Space Treaty but have been adapted to support safety of operations, reduce uncertainty and promote the sustainable and beneficial use of space . The Artemis Accords were signed by the Head of the Australian Space Agency at the virtual 71st International Astronautic Conference in October 2020.



Australia-UK Space Bridge: In September the Australian and the United Kingdom announced the new Australia – UK Space Bridge designed to enable the nation's space businesses better access to the global space sector. The Bridge will facilitate new trade and investment opportunities and the exchange of knowledge and ideas. The 2030 RoadMap will strengthen Australia's ability to leverage this and other international agreements which already exist or will come into being in the future.

2026 Spatial Industry Transformation and Growth Agenda: This Agenda and its complementary plan has been in operation for three years. It comprises over 30 key initiatives to grow the spatial industry built up from a comprehensive, nation-wide program of consultation. Industry-led by SIBA|GITA, the 2026 Agenda is governed by a Leadership Group that equally comprises spatial industry leaders and leaders from key end-user industries. The 2026 Agenda represents a well-established program with substantial momentum that will be readily rolled into the 2030 RoadMap.

Surveying & Spatial Sciences Institute (SSSI): Is the national peak body catering for the 2200 professionals who make up the spatial information industry. SSSI gives a voice to the members of the spatial science community in both the national and international arena. SSSI through its Remote Sensing Commission is heavily involved in utilising earth observation data and has an active community of practice within the professionals. SSSI also plays a significant role in the area of capacity building of spatial professionals through its body of knowledge and internationally recognised certification programs. The space community could leverage the experience of SSSI by developing a space commission within SSSI to cater to the need of space professional development and capacity building. SSSI has significant international relationships with ASEAN, Pacific Island and European and North American Professional Bodies which could be utilised for capacity building cum international dialogue by the space sector.

Interconnected national systems for greater resilience: The Government has increased Australia's national focus on protecting critical infrastructure and systems of national significance. This aims to identify and understand the vulnerabilities of our society arising from interconnected and interdependent critical infrastructure, much of which is owned by commercial organisations whose business models rely on the interconnected global economy. The assessment of critical risk areas for space and spatial systems and services and the opportunities for a more sovereign national space and spatial sector will be addressed through this Plan. This work is being oversighted by the Department of Home Affairs through the Space Cross-sectoral Interest Group which is part of the Trusted Information Sharing Network, with secretariat support provided by the Australian Space Agency.

Capacity Building – STEM: The nation is facing a growing shortage of STEM skilled workers. A vital requirement is an expansion of the capacity of the education sector across all the space and spatial disciplines to fulfil the skillset needs for under-graduate, post-graduate, to vocational and micro-credentialing.

Academies National Science Initiatives: The two science academies, the Australian Academy of Science and the Australian Academy of Technology and Engineering, are currently developing a national space science strategy that has a number of elements including; capacity development, communications technologies, demographics, education and training, planetary sciences, remote sensing and PNT, space health and life sciences, space situational awareness &space weather, space technology, and the heliosphere. The 2030 RoadMap will augment these planning efforts.

Emergency Response to Natural Hazards: An effect of climate change is increased frequency and severity of natural hazards including but not limited to bushfire, floods, cyclones and drought. The need to predict, prepare, respond and recover from these natural hazards will be a critical element of national resilience. Space and spatial technologies and capabilities are poised to play a central role in equipping the nation to address this challenge.

Low-Carbon Economy: The global effort to counter climate change requires governments and societies to transition to low-carbon economies. This will force change through many sectors including energy, transport, agriculture, mining and others. The low-carbon economy is going to become increasingly important as the fight against climate change intensifies. Many sectors have been transitioning to systems that have less intensive carbon emissions. Spatial information and technologies provide a pivotal role in analysing trends in business and society such as commute patterns by transport type and energy consumption behaviour. Advanced spatial technologies such as machine learning and artificial intelligence, can unlock great potential in constructing strategies for reducing carbon emissions in Australia.

Circular Economy: A circular economy is based on the principles of designing out waste and pollution, keeping products and materials in use, and regenerating natural systems. Spatial information can be an enabler of circular economy activity in cities in the same way it is used for land use planning as waste is produced at a location and will travel to a location for processing and reuse as part of a circular economy. Spatial information can provide visibility on the flow of materials, products and society across the city. Examples include patterns of optimal mobility routes, waste generation, congestion and energy demand. The ability to spatially visualise, map and monitor waste generation from businesses and households, waste and recycling centres by location, layered with valuable insights from other sources (i.e. census data, traffic routes and material information data) allows experts to assess the health of the circular economy as it functions (in real time) along with risks in recycling capacity and plan targeted strategies to address the risks.

2. THE SPACE AND SPATIAL ECOSYSTEM

2.1. Space explained

Space is almost universally considered to be the region surrounding the earth and beyond where atmospheric friction has little or no impact on the motion of objects. The Karman Line, an imaginary boundary located 100km above the mean sea level of earth, is commonly known as the beginning of space.

Orbital space is the region of most interest to this work and comprises a number of bands where satellites can be injected and are subject to the physical laws of orbital motion as first described by Kepler. The motion of satellites in orbital space are largely determined by the gravitational forces generated by the mass of the earth

Humans also exploit space through short duration sub-orbital missions, whereby the platform does not generate sufficient velocity to escape Earth gravity and enter orbit, and deep space missions where spacecraft enter deep space beyond earth orbit.

As an operating environment, space is challenging and risky. Engineered systems that function in space must contend with near zero vacuums, high energy radiation, extremes in temperature variations and be built to withstand the violence of launch, extreme accelerations, vibration, acoustic loads and atmospheric loads. Whilst reliability has vastly improved in the previous decades, for both spacecraft manufacturing and launch vehicle performance, there is still high risk of complete mission failure during launch and space operations. This drives up the cost of manufacture and makes launch expensive. Insurance and financing can also be challenging and drive the cost of delivery of a space system.

Finally, as a “global commons”, space attracts heavy regulatory attention through international bodies such as the UN and national regulators such as the Australian Space Agency and the Department of Infrastructure, Transport, Regional Development and Communications.

The space sector comprises organisations with specialist skills, facilities and infrastructure that support conceptualising, designing, building, deploying and operating space objects. There is a large, complex and interconnected value chain that enables and supports the space sector. Given the nature of required skills, many organisations that service the space sector, also operate in other sectors, most notably the aircraft industry.
The coupling of these two industries is so tight it is often referred to as the aerospace sector.

2.2. Spatial explained

Spatial science, and the industry it supports, is at its core about positioning and location. Traditionally it has been represented by cartography and surveying. Over the last century, photogrammetry, Geographic Information Systems (GIS), remote sensing through earth observation and PNT, through GNSS and RNSS, have come to characterise what is commonly known today as 'spatial'.

Spatial data gives the location of something, usually defined by coordinates, like the location of a road, or through the identification of area with a place name, together with some understanding of what is happening there (i.e. the characteristics of the object, event, or phenomena concerned, such as the size of an earthquake or the number of children living in a suburb), and often how it changes through time (e.g. the position of a moving vehicle or the spread of an infectious disease). Spatial data gives us a more complete picture of our ever-changing world so that we can better understand and manage it. Examples include; satellite positioning, earth observation and digital mapping of the features around us.

Spatial embraces both the collection of information related to position and location and its analysis to produce information products that include metric information about position. These information products span the production of simple analogue or digital maps to highly complex derivative products in 3D, time stamped to render them in 4D and value added with many other data sources to take them into the nth dimension. In fact with continuous streaming of data from sources like geostationary satellites, the data is real-time and persistent.

Spatial information products are now ubiquitously used by society; Google Maps, Bing and Open Street Map. Most industries use spatial technologies; agriculture to monitor crops and plan the transport logistics for harvest to market; mining for exploration and robotics in autonomous mining; banking and finance for GNSS atomic clock based timing for transactions; health for analysing population demographics; water industry through the use of digital elevation models to aid in catchment management. These are just a small fraction of the uses to which spatial is being put.

2.3. The Space – Spatial Value Chain

In recent years, and as technical capabilities evolve and improve, both the Australian space and spatial sectors have become more diverse in terms of users, more complex in terms of stakeholders and responsibilities, and more holistic in the way space and spatial data is used and managed.

Today, each sector alone delivers a substantial benefit to support a wide range of Australian interests. However, there is a huge opportunity from the integration of space capabilities into spatial services to provide new, previously unimaginable capabilities. As these capabilities mature they will, in turn, generate new requirements for the space sector to meet (see Figure 2 and Figure 3).

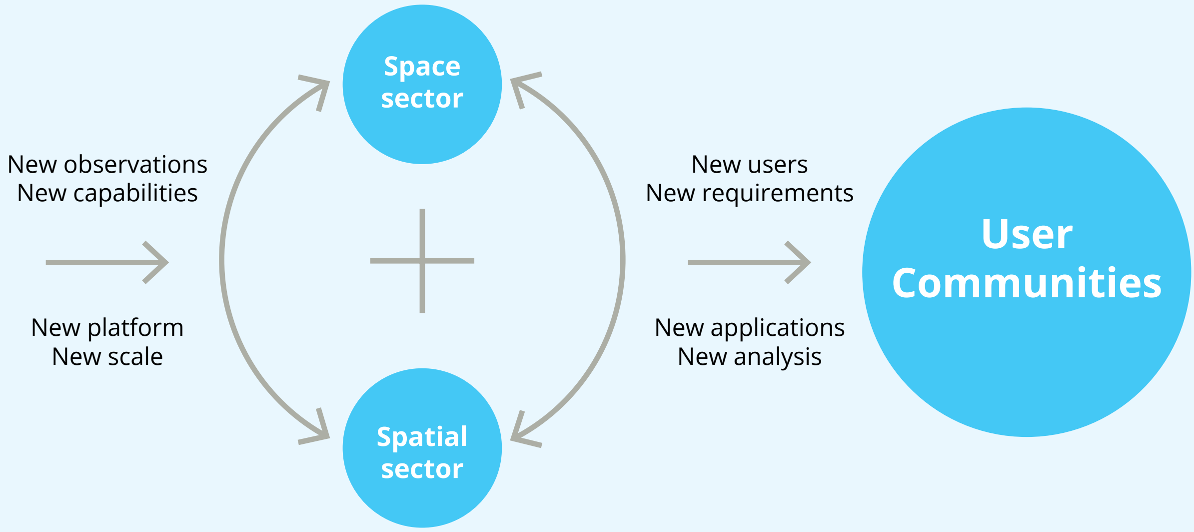
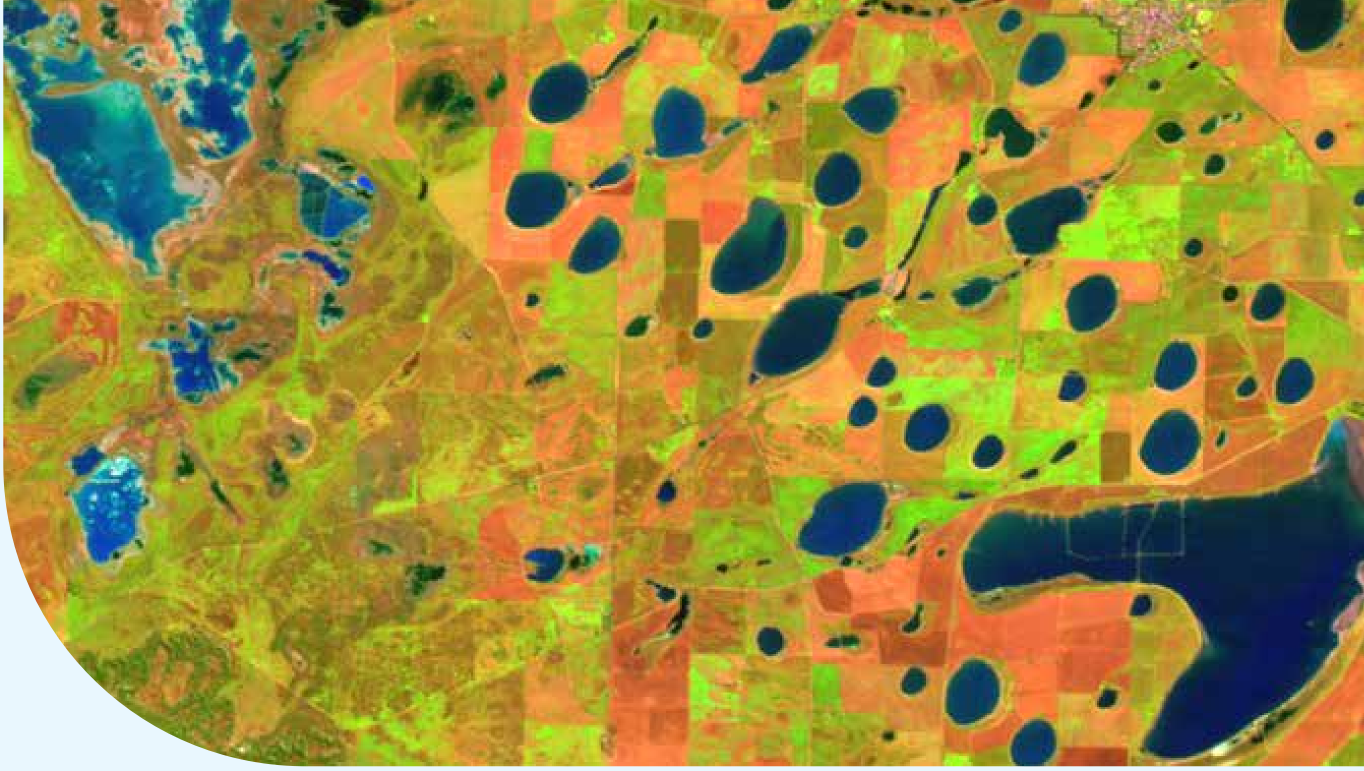


Figure 4: The Space-Spatial feedback loop

This diagram shows the synergistic relationship between space and spatial capabilities, highlighting how integration leads to benefits that would not be realised through each sector operating in isolation

Space and spatial technologies frequently form integral components of the same supply and value chains. One example highlighting the positive impact of the space and spatial sectors on each other is how the advancements in high resolution satellite imagery led to the development of a new method of coastal mapping to support hydrographic charting. In 2007 the Worldview-1 satellite launched by Digital Globe Ltd, heralded a new era of high-resolution optical imagery for the sector. However, while Worldview-1 provided new capabilities to many sectors, the coastal mapping and bathymetric mapping communities found their applications did not benefit greatly from the greater resolution and new spectral bands. The spatial user community, specifically hydrographers, fed this feedback into the space sector engineering teams for this satellite series who were then able to be incorporate a new coastal mapping band into the next satellite WorldView-2 launched in 2009. This band then allowed for a new standard of shallow water bathymetry mapping that opened up a new field previously thought to be impossible from satellites – using satellite imagery for shallow water hydrographic charting.

The opportunities presented through increased integration of space and spatial sectors is gaining increased recognition internationally. Reflecting this, the 2019 Group on Earth Observations (GEO) Ministerial Summit was held in tandem with the United Nations Committee of Experts on Global Geospatial Information Management Asia Pacific (UN-GGIM AP), the Asia Oceania Intergovernmental Group on Earth Observations (AOGEO) and the Asia Pacific Regional Space Agency Forum (APRSAF). This co-hosting approach of all the major regional-level space and spatial organisations highlights opportunities not just for collaboration between the sectors but also delivery of joint infrastructure between the sectors.



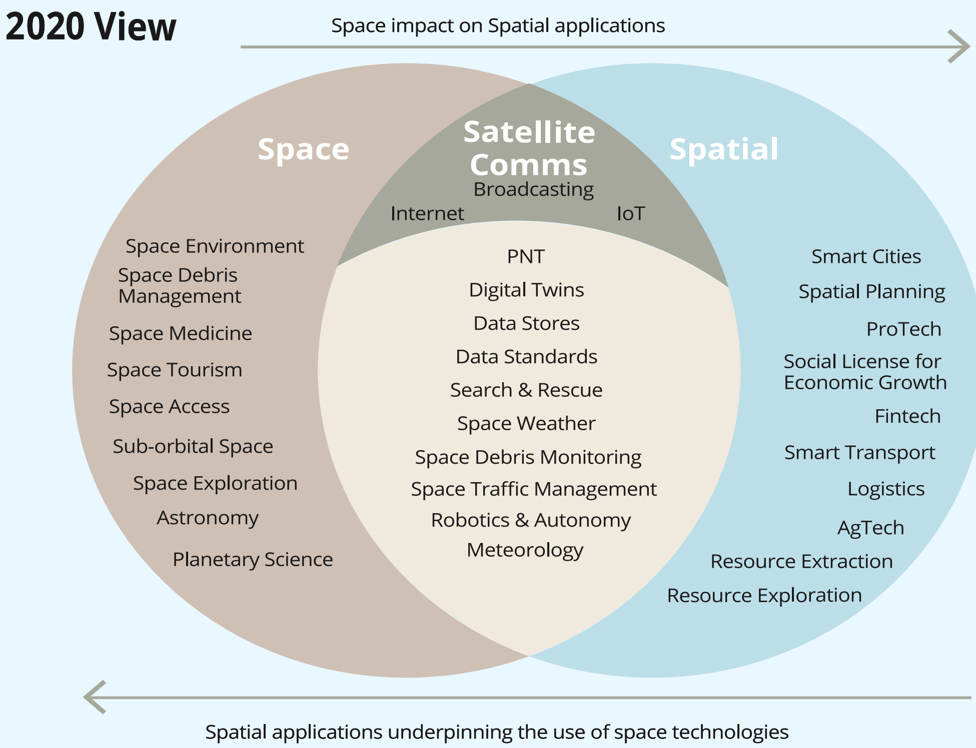


Figure 5: Venn diagram of Space and Spatial Sectors.

Space provides a vantage point to collect and deliver “ubiquitous data”. Space underpins the availability of spatial applications “everywhere”. Spatial applications demonstrate the value of space capabilities.

2.4. Investing in Australia's Future Capabilities

In recognition of the current and future potential of space and spatial services to support the Australian economy and society, the government has made major infrastructure investments including the Positioning Australia Program and DEA. They have also established a national agency to drive industry growth and space coordination, the Australian Space Agency. These developments will position Australia well to harness the growing potential of space and spatial, including driven by the exponential rate of technological development.

The 2018-2019 Australian Government Budget allocated $225 million for better positioning systems for Australia. The Positioning Australia program, led by Geoscience Australia, will be delivered in partnership with New Zealand (Land Information New Zealand (LINZ)). The program is being delivered by: establishing a national network ground stations (multi-GNSS reference stations) that will track, verify and optimise data for precise positioning across Australia - known as the NPIC; and, a system to deliver corrected positioning signals directly via satellite technology through an Australian Satellite-Based Augmentation System (SBAS), which will overcome the current gaps in mobile and radio communications. SBAS augments and corrects GNSS signals to improve the accuracy of positioning data and makes it available across Australia and its maritime zones without the need for mobile phone or internet coverage. Current technology typically allows for positioning within 5-10 metre accuracy, but through the Positioning Australia program, accuracy will be improved to within three centimetres in areas with mobile phone coverage and ten centimetres everywhere else. This will deliver accurate, reliable and instantaneous positioning across Australia and its maritime zones.

The same Budget announced an ongoing investment of approximately $13 million a year to unlock the power of earth observation data for all Australians. The DEA Program translates over 30 years of satellite imagery into evidence of how Australia's land, vegetation, and waterbodies have changed over time.
DEA provides Australian businesses and governments a snapshot of the entire Australian landscape every five days, providing detail about water availability, the development of regions and cities, and the productivity of our land. DEA provides Australian businesses with access to free and open satellite imagery, enabling the development of products that improve productivity and sustainability. DEA reduces up-front costs for businesses, allowing them to focus on innovation and value adding for their customers. DEA also enables the Australian Government to use satellite data to support decision-making in areas such as agricultural productivity, water availability, land use and management. For example, in 2019-20 DEA and the NSW Government collaborated to identify water seen over the past 30 years in almost 300,000 waterbodies across Australia, enabling government and industry alike to better understand trends and ultimately work towards their productivity and sustainability goals.

In 2019, Australia was ranked 15th globally in The Country Geospatial Readiness Index, rising from 17th place in 2017, and was recognised both as a regional leader in the Asia Pacific and as one of several "challengers" to established geospatial capability world leaders . Going forward, continued investment in Australia's capabilities and taking fuller advantage of the space-spatial nexus by supporting this area to "scale up" its integration will see Australia's international rank rise even further.

In Telecommunications the two main Australian operators are Optus, a publicly listed company traded on the Singapore Stock Exchange, and NBN, a Commonwealth Company, defined as a Government Business Enterprise under the PGPA Act .

NBN has invested ~$2bn in establishing their Long Term Satellite System (LTSS) network providing broadband internet to regional, rural and remote customers. The LTSS comprises two satellites (manufactured by Space Systems Loral in California), 10 "gateway" ground stations (supplied with satellite/terrestrial interface equipment by Viasat inc.) and two network management facilities. Spacecraft operations are conducted under contract by Optus from their Belrose facility.

As of January 2021, NBN supported about 109,000 satellite customers with NSW and QLD accounting for more than 50% of these customers. They indicate 438,000 premises are ready to connect.

Optus Satellites are the major commercial satellite service provider in Australia and since its initial operations as the Government owned Aussat in 1985 , has launched a total of 10 satellites. Five of these are still active including the Defence Payload System on the C1 satellite, D1, D2, D3 and Optus 10.

In July 2020, Optus announced its next generation of geo-stationary satellite would be based on the Airbus Defence and Space OneSat platform. This new class of satellite offers all electric propulsion and fully programmable communications payload offered a potential step-change in flexibility for future Australian satellite communications services. As an example, Optus disclosed its intention to use the Optus 11 satellite to "back-haul" mobile telephony black-spots improving coverage for rural customers. Airbus also announced the ability to add additional payloads, such as SBAS, on this satellite.

In 2020 the Department of Defence published its 2020 Defence Strategic Update & Force Structure Plan (over the 2020 – 2040 timeframe). The following list presents the lower published funding envelope for all planned primary space and spatial capabilities announced with the Defence Strategic Update 2020:

- Satellite Communications ($4,600m)
- Satellite Communications Assurance ($1,700m)
- Space Domain Awareness ($1,300m)
- Terrestrial Operation in Contested Space ($1,400m)
- Satellite Imagery Capability (access) ($400m)
- Sovereign Satellite Imagery Capability ($3,200m)
- Additional Sovereign Satellite Imagery Capability ($1,200m)

In addition to the increased funding allocation the space capabilities, Defence has also heavily invested in space and spatial research and innovation activities through the Defence Innovation Hub (DIH), the Next Generation Technologies Fund, the Sovereign Industrial Capability Priorities grants and Defence Science and Technology (DST) Group research. The total funding for announced Defence projects under these and other schemes is ~$50m including large scale activities such as the Buccaneer Main Mission satellite, novel sensor technologies for Space Domain Awareness, the establishment of the AGO Analytics Lab program and a range of space technology development projects.

The Office of National Intelligence (ONI) has also seeded space innovation activities through the National Intelligence Community Satellite (NICSat) program announced in May 2020 worth $4-6 million. Whilst not publicly announced by ONI, US media reported the launch of a Spire Global Lemur satellite named Djara in November 2020 as a partnership with ONI.

There have been a number of government programs from a range of agencies also announced in recent years aimed at supporting and driving research and innovation led industry growth. Collectively these programs support development and commercialisation of a range of space and spatial technologies with the aim of building a more globally competitive industry sector whilst simultaneously contributing to Australia's economic, social and national security

The Australian Space Agency have announced an extensive range of programs aimed at supporting niche technologies and addressing infrastructure gaps across the space sector including:

- NASA Moon to Moon - $150m over five years
- International Space Investment Initiative - $15m over three years
- Space Infrastructure Fund - $19.5m for seven projects
    - Mission Control Facility ($6m)
    - Robotics, Automation and AI Command and Control ($4.5m)
    - Space Payload Qualification facilities ($2.5m)
    - Space Manufacturing Capability ($2m)
    - Space Data Analysis facilities ($1.5m)
    - Tracking Facility Upgrade ($1.2m)
    - Pathway to launch ($0.9m)
- Australian Space Discovery Centre - $6m

The SmartSat CRC is deploying $235 million over seven years to 2026 comprising:

- $55m funding from the CRC Program
- $12m funding from the Defence Next Generation Technology Fund
- $33m Partner contributions
- $135m in-kind contributions

SmartSat CRC is developing an integrated and collaborative research program between industry academia and government research agencies focused on communications, earth observation and intelligent satellite with cross cutting program in Artificial Intelligence and Cyber Security and Resilience. The CRC aims to build an Australian sovereign space capability through world-class research and development in space systems, technology and solutions to enhance Australia's economic prosperity and deliver national benefit. An example of the role SmartSat CRC aims to fulfil is the recent announcement by the SA Government that SmartSat CRC will work with them to deliver a hyperspectral imaging and communications satellite in partnership with local industry to provide benefit to all South Australians.

CSIRO launched the Space Technology Future Science Platform in November 2018 to generate new space-based innovations aimed at generating significant societal benefits for Australia. The program was extended by a year in 2020 bring the total funding up to $21m. Amongst many other initiatives, this program supported CSIRO's partnership with Surrey Satellite to gain a 10% share of access to the NovaSAR S-band Synthetic Aperture RADAR (SAR) system worth more than $10m over seven years.

2.5. Australia's space sovereignty

Delivery of space-enabled services depends on reliable and continued access to satellite systems and their data streams. With some minor exceptions Australia does not have a history of ownership of satellites and systems. Instead, the national focus has been on exploitation of the systems of other nations or organisations through a globally well-regarded approach to collaboration. Characterised by a multi-source approach, Australia has developed applications that integrate different types of data from different suppliers and partners with the benefit that:

- the applications are richer (e.g. by exploiting the strengths of different systems in a complementary manner, or using multiple systems to provide additional data to increase spatial and temporal coverage); and
- Australia is more insulated from technical failures (e.g. instrument failure) or sudden changes in the policy environment (e.g. sudden changes to data policy).

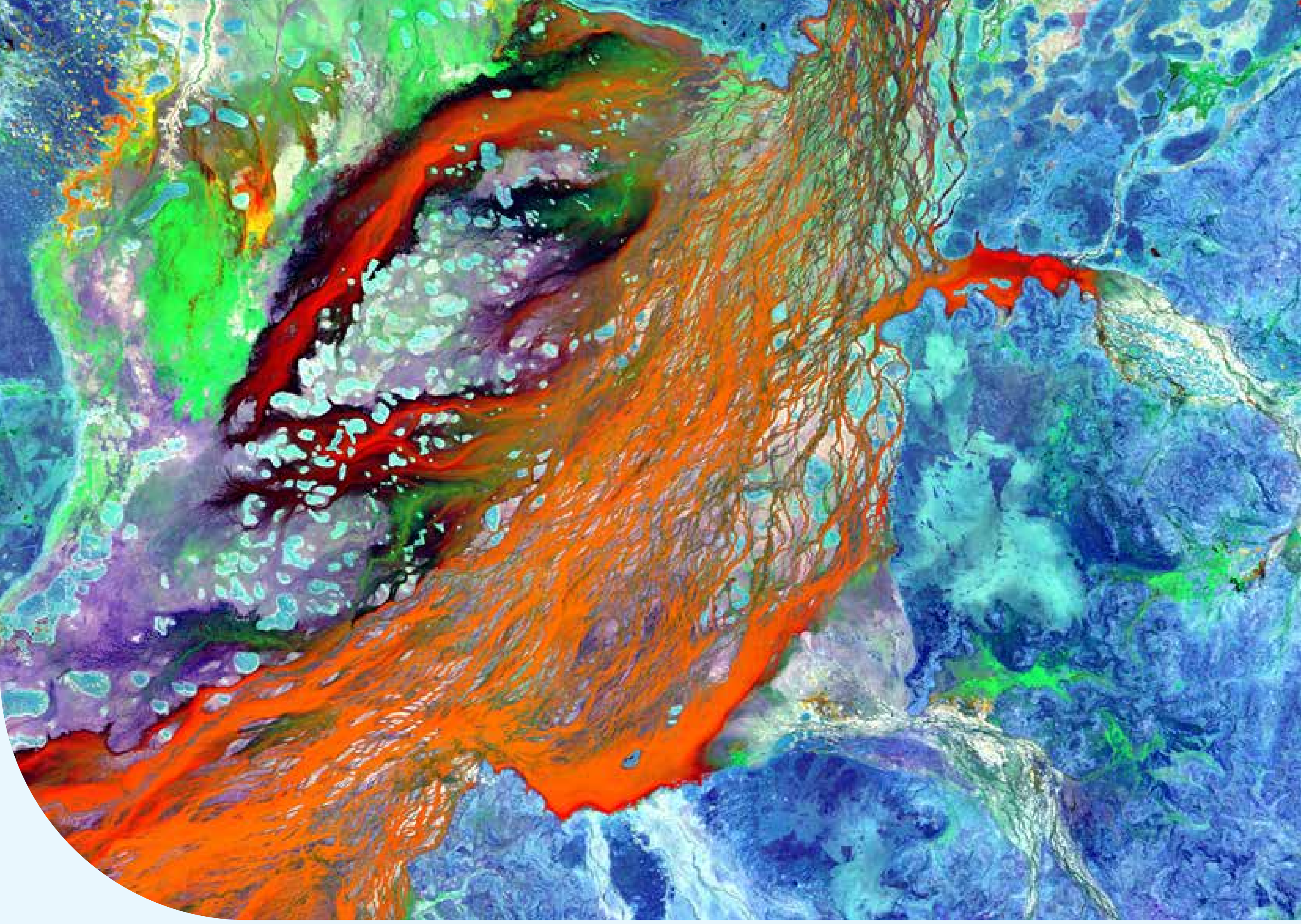
Australia is likely to continue to build on this approach to enable the delivery of better products to users and consumers locally, and globally. Moreover, Australia's openness to using what is available is not just of interest to Australia, but also to the approximately 170 or so other nations who would prefer not to be dependent on data controlled by a single major supplier. Continued encouragement of the multi-source approach positions Australia well to export space-enabled services.

However, Australia must also consider how to better manage the risks associated with dependence on other nations and foreign companies. Continued and increased investment in ground segment partnerships will continue to be a key part of generating goodwill. Australia is keen to continue to encourage global coordination of satellite systems, the use of standards and 'open public data'. This approach has given Australia access to a richer diversity of data types than would be available under an uncoordinated approach with every nation focussed only on unilateral outcomes.

Australia's space industry could, however, play an important role in developing niche capabilities and systems that address key risks and opportunities. This capability should be developed, and then leveraged, to address scenarios where Australia:

- has something of value to contribute to the space segment of critical partner programs (in return for assurance of future data supply).
- has unique local or regional needs, that are highly unlikely to be met internationally.
- can support users to strengthen the 'multi-source' approach, for example by providing cross-calibration of foreign missions.
- can make contributions to the global observing system, and thereby encourage ongoing coordination and data sharing by others.
- can identify risks where sovereign access or control can reduce our exposure to an acceptable level.
- can obtain timely access to data, as one component of assurance, that contributes to high priority national needs

Developing and nurturing our nascent space industry's capabilities to meet these needs in any operational (as opposed to experimental) sense will take time. It will need support and encouragement from government, including to ensure our industry has the necessary maturity and technical readiness. Australia has highly trained people, and many innovative businesses. However, many of the satellite systems Australia relies upon for the data that underpins spatial services are highly sophisticated with a proven record for operational reliability. Although changes in satellite technology do lower barriers and create new opportunities, a clear-eyed approach, responding to requirements and drivers in the market, will be needed when considering the development of national missions.



Defining Australian Space and Spatial Sovereignty

There has been increasing use of the term sovereignty and concern about supply chain vulnerability in relation to the space sector by Government in recent times. Major legislative and policy announcements such as the Security Legislation Amendment (Critical Infrastructure) bill, the Modern Manufacturing initiative and the Defence Strategic Update all make reference to a need for sovereignty and reduced reliance on global supply chains for critical infrastructure, systems and technology including space.

It would be useful to derive an agreed definition of 'sovereignty and the national need' in the context of access to Australian space and spatial services.

A working definition of sovereignty and the national interest would address the required degree to which Australia is capable of determining and prosecuting actions deemed by Government to be in our national interest; free of interference, coercion or limits imposed by other nations.

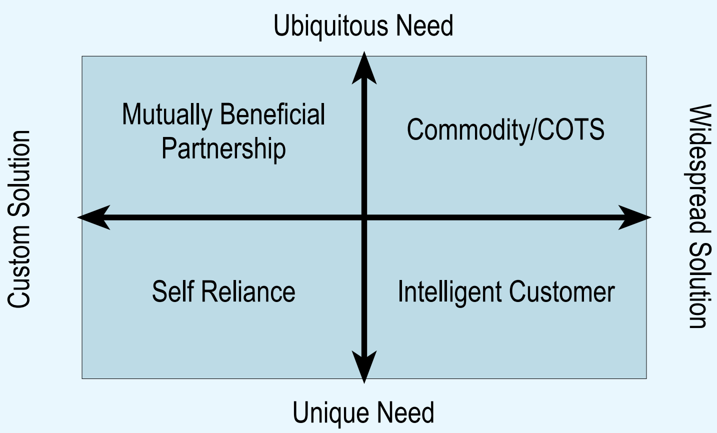
This might include access to, and the operation of, the space systems themselves, or to intellectual property allowing effective operation of the system in question.

Sovereignty and the national need might be implied to infer requirements for ownership and /or control from Australian legal entities or from within Australian geography. Within the space and spatial sector, this could extend to the industrial capability that supplies goods and services and ownership/control of supply chains upon which acquisition, operation and sustainment of all components of the enterprise depend, and the skillsets and capability in the workforce, the research sector and the public service.

Interference, coercion and limits might result in constraints on what space services Australia can access. It may also be observed as degradation of available services if Australia's interests do not align with the interest of the supplying organisation or their host nation.

For example, an imagery provider may not support request for data over certain geographic areas or a government operator of a GNSS system may degrade or turn off a timing signal for a certain time or over a certain geographic area. A communications service provider may not, or may not be able to, provide coverage or limit available RF bandwidth at certain times or over certain locations.

The following diagram shows how procurement strategies might recognise when such controls could hinder our freedom of action and drive the need for national self-reliance or sovereignty.



Commodity/COTS – if a service is truly available from multiple independent sources it might be possible to achieve sovereignty without any self-reliance. But if the market changes, and in the space sector it can change with little notice, the Government must be prepared to move quickly to create alternate sources to support critical services.

Intelligent Customer – a term used by the UK Ministry of Defence would mean that Australia maintains the ability to define our needs and specify a capability solution, including oversight to ensure effective contractual delivery even if the goods/services are sourced entirely from overseas. An intelligent customer also takes a hands on approach to operations and sustainment (including upgrades) throughout the life of a capability. Optus is a prime example of an Australian space service intelligent customer and acted on behalf of Defence in this role during the acquisition of the Defence Payload System on Optus C1.

Mutually Beneficial Partnership – Describes an approach where no one country or organisation has the ability to develop, deliver, operate and sustain a capability so creates a partnership to do so. This only delivers sovereignty if partners have strongly aligned interests in the development and operation of the capability and a degree of mutual inter-dependence can be achieved. JSF is an example of this model as is the Wideband Global SATCOM MoU which had a number of specific provisions to enhance Australian sovereignty within this partnership.

Self Reliance – describes acquisition and sustainment of a capability where Australia controls/directs a significant portion of the value-chain. Critical components of the capability are sourced from Australian suppliers. It is impossible to attain full self-reliance due to the globalised nature of supply chains, especially for electronics which is a crucial component of almost every Australian space capability. The best example of self-reliance is JORN and arguably the Collins Class has forced Australia into self-reliance during the sustainment of that capability.

It is possible that self-reliance may deliver a lower level of capability unless Australia is prepared to support (and this may mean significant financial support) a high level of industry capability across the space value chain, especially R&D. This is because the financial base of Australia may not support the same level of research, development and innovation as larger North American or European manufacturers. Evidence for this can be found in previously published research from the UK that showed a strong correlation between national R&D funding and defence equipment capability levels.

This issue is identified within the 2020 Defence S&T Strategy which states:

> ***"There are some Defence capabilities that must be developed domestically, because overseas sources may not provide the assurances we need or the capability requirement might be unique to Australia. Through the 2018 Defence Industrial Capability Plan, the government is committed to growing Australia's ability to operate, sustain and upgrade Defence capabilities with the maximum degree of national sovereignty. A well connected, informed and vibrant defence S&T enterprise will be critical to this objective."***

Based on this and the complexity of supply chains contributing to space-based capabilities that provide communications, PNT, imaging and other forms of sensing it is difficult to determine which elements of a system need to be produced or operated from within Australia as the needs may change over time.

Space and spatial service rely as much on ground-based infrastructure as space-based assets. Ground infrastructure located within Australia may still be subject to international agreements which can place constraints on Australian usage inhibiting access despite being located on Australian territory.

For space systems, assured access (including the ability for timely tasking and commanding of a spacecraft) may achieve the same outcome as sovereign ownership or control. A viable pathway to assured access may be through partnership whereby a two or more nations pool resources to deliver a system with contributors gaining guaranteed access to the joint system. This may include provision of ground infrastructure in a suitable geographic location for critical facilities along with dependable undertakings by owners that these facilities will be maintained, including through access to expert staff, to ensure an agreed level of assurance that services will be available when and where needed.

Under this collaborative partnership model, which is quite common in the space sector, a more nuanced approach to both critical infrastructure protection and sovereignty may be required to ensure the desired outcome of service availability for Australia customers are met.

Risks arising from non-sovereign ownership and control of assets may also mitigated through the underlying technology employed by the system. For example, modern GNSS receivers can access signals from multiple systems meaning customers do not rely on any single provider (note there are six Global and Regional Navigation Systems that operate over Australia). If one operator disables or denies access to their system, users can still access a viable service. Such inter-dependencies and alternatives need to fully understood when determining appropriate approaches to ensure assured access to space and spatial services.

2.6. Benefits of the Integration of Space and Spatial

Australia's space industry, although small, has well recognised world class expertise in certain areas from which we can build. By contrast, Australia's spatial community is much more dominant by world standards but still exhibits strong growth potential. Operating in tandem, these competitive advantages serve as strong basis from which both industries can grow.

A coordinated, strategic approach to integration of Australia's space and spatial sectors could:

- increase productivity in key Australian sectors including agriculture (food, fibre and carbon), mining, aviation, intelligent transport, construction and energy through improved coordination between the end users and technology/data providers developing solution-based products and services.
- support the delivery of public good services including defence, national security, disaster response, emergency management, environmental monitoring, urban planning, sustainable cities and digital twins to name a few.
- grow the domestic space-spatial industry so that it achieves an international competitive advantage in high value-add areas including:
  - advanced instrumentation; advanced geospatial;
  - location intelligence services; and
  - telecommunications.
- accelerate the maturation of the Australian space industry, by leveraging off the successes of the Australian Space Agency, SmartSat CRC, Frontier SI, DEA and the NPIC, amongst other programs.
- better align academic programs with industry needs, including by producing industry-ready graduates who meet the skills demand.
- increase Australian participation in the global space industry.
- increase the commercialisation and utilisation of research in the space-spatial sectors.
- increase surety of access of vital information supply chains
- establish the nexus of an enduring space-spatial integration in Australia.
- address the challenges and opportunities presented by open data, open technology and the introduction of the NBN.
- reduce duplication and increase efficiency in the delivery of state and government geospatial services.

2.7. Collaboration – National and International Partnerships

Enhancing the network of collaboration is vital to the space and spatial growth agenda. Collaboration unlocks innovation, builds critical mass and increases national resilience. Australia has a long history of collaboration in the national and international science community including those of space and spatial. Figure 6 depicts conceptual ecosystem of Australia's collaboration with Space and Spatial sector.

Figure 6: Australia's Space and Spatial International Collaboration Ecosystem

CSIRO has a long and proud history of national collaboration on space and spatial sciences for industrial and public good activities going back 60 years. CSIRO Centre for Earth Observation (CCEO) is the hub for our national and international earth observation activities. CSIRO are a member of the inter-agency Committee on Earth Observation Satellites (CEOS) and an Australian delegation member to the intergovernmental Group on Earth Observation (GEO). The CCEO worked closely with Australian government partners to host the 2019 GEO Ministerial Summit. The Centre also plays a key role in our international engagement with the global EO community.

The Centre for Earth Observation's key priorities include :

- coordinating internal communities of practice (SAR, hyperspectral, LiDAR), and liaison with domestic government
- coordinating representation (including on boards and working groups) at international fora, such as GEO and CEOS
- managing CSIRO's requirements for satellite tasking, downlink and data distribution for the NovaSAR-1 satellite
- hosting events to facilitate research collaborations for the EO community, including Symposia and workshops
- overseeing the Cubesat technology demonstrator project, a collaboration with university and industry partners
- researching new satellite sensor and on-board processing technologies and ongoing satellite calibration/validation

GA has a long history of partnerships throughout government and with the publicly funded research sector and the private sector. GA's DE is a platform that uses spatial data and images recorded by satellites orbiting our planet to detect physical changes across Australia in unprecedented detail. DEA prepares these vast volumes of earth observation data and makes it available to governments and industry for easy use. GA is delivering on Digital Earth Africa (DE Africa) which is building the world's largest operational platform for accessing and analysing decades of satellite imagery specific to Africa's land and seas. DE Africa will translate data from the world's free earth observation satellites into ready-to-use insights about the continent's environmental conditions. Such insights will enable African governments, NGOs, businesses, and individuals to make more informed decisions about soil and coastal erosion, agriculture, deforestation, desertification, water quality and changes in human settlements.

The South Pacific Regional GNSS Network (SPRGN) was initiated during Phase III of the AusAID funded South Pacific Sea Level Monitoring Project (SPSLMP). The SPSLMP was developed in 1991 as an Australian Government response to concerns raised by member countries of the South Pacific Forum about the potential impacts of human induced global warming on climate and sea levels.

A Satellite-Based Augmentation System (SBAS) uses space and ground infrastructure to improve the accuracy, integrity and availability of GNSS signals needed for vertical guidance. GA in partnership with New Zealand Government is fostering research and a test bed in the Pacific region. Its aim is to monitor vertical movement of the Earth's crust in conjunction with tidal measurements as part of the SEAFRAME network located in the South Pacific Ocean.

Australia currently holds the Presidency of the United Nations Global Geospatial Information Management (UNGGIM) for Asia Pacific . ECOSOC established the Committee of Experts as the apex intergovernmental mechanism for making joint decisions and setting directions with regard to the production, availability and use of geospatial information within national, regional and global policy frameworks . Led by United Nations Member States, UN-GGIM aims to address global challenges regarding the use of geospatial information, including in the development agendas, and to serve as a body for global policymaking in the field of geospatial information management. The tenth session of the United Nations Committee of Experts on Global Geospatial Information Management (UN-GGIM) was held, on 26-27 August and 4 September 2020 which announced the following initiatives which are highly related to space and spatial collaboration.

- United Nations Global Geospatial Knowledge and Innovation Centre in Deqing, China
- United Nations Global Geodetic Centre of Excellence in Bonn, Germany
- United Nations Global Service Centre of the United Nations Office on ICT (UN OICT) in Brindisi, Italy

The Australian Space Agency sees international collaboration as a critical enabler for Australian industry . It has established MOUs with nine international partner organisations and a large number of Australian and international companies. The Australian Civil Space Strategy 2019-2028 sees international partnerships and collaboration, especially with national space agencies, as a mechanism to “open doors” and create business opportunities for industry through contribution to large scale space missions such as the NASA led Artemis Program and the UK Space Agencies International Partnership Program.

The Defence Science Technology Group has evolved and expanded its approach to collaboration, within Australia’s innovation system and with international allies. In the most recent strategy, the Minister for Defence outlines the strategic basis for enhanced R&D collaboration across all facets of Defence capability development and operations, including space

> ***“In a new era of strategic competition, the Defence strategy aims to ensure our defence force is technologically superior and fully integrated into a joint Australian force to be seamlessly interoperable with our Allies and partners globally. To achieve this we need seamless collaboration with our trusted industrial base and academic partners in Australia.” (More Together)***

The strategy aims to drive transformation in the way Defence partners across the national S&T enterprise in order to achieve impact through strategic research. The headline program to achieve this outcome is the Science, technology and Research Shots (STaR Shots) program which includes Resilient Multi-mission Space as one of the eight focus areas. Defence clearly states that achieving the scale of effort to deliver impact across the critical task outlined by the Minister cannot be done without collaboration.

The Surveying and Spatial Sciences Institute, the peak Spatial Professional body in Australia has signed a Memorandum of Understanding with the International Society of Digital Earth (ISDE). The ISDE Leadership has been instrumental in developing the Big Earth Data in Support of the Sustainable Development Goals (SDGs) (2020) . The report focuses on six SDGs including Zero Hunger (SDG 2), Clean Water and Sanitation (SDG 6), Sustainable Cities and Communities (SDG 11), Climate Action (SDG 13), Life below Water (SDG 14), and Life on Land (SDG 15). The case studies present the use of earth observation data for developing data products, new evaluation methodologies and models to monitor progress and inform policy-making at local, national, regional, and global scales. The SSSI’s International partnership with FIG (International Federation of Surveyors), ISPRS (International Society for Photogrammetry and Remote Sensing), OGC (Open Geospatial Consortium) and ISDE are crucial for capacity building and professional development are important components of spatial and space collaboration.

FrontierSI currently has 35 partners and its predecessor the Cooperative Research Centre for Spatial Information (CRCSI) had over 100 partnering organisations across both Australia and New Zealand. FrontierSI has several international partnerships such as JAXA, Japanese space agency, EARSC (European Association of Remote Sensing Companies) and Copernicus (European Union’s Earth observation programme). FrontierSI has been a key player under the leadership of GA in SBAS, also partnering with the New Zealand Government.

Further consideration of formal partnerships in multi-national collaborations, such as the European Space Agency (ESA), should be reviewed based on the opportunities and risks to industry growth. These are not straight-forward considerations and input is sought on the key issues to consider when forming collaborative partnerships, especially those involving creation of intellectual property with commercial value.

3. NATIONAL SPACE MISSIONS

It is important that consideration and action on these topics be viewed through the lens of one or more National Space Missions that can deliver benefits to Australia's society, environment, economy and security for better or new applications of space and spatial systems.

With all Australian governments, national, state and territory, focussed on economic recovery from the effects of the global pandemics, there is a window of opportunity to build an argument for large scale investment in infrastructure to facilitate economic growth.

The space and spatial road mapping activity is well positioned to shape consideration of these missions and support industry groups in the development of nation building proposals that deliver critical outcomes for Australia whilst simultaneously driving industry growth and sustainable business models across these sectors.

3.1. Exemplar Missions

The following "exemplar missions" are included to stimulate thought and discussion. These are not proposed as the National Space Missions but could evolve into one or more. An outcome of the 2030 Space and Spatial Industry RoadMap development process should be to identify and develop 3-5 proposals for National Space Missions that are strongly supported by industry and are capable of being delivered largely or entirely by Australian organisations. They must fill a pressing need for Australia and create opportunities for the space and spatial industry sector growth over the medium-long term.

1) Disaster Management

Scenario

This scenario provides an example of how next generation space and spatial technologies could be deployed to augment and enhance the current capabilities used for land management, emergency response and recovery in catastrophic crises such as bushfires and floods.

The Problem

Catastrophic events during the 2019/20 bush fire season devastated communities, property, businesses and our natural environment. At least 28 people died nationwide, over 4 million hectares burnt, and in New South Wales (NSW) alone, more than 3,000 homes were destroyed or damaged. State and federal authorities struggled to contain the massive blazes, despite mobilizing a massive firefighting effort with international support. Critical terrestrial communications infrastructure is often disabled or damaged during a major fire incident, hampering rescue efforts, put lives at further risk and reducing the coordination and effectiveness of the response effort. On New Year's Eve, 2020, residents at Moruya Heads NSW South Coast, were continuously monitoring weather and fire information until mobile coverage, home internet connections and the local ABC radio transmitter all dropped out. Copper wire survived where it was buried underground, but this can be fragile and is being removed in many areas. Better access to and integration of information sources, coordination of community efforts and provision of assured emergency response systems are important in mitigating the risk to lives, homes, property and the environment. Management of the entire ecosystem is essential as is the early warning systems necessary to ensure that fire detection is timely and the response immediate. Technology has an important role here.

The Solution

Technology can play a significant role in all the phases of the emergency response effort. This scenario proposes the development of 'The Australian Disaster Resilience Digital Twin1' to integrate existing information systems and response mechanisms and develop semantic models as well as artificial intelligence-enabled decision models that will provide information products and decision support in land management planning and prevention of major catastrophic crises such floods and bushfires. Such a system will bring together spatial data, including digital elevation models, structural and floristic vegetation data, location of people and built assets, including critical infrastructure, land management and fire history, hydrology, climate and meteorological data, and assessments of risk . It is important to note that environmental conditions can change rapidly and insufficient temporal and spatial sampling of these data sets can result in inadequate situational awareness for decision makers and lead to sub-optimal outcomes or at worse, put lives at risk.

Satellite remote sensing data sets will be integrated from existing and proposed technologies, some of which may be developed within SmartSat CRC projects or from other Australian initiatives. In order to augment and validate satellite data, terrestrial IoT sensor networks will be established to measure moisture levels and other parameters as well as serve as an early warning system. For example cameras with thermal infrared sensors could be installed and work in unison with satellite image data to identify fires at the instant that they are lit and provide an early warning notification so that the fire crews can respond early and prevent the fire from spreading. Deep learning neural networks can be developed to identify fires quickly, with software that can be loaded in-situ on the sensors themselves (on the 'edge'), including on-board satellites, to provide near-real time processing and analysis. This would permit the swift identification of the burning fire fronts and provisioning of that information to emergency responders. The SmartSat CRC plans to develop technologies that will enable the creation of integrated space and terrestrial networks so that separate expensive satellite terminals are not needed in situations where part of the local terrestrial communication network has been rendered inoperable as a result of the fire. These networks will aim to provide ubiquitous reliable connectivity at all times so that the emergency crews, residents and the general public remain connected and fully informed at all times.

Protecting people is critical during a catastrophic crisis such as a bushfire. Next generation personal locator beacons will be developed similar to those used in maritime environments. As the IoT technologies are becoming extremely inexpensive these will be deployed across the nation to ensure the location of humans and mobile assets can be accurately determined when required. These could be developed as wearable device or integrated into vehicles to provide alerting and allow people in distress to be rapidly located. Similar systems are used by the military and have been proven to reduce risk of loss of life in complex and dangerous environments characterised by the need for rapid decision making with incomplete data. We have the capacity and knowledge within our research programs to develop a prototype national "Blue Force Tracking" network to be deployed in high-risk environments during times of crisis or when conditions indicate high probability of catastrophic outcomes. The system could connect into a new Australian emergency response network and incident data management system. The system will work by gathering sensor data tethered to widely distributed devices which will generate reports from incidents. This can be combined with data from a variety of sources including hyper spectral and thermal imaging satellites to detect and monitor bushfires, multiple earth observation satellites and the feeds from the Bureau of Meteorology. After processing, this will be distributed in near real time to provide information on the well-being of people in areas of high risk and allow developing situations to be monitored.

2) Ubiquitous Communications

The civil satellite communications sector has four priority addressable market segments, each with decreasing availability of government support:

1. Resilient and widespread emergency services and public safety communications networks
2. The national Universal Service Guarantee (USG) market for voice and broadband services;
3. The broader national commercial market; and
4. The global commercial market

The end-user needs, technical solutions, costs, level of competition and barriers to entry are quite different for each of these market segments. The SmartSat CRC seeks to understand each of these and work with Australian policy makers and industry to ensure our research program positions them to provide optimal, competitive solutions to drive economic growth for Australia.

The USG addresses voice services and “broadband” internet connectivity and is driven by the need to provide reliable, affordable services to Australians, irrespective of location. In the development of the Universal Service Guarantee, the Department of Communications and the Arts noted that *“fixed voice services could be provided at much lower costs by using wireless and satellite technologies”* compared to delivery via Telstra’s copper network.

For the national commercial market, new opportunities to utilise satellite communications more broadly across the economy will drive productivity. Examples include agriculture, mining (especially remote/autonomous operations) and transport/logistics. These are all target end-user application areas for SmartSat CRC and not just for improved satellite communications.

Morgan Stanley forecasts the global space economy will nearly triple in size to US$1.1 trillion in 2040. Satellite broadband is projected to be half of the projected growth. The global space economy is growing dramatically, estimated at US$383.5b in 2017, yet Australia’s share is projected at only US$3 billion, less than 1%, even though Australia currently enjoys nearly 2% of global GDP.

At present, Australia satellite communication service providers are heavily focused on the domestic market through adoption of technology developed by international partners. This lack of indigenous technology development limits the scope for Australian telecommunications companies to compete in regional or global markets where much of the increased economic activity will be generated.

Innovation in satellite design, manufacture, launch and space operations are opening up access to low earth orbit for small satellites. Miniaturisation and increased power efficiency of electronic circuits (Moore’s Law) is enabling greater functionality in smaller form factors and tipping cost/benefit outcomes towards smaller satellites.

Moreover, the world is experiencing exponential growth in computing power, reduction in storage costs, the ‘cloud’, computing on the edge, artificial intelligence & machine learning, software defined radio (SDR), software defined networks (SDN), IoT, quantum information science all of which are driving down the cost of infrastructure typically needed to provide customer access to space services.

Communications by satellite is the most effective means of communication in rural and remote areas due to Australia’s geography. Our current satellite communications are not optimised to deliver both fixed and mobile, secure, high speed, low latency data, particularly for agriculture, asset management, and Defence.

Australia's nbn network is comprised of two geostationary satellites and an extensive ground infrastructure. However, nbn's Sky Muster suffers from 'latency' (communications response time) due to the signal transmission delay to/from satellites in geostationary orbit. The delay is 20 times higher than terrestrial communication systems and is unsuitable for many forms of device-to device IoT connectivity for augmented reality, autonomous vehicles, some remote robotic applications and some social interactions.

A solution to the latency problem is to provide satellite services from Low Earth Orbit (LEO) or Medium Earth Orbit (MEO) which are physically closer to the earth and incur less signal propagation delay. There are other challenges arising from LEO constellations for which the SmartSat CRC is well positioned to identify solutions.

A characteristic of LEO satellites is their movement relative to the earth meaning persistent coverage requires multiple satellites. The Australian landmass represents 1.5% of the surface area of the world and a LEO constellation developed to service Australia is also equally useful globally.

The ESA is anticipating a shift from geosynchronous satellites to MEO and LEO satellite constellations, driving change in technology and the number of satellites. There is also a shift from TV satellites to satellites for high bandwidth data communication.

Although, LEOs orbit at much lower altitudes than traditional communications satellites, signal strength is a challenge with the constraint of low power to ensure long battery life. The potential deployment of millions of sensors will pose a significant signal processing challenge. The development of mission and safety-critical applications addressing security and reliability challenges is crucial.

Constellations of small, inexpensive satellites (micro-sats) are currently being launched in their thousands. Space X, founded by Elon Musk raised $500 million on a constellation of satellites called Starlink and has already launched a number of its satellites which fly as low as 550 km. SpaceX gained approval to launch a total of almost 12,000 satellites for internet services worldwide. By January 2021, Space X has launched over 1000 small satellites meaning is has become the largest satellite operator in the world. Space X and OneWeb, backed by Virgin, Airbus, Qualcomm, Kepler Communications, Boeing and Telesat and others, also have similar plans for high-speed internet constellations.

4. RISK AND RESILIENCE

4.1. Risk Analysis

The Space Cross-sectoral Interest Group, which is part of the Trusted Information Sharing Network of Australia's Critical Infrastructure Advisory Council is undertaking a detailed analysis of the risks and dependencies faced by Australia's reliance on space assets (Satellite communications; PNT; and earth observation) in every area of Australia's critical infrastructure (including but not limited to health, food and agriculture, banking and finance, transport, water services, communications and energy). Critical infrastructure in the Australian context includes not just the tangible assets but also the information supply chains on which they critically rely. This work, by its very nature, marries the space segments with the information supply chains, many of which carry vital spatial information to end users. Its success will rely on a close working relationship between space and spatial and which will feed into the deliberations of the RoadMap, especially the elements that address Australia's vulnerabilities and the essential actions to improve our resilience to threats.

The analysis of threats and dependences include an examination of the full supply chain for each of the critical dependencies. The analysis is based on the international risk standard ISO 31,000:2018. A risk matrix is being developed comprising the threat, risk description, the potential impact, the risk owner, the existing controls, the risk rating, the current monitoring strategies, the current risk treatments, and the residual risk rating.

Importantly the analysis will identify principal risks that represent an unacceptably high residual risk. These will be gathered up in a principal risks register that will form the basis of further analysis that will dimension and propose additional treatments and controls. Additional actions required will then be considered for inclusion in the 2030 RoadMap.

As part of the Risk Assessment, an initial focus will be the on the impact of outages on critical infrastructure and services of national significance related to GNSS. A number of international reports are being reviewed to analyse the vulnerabilities inherent with PNT as provided by GNSS. At the core of this initial activity is a plan to document levels of dependence on PNT in a highly constrained scenario, a major metropolitan centre and the impact on a narrow section of the economy. This does not aim to identify threats or economic impact but rather focus on the scale of the problem and the associated dependencies and interdependencies between the identified sector (most likely transport and logistics) and space-based GNSS services.

Note this would be a technology/technical focused study, not an economic study.

Firstly, a Use case study would be carried out to identify critical and significant elements of the integrated transport and logistics sector for a capital city, which currently utilises satellite-based GNSS systems. It would also estimate the high-level impacts on the local, regional and national operations in these sectors, should access to space systems be lost for various periods of time.

Secondly, using the results from the above Case study, a framework would be created that would allow for a deeper dive into what is needed to improve the resilience of critical infrastructure, namely to mitigate the effects and impacts of outages. It is also considered to develop feedback that would be shared with the TISN and other groups responsible for maintaining industrial productivity.

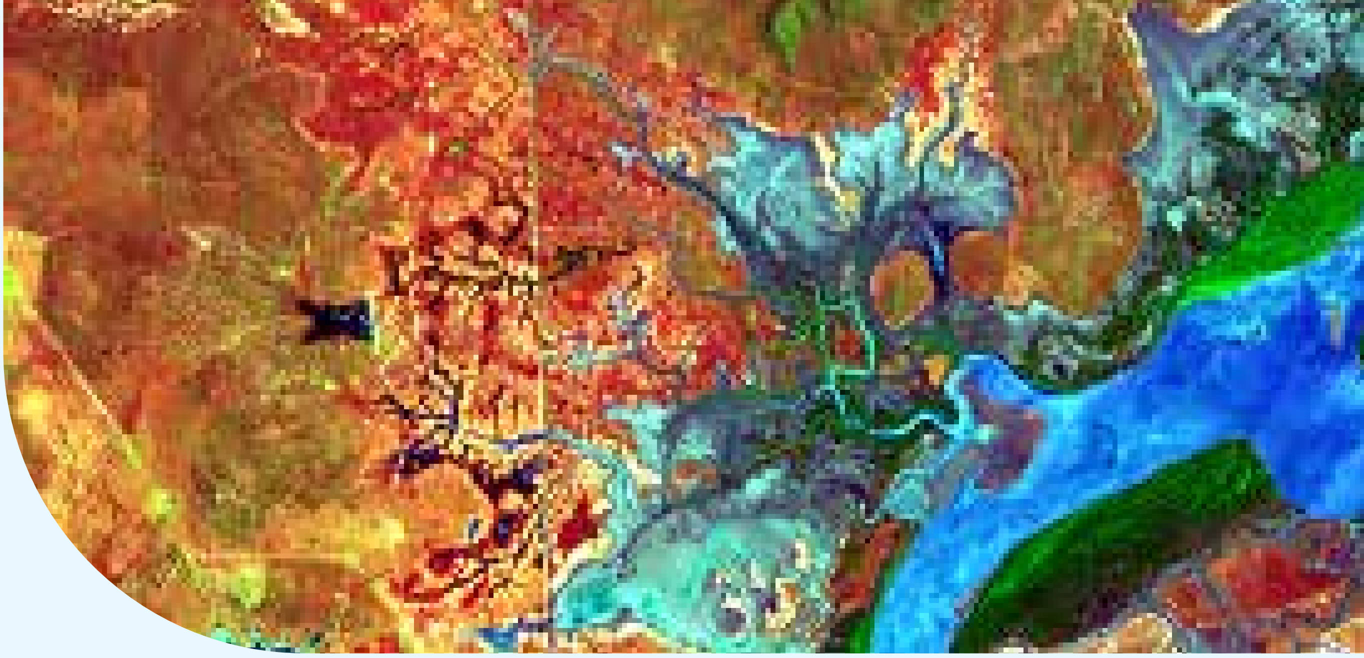
4.2. Risks and Hazards

A hazard may be defined as “a situation or thing that has the potential to cause damage or harm”. The international risk standard defines risk as the “effect of uncertainty on objectives - and an effect is a positive or negative deviation from what is expected”. A risk is the probability that exposure to a hazard will result in harm or damage. The table below lists indicative hazards potentially affecting space based systems.

Hazard	Description
Solar Coronial Mass Ejection (CME) • Geomagnetic storm • Radiation Storm	A solar CME intersects one or more of the orbital belts and the ionosphere
Large solar flare • Radio Burst • X-Ray Flare	A large scale geo-magnetic storm intersects with one or more of the orbital belts and the ionosphere.
Medium solar flare • Radio Burst • X-Ray Flare	A moderately large geo-magnetic storm intersects with one or more of the orbital belts and the ionosphere.
Meteorite passes through orbital belts	A meteorite passes through one or more of the orbital belts causing satellite operators to undergo defensive manoeuvres.
Natural disaster affects control or management segment	A natural disaster (bushfire, flood, cyclone, earthquake) destroys, damages, prevents operations or access to critical satellite operations facilities
Unavailability of key specialist personnel	Highly trained personnel are unavailable to work for an extended period of time (> 1 week)
Equipment failure - systemic	A manufacturer builds a series of satellite with a common design flaw putting multiple satellites at risk of premature End-Of-Life (EOL)
Equipment failure - isolated, limited	A component on a single satellite fails reducing the performance of the primary payload
Equipment failure - isolated, severe	A component or components fail prematurely causing the loss of the satellite
Cyber-attack - satellite control segment	State or non-State cyber actors target major element of a satellite operations system that controls the spacecraft. This includes risk of “silicon trojans” that may be implanted in space based computing hardware.
Cyber-attack - payload management segment	State or non-state cyber actors target major element(s) of a satellite operations system that control satellite payloads.
Cyber-attack – supporting infrastructure	State or non-state cyber actors target supporting ICT infrastructure that delivers space and spatial products and services to customers
Out of control satellite - geostationary arc	A failed satellite that cannot be controlled drifts through the geo-stationary belt causing other satellite operators to take episodic evasive action

Out of control satellite - LEO/MEO	A failed satellite that cannot be controlled drifts through the LEO or MEO orbital belts causing other satellite operators to take regular evasive action
Equipment failure - satellite control segment	Equipment failure without the satellite control segment prevents routine satellite control activities
Equipment failure - payload management segment	Equipment failure within payload management facilities (including end-users) prevents routine satellite operations
Launcher operations failure	A single launch vehicle suffers catastrophic failure
Launcher operations extended unavailability (> 1 month)	One or more launch operators ceases to provide services for an extended period of time
Warfare	The outbreak of conflict between states (and in some cases non-states) increases the likelihood that military and commercial space assets may be targeted to achieve a military effect.
Space warfare	Military or advanced non-state actors target objects in space to achieve a military or political advantage through means including kinetic attack, electromagnetic attack or cyber-attack (including potential insider attack)

Table 2: List of Space Hazards



5. KEY ISSUES

The key issues set out in this section are intended to generate feedback through the stakeholder consultation. Once consolidated this feedback will be used to finalise the 2030 Space and Spatial Industry Growth RoadMap.

Are these the main issues that need to be addressed and that are not already part of established plans? Are there any key issue missing that should be included?

5.1. National Space Sovereignty – Needs and Aspirations

Challenge

Growing regional strategic competition, global trade disputes, exposure to information operations seeking foreign influence in Australian businesses and institutions, cyber threats and the economic impact of the SARS-CoV-2 pandemic have led to a renewed focus by the Australian government on sovereignty.

The space and spatial sector are fundamentally enabled by global supply chains dependent on international partnerships. Underpinning these supply chains is critical ICT infrastructure. There are two key questions in this regard; what level of assured access does Australia aspire to over the next decade and in which specific space and spatial technologies?

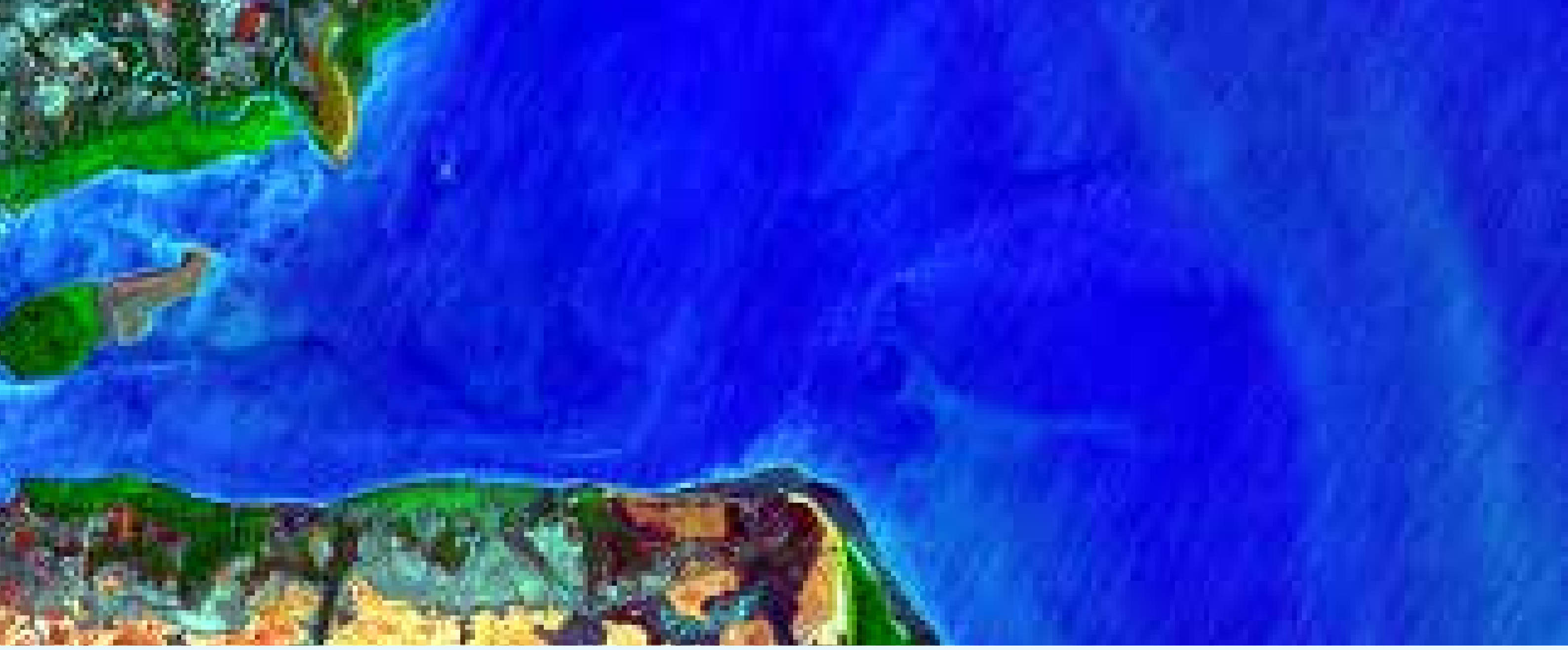
Opportunity for Growth

Australia could strengthen and expand its national capabilities and capacity in areas that lead to increased resilience of critical infrastructure and national systems of importance. This growth could lead to greater development and exploitation of national intellectual property and contribute to national security outcomes.

Australian could also make stronger contributions (financial and in-kind) to selected international programs to guarantee access and create opportunities for local industry.

Actions

1. Identify priority investment areas for Australian where self-reliance supports operation of critical infrastructure and national security.
2. Support selected international programs that create opportunities for alignment of national interests between Australia and like-minded nations, through activities including contributed intellectual property and work-share/supply chain.



5.2. Space and Spatial Sector Workforce – STEM

Challenge

Australia's past educational space and spatial outcomes have been strong. Its industries, however have not been large enough to fully utilise those skills and consequently Australia has experienced a 'brain-drain' in this area. The current global disruption of the space and spatial industries has resulted in new skill requirements for these industries. Concurrently, in recent years, there has been a dramatic reduction in student interest in STEM academic and training programs. This is likely to result in significant workforce skill gaps in the space and spatial industries and is now the case in mid-experience level (5+ years) resources with space experience particularly for Defence projects requiring security clearances.

Opportunity for Growth

There is a significant opportunity for the space and spatial industries to work together with Australia's strong educational and vocational training systems to develop long-term and sustainable growth in space and spatial educational and training outcomes to build and further enhance Australia's space and spatial industry workforce. In doing so, there is a need to adopt a two-pronged approach to building the STEM education pipeline. Firstly, further grow the interest and natural connection of young people with space, by informing them of the importance of space to the Australian economy and their daily lives and the growing opportunities that exist for them, to future proof their careers. Secondly, they should work together with the education systems to identify the space and spatial skills requirements of the future and thus develop relevant academic and training programs to ensure that graduates find employment in Australia.

Actions

The opportunities for growth in this critical area can be realised through the following actions:

1. Identify existing STEM education programs and work to direct and amplify the space and spatial elements of these programs through the development of K-12 student and teacher resources;
2. Review and extend the current skills gap analysis project undertaken by the Australian Space Agency and SmartSatCRC to ensure that it identifies both space and spatial skills that are not currently adequately meeting industry needs; and
3. The space and spatial industries should work together with the education and training sectors to co-design curriculum as well as Work Integrated Learning (WIL) programs that will be relevant to future industry workforce requirements.
4. Higher education and vocational training providers should work with the space and spatial industries to develop a framework for space industry certification programs and opportunities for micro credentialing to increase pathways into space and spatial careers and thus accelerate workforce development.

5.3. Optimising the start-up ecosystem

Challenge

To optimise across Australia the key and complex elements that together will ensure a thriving and self-sustainable space and spatial start-up ecosystem capable of organic growth.

Opportunity for Growth

An agile, risk-loving and ground-breaking private sector is what drives the productivity and innovation that creates economic growth.

The process of developing, testing and scaling innovation to support a trajectory of sustainable and productive economic growth cannot be undertaken by a start-up in isolation. It requires the support of a wide range of actors across the value chain and start-up ecosystem. It is the dynamic interactions and collaboration between innovation stakeholders that underpins the constant feedback within start-up ecosystems that drives innovation to fuel the long-term cycle of productivity gains and the creation of high-value adding employment.

In the long run, the process of innovation relies on the flow of new scientific ideas, inventions and innovations. Experimentation, research and development activities are a small proportion of the broader information/knowledge economy, but they are at the heart of the complex process of innovation:

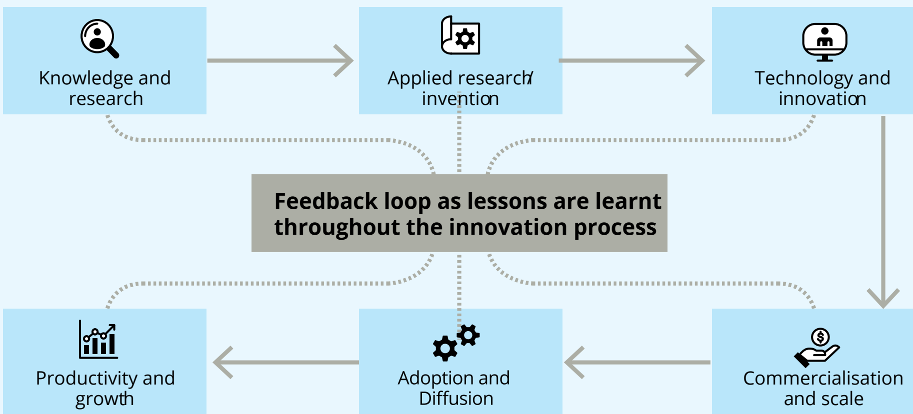


Figure 7: The Innovation Process

The key enablers that create value in the start-up ecosystem include research institutions, disruptive technology, entrepreneurs, investors, government, regulation, capital, skilled labour, land and existing companies

At a seminar run by LaunchVic in June 2020 number of successful start-up entrepreneurs noted that what they were particularly looking for, in addition to capital and markets, in their local start-up ecosystem included; a cluster of start-ups in the same precinct not necessarily from the same industry, light touch accommodation arrangements that permitted scale up or down readily with little red-tape, and ready access to public transport for ease of movement.

These key questions need to be answered for the space and spatial industries:

- How can we grow the funnel of the start-ups per million people in Australia?
- How can we increase the start-up success rate?
- How can we maximise the economic value-add to Australia?
- What impediments do we need to identify and address?
- How do we prioritise areas of innovation for start-u ps to maximise chance of success?
- How to encourage 'fail-fast' as a learning process?
- How to create more training opportunities for entrepreneurs (knowing that the people involved are a major factor in success and what VC's look at)?
- How to use programs like Moon-to-Mars to support start-ups with good ideas (do we try to pick winners?)?

There are a number of known impediments to the start-up ecosystem. These include; access to ready capital, availability of suitably skilled people, and a national cultural mindset that is too tentative when it comes to risk taking and too dismissive of the hard-won experience of repeated failure <others?>.

Actions

1. Poll selected members of the ecosystem for their advice against the four questions raised above. Suggested organisations for polling include: AURORA (SmartSat CRC's formal ecosystem of around 40 start-ups), SIAA members and SIBA-GITA (successful companies have an enormous store of knowledge about their start-up period), and SIAA members (who collectively span many of the key elements of the spatial ecosystem, and probably the space ecosystem as well). This advice can then be assembled and an action plan developed.
2. Others?

5.4. Improving the growth environment for SMEs and large corporates

Challenge

SMEs face three fundamental and enduring problems:

1. Access to markets to warrant expansion;
2. Access to capital to fund expansion;
3. Time, typically of founders and CEOs;
    a. To develop new markets,
    b. To make connections with companies with which collaboration would be to mutual benefit, and
    c. To develop compelling responses to tender invitations and grant opportunities.

An additional issue is the difficulty in winning contracts, especially from governments, which tend to favour larger companies that have a much stronger chance of being in business in five and ten years' time than do many SMEs.

SMEs are critically dependent on cash flow for their month-on-month survival. They need certainty around repeat business in order to be able to plan, invest and grow. SMEs value highly purchase orders from government. A purchase order indicates a degree of confidence by government in the product or service on offer as well as in the company itself.

Almost all of the larger companies (Primes) that operate in Australia in the space and spatial sectors are subsidiaries of global corporations with their headquarters offshore. The focus of the Australian subsidiaries is sales and sales support. Local boards and CEOs have limited discretion and major decisions are routinely referred to the offshore parent for decision. The principal task of these companies is to win major Government contracts (including in the Defence domain) to both supply new platforms and systems and then to sustain them. These companies employ many Australians directly and others through sub-contract arrangements.

Some Primes report difficulties in recruiting suitable staff locally. Some, perhaps many, Australian SMEs struggle to meet the exacting standards for induction into the supply chain programs of the Primes.

Many SMEs do not have a good understanding of the quality and other standards that they must meet and sustain to sell directly to governments or to become integral to the supply chains of the Primes. Others understand but are deterred by the time and dollar costs associated with overcoming these barriers.

The principal difficulty faced by any large company operating in Australia is the small size of the Australian market which engenders intense competition in the local market.

Opportunity for Growth

As noted in a previous section, opportunities for growth in the Australian market are limited by its small size overall and its distributed nature. Larger companies, such as the Primes in the Defence market, have the resources and the patience to shape the market through routine engagement with Ministers and their staff and senior officials. Conversely there is little evidence of similar high-level contact and collaboration amongst executives of companies across the space and geospatial sectors.

With the announcement in 2020 by Defence of its forward budgets for space and spatial totalling $10 billion and with the renewed imperative of the nation to significantly enhance its sovereignty and resilience throughout its important supply chains, and to do so at an accelerated pace, there is a real opportunity for significant restructuring of the space and spatial industry sectors.

Formation of clusters of companies that bring critical mass along the supply chain in the short to medium term around large defence procurements would see an acceleration of the growth the domestic private sector. It will increase the opportunity for innovation as start-ups and SME's bring a welcome degree of innovation whilst helping insulate the risk of lack of critical mass by partnering with larger sme's and primes. In the medium to long term this form of restructuring will increase the likelihood of mergers to form larger companies consolidating the private sector and allowing it to take its place as a mature contributor to both domestic and international markets, civilian and defence.

Actions

The following actions are proposed to improve the prospects of companies large and small, that are operating in Australia's space and spatial markets.

1. Develop a coordinated national approach for the defence and the civilian sectors in contributing to the design and development of a national space and spatial ecosystem, focussing on policies and practices that facilitate cluster formation in the short to medium term and mergers in the longer term.
2. Foster a culture of collaboration where practicable and commercially sensible to do so within and across the space and spatial sectors, especially where this improves supply chains. This might be achieved by the Space Industry Association of Australia (SIAA) and the Spatial Industries Business Association and Geospatial Information and Technology Association (SIBA – GITA) developing specific programs to facilitate collaborative activities.
3. Introduce companies that work in the space and spatial sectors to each other in a more deliberate and constructive way than may have occurred in the past. These activities might be facilitated by the SIAA and SIBA – GITA.
4. Encourage SMEs in both sectors to understand what it takes to become an accredited member of the supply chains of the Primes and to encourage them to apply for supply chain improvement grants, such as those that are administered by the Centre for Defence Industry Capability (CDIC). In this regard, Australia's experience with the Joint Strike Fighter (JSF) program is instructive. For some Australian companies that are now embedded in the supply chain of this aircraft, the journey has taken at least five and, in some cases, 10 years. Patience and commitment are required. Not all companies will want to make such a commitment and some that do, may not be able to afford to do so. However, those that do, in the high stakes, high precision worlds of aerospace and space engineering and spatial data manipulation, the rewards are likely to be consistent, growth focussed and long lasting.
5. Encourage space and spatial companies to apply for grants from sources about which they may not be familiar, including the Centre for Defence Industry Capability (CDIC). Such encouragement, backed by relevant information, might be provided by SIAA and SIBA – GITA.
6. Develop an export strategy for the products and services offered by Australian space and spatial companies. SIAA and SIBA – GITA might work with AUSTRADE to develop this strategy.
7. Prepare a carefully argued and well-documented submission for presentation to the review of the Australian Space Agency that is anticipated to occur in the latter part of 2021, extending in to 2022.
8. Develop a taxonomy of the space and spatial industries to support clear an accurate capture of changes across these sectors. The current 2006 ANZSIC (ANZ Standard Industry Classification) codes used by the ABS for capturing economic growth and business growth sees space and spatial referenced as subsidiaries in a number of other headings. This makes it difficult for the nation to adequately track progress and activity in these two vital sectors. It also increases the opportunity for confusion, the risk of misclassification or even being left out. It would be helpful to have this issue rectified.

5.5. A Coordinated Approach to Government Procurement

Challenge

There are a number of impediments to better coordination of government procurement practices. Five of the more important challenges are outlined below:

Cabinet Government: The Commonwealth, States and Territories all run versions of Cabinet Government. Ministers essentially compete for resources for the departments and agencies for which they are responsible. One measure of success of a Minister is the extent that the funding sought through the Budget process is actually allocated. These arrangements, in principle and in practice, do not necessarily promote a climate or an imperative for collaboration. Indeed, the reverse can be true. The process is competitive and the outcomes zero-sum.

Where coordinated procurement has occurred, such as in the arrangements between the Departments of Defence and Transport to establish a national air traffic control and management system, coordination processes can introduce their own delays and, from the point of view of procurement, inefficiencies.

Are higher value contracts desirable? An outcome of improved coordination might be fewer contracts overall, with those being let of higher value. This may be attractive to governments because overall bidding and contact management overheads may well be reduced and successful SME's will be able to grow substantially. The downside is that many SMEs, notably in the spatial sector, might struggle to compete against their larger competitors. This development requires careful management.

Dual Use Technologies and Dealing with Classified Projects: Defence is the largest Commonwealth consumer of space and spatial goods and services. This is unlikely to change any time soon. However, both the intelligence community and the Department of Home Affairs have strengthening commitments in space and spatial services. The former has recently purchased a satellite in order to research the advantages of edge processing and the latter, especially through its critical infrastructure protection responsibilities, is seeking to mitigate the impacts on Australian society and the economy of the loss of access to space and spatial services. By definition, space is a dual use environment and, as noted above, much of what Australia does and does not do in space occurs within the context of Australia's alliance with the US. Spatial services, for example, although provided increasingly from commercially derived data quickly fall into the classified domain when Defence is the customer. This presents multiple problems for all companies, SMEs in particular. These include:

- The cost and difficulty of obtaining and retaining the high-level security clearances for staff who conduct space and spatial business with Defence, the national intelligence community, and the Department of Home Affairs as well.
- The cost and difficulty of gaining accreditation under the Defence Industrial Security Program (DISP), which mandates a series of personnel, physical, cyber and other protective security measures that must be met.
- The cost and difficulty in handling US export-controlled data that may be released to Australia and that may be essential to a company's capability to execute a particular contract. Much space and spatially related activity in Australia needs to be cognisant of US export controls.
- Associated limitations on seeking to export some products and services because they contain components that have been released to Australia by the United States in the understanding that they not be released to any other country, at least not without the approval of the US Government.

Commonwealth space and spatial procurements made by Departments and agencies other than those listed above do not attract these security overheads, which is an argument for separation rather than coordination of some space and spatial procurements.

The States and Territories: Turning to the States and territories, they have prime responsibility for industry development and for land management within their jurisdictions, although in practice these responsibilities are shared with the Commonwealth as well. Emergency management (notably the planning for, response to and recovery from floods and fires) is one area that attracts considerable attention in terms of calls for better coordination between jurisdictions, including in space and spatial matters.

Emergency management authorities seek data, from many sources including from databases (to understand trends and variations), satellites, aerial sensors and ground sensors. A frequent comment is that emergency management authorities struggle to make best use of the remote sensing data that is at their disposal. The NSW Inquiry into the 2019-20 bushfires has made this point and recommended (Recommendation 4, p vii) the establishment of a “spatial technology acceleration program” [2]. The issue is not so much with the data but with the culture and understanding of emergency management staff. There is an important end-user training and confidence building task to be undertaken if data currently available, let alone data that may be available in future, is to be used to its full potential.

Of note, the NSW Inquiry report recommended “a single whole-of-government procurement and acquisition program for imagery and LiDAR and that the Government accelerate the building of the State Digital Twin and associated Digital Workbench” (Rec 18, p ix).

A Commercial View: Australia, mainly through the efforts of GA, has comprehensive coverage of the Australian continent dating from the 1970s. Numerous companies have tried unsuccessfully to convince Australia to invest in its own fleet of earth observation satellites and to purchase a variety of spatial data products on long term contracts. These efforts have met with only limited success. Recent experience suggests that space companies that seek to serve just the Australian market will struggle to succeed because there will be insufficient demand to sustain the business. This pessimistic scenario may change if Governments wish to develop a stronger sovereign capability and recognise that there may be additional costs to do so. Without such support, Australian space companies must have an export-oriented mindset and a global business proposition (such as those of Myriota, Skykraft and Fleet) to have any realistic chance of stablishing enduring business success.

The spatial sector is dominated by small companies that serve small numbers of clients mainly in local markets. There are industry sectors in Australia, that may increase productivity if they made better use of spatial data. These opportunities, however, are limited and niche.

Opportunity for Growth

Jurisdictions are increasingly recognising the need for improved procurement. For example ANZLIC supports a shift to whole-of-government and whole-of-jurisdictional thinking, enterprise-wide. ANZLIC sees that this has the potential to yield some substantial benefits including a national approach to imagery acquisition, more certainty for providers, promotion of big data analytics rather than small, piece-meal processing, more effective use of public funds procurement of imagery, and licencing of commercially available analytics software.

Similarly, defence has a potentially very significant role in this regard as explained more fully in the issue on improving the growth environment for SME's and large corporates (Issue <#>).

The various reports produced in the aftermath of the bushfires of the 2019-20 summer have done much to normalise the fact of climate change in the Australian body politic and in political discourse. Whilst some still question the importance or relevance of anthropogenic influences, those voices are diminishing, leading to the potential for more considered debate about climate and energy policy and the links between the two. This changing dynamic offers the space and spatial sectors an opportunity to dispassionately and carefully place data before politicians, officials and the broader public that shows change and impact (including evidence of recovery especially as a result of the present La Nina cycle).

There may be opportunities to revisit Australia's use of offsets as well.

Actions

This section sets aside Defence procurement in both the space and spatial sectors. Issues and opportunities from this specific issue are addressed elsewhere in this paper.

Actions that might lead to jurisdictions making more effective use of space and spatial service include:

1. Adopting and broadening the concept proposed in the NSW Bushfire inquiry of a spatial technology acceleration program. A vital element of this program is to inform and educate end users across government of the uses and value of remote sensing data. To have any chance of success, this would be a multi-level program with briefings offered to Ministers and MPs, and to senior departmental and agency officials. Business benefits, not technology, would need to be the emphasis of this program. It should be vendor neutral and could be delivered under the auspices of the SIAA and SIBA – GITA.
2. Facilitating more assistance to the Australian Space Agency in order that it has greater capacity to provide assistance to space companies to obtain launch licences and related approvals.
3. Developing industry wide views on what sovereign space and spatial sectors would do and not do and how big these sectors would need to be to meet test of necessity and sufficiency.
4. Providing further encouragement to the Commonwealth to develop national policy with respect to space exploration that is then resourced, funded and managed over an extended period to give companies the certainty they need to invest in long lead time technologies, specialist tools and facilities and appropriately trained and qualified people.

5.6. Space and Spatial Enablement of the Public Service

Challenge	The Thodey report https://www.apsreview.gov.au into the Australian Public Service pointed to the need for urgent improvements so that Australia can leverage the full potential of digital systems and data analytics facilitated by suitably skilled people. This observation is particularly prescient for space and spatial.
Opportunity for Growth	The understanding of space and spatial, their science and critical industries, and the fundamental role they will play in our future is critically lacking as a general capability in the civilian arms of the public sector (with some exceptions including the Australian Space Agency, GA, and the operational arms of the spatial areas in State and Territory agencies). The Thodey review recommends an ambitious transformation program that is owned by APS leaders, with measurable targets to track progress and ensure a major capability rebuild. It is crucial that space and spatial be included explicitly in this transformation program.
Actions	1. Develop and implement a space and spatial awareness program for public service at all layers of government aimed at enhanced understanding of policy, technological and regulatory implications of space and spatial systems and services across Australia's society and economy as a formal part of the implementation of the Thodey review. 2. The development of case studies of existing best practice would inform the awareness program.

5.7. A Dedicated R&D Section within the Space and Spatial Growth RoadMap

Challenge

Creating and harnessing the enormous number of innovations that are set to occur in the space and spatial industries requires a national approach and a long-range view.

Opportunity for Growth

Australia has a large amount of space and spatial related R&D activity occurring across the publicly funded research sector and in the hundreds of Australian SME's. This research activity is fragmented, lacks critical mass and prior to the recent development of SmartSat CRC, lacks focus against an over-arching conception of where the nation needs to be in a decade's time and beyond.

For space and spatial innovation to lead to successful and enduring outcomes of national and international significance decadal plans need to be laid and a coordinated approach articulated and agreed to by the key contributors.

SmartSat CRC has identified a series of technologies as priorities for its collaborative research in a roadmap. Whilst this roadmap has been set up to serve the needs of the SmartSat CRC's 100 partners and has been designed to serve both the ASA's priorities and those of Defence, it represents only part of the national R&D requirements. Other important parts are provided by CSIRO, Defence (primarily through DST), universities, government agencies (e.g. GA) and companies. Which areas of R&D represent the highest priority for Australia? Are they sufficiently resourced at present? Candidate priority areas include quantum key distribution, PNT and its convergence with communications, digital engineering (building on BIM's), Digital Twins, spatial knowledge infrastructure, and optical/hybrid RF communications amongst others.

Actions

1. Develop an R&D component of the RoadMap for the space and spatial industries that sets out the national challenges, the priority areas for investment, and the mechanisms by which the private sector and the publicly funded research sector can best cooperate to optimise the innovation pipeline.
2. The RoadMap could usefully include a statement on the R&D infrastructure that could be developed for use by all interested organisations.

5.8. Effectiveness of Space and Spatial Governance Arrangements, Particularly for Disaster Response

Challenge

Climate change is the great challenge our time. In Australia it is causing devasting fires on a scale never before seen with predictions of much worse to come. Other natural disasters are expected to increase in frequency and intensity including droughts, cyclones, extreme storms and massive coastal inundation putting lives, livelihoods, ecosystems and critical infrastructure at grave risk over the coming century. These are occurring over increasingly greater areas. The role of space and spatial systems in providing monitoring capabilities and supporting forecasting, planning, and recovery operations will be vital.

So what more can be done, that has not already been identified to deploy space and spatial capabilities to greater effect in the effort to deal with disasters?

Opportunity for Growth

The Royal Commission into National Natural Disaster Arrangements found that better national coordination in response to natural hazards is needed. A series of recommendations supporting better decision making involve data management as applied to spatial data.

"Australian, state and territory governments should explore the feasibility and practicalities of developing and maintaining nationally consistent assessments and projections of the frequency, intensity and spatial distribution of natural hazards in Australia."

The source of much of this data is earth observation satellites owned and operated by non-Australian entities . Submissions from every state and territory as well as the Bureau of Meteorology, CSIRO and Emergency Management Australia stated that improved data capabilities from sensors, including satellite-based sensors, was required [page 116 of report].

The report noted that recommendations for nationally consistent data for disaster information has been a recurring theme in reviews and enquiries since at least 2002.

Actions

The development of a nationally coordinated approach to the use of space and spatial capabilities is becoming an increasingly high priority.

1. Australia should consider the development and implementation of a national capability plan to exploit advanced satellite enabled communications and IoT connectivity technologies that augment current systems, especially through the ability to provide short notice emergency connectivity and the rapid restoration of medium-term communications during the response and recovery phases of a natural disaster.
2. Australia should consider investing in nationally coordinated and consistent approach to data management, data fusion and analytics systems with the objective of building the equivalent of an Australian Disaster Resiliency Digital Twin. This development could support the development of optimized and sovereign solutions to gaps in national capabilities for real-time data fusion and analytics. The outcome would be a national asset that supports more effective land management, planning, emergency response and recovery across the nation.

5.9. Diversity and Inclusion Across the Space and Spatial Communities

Challenge

The space and spatial sectors are facing a shortage of talent in Australia. In the space sector, the Australian Space Agency is responding with the goal of creating 20,000 new jobs by 2030, whereas the spatial sector has several dedicated initiatives to increase the pipeline of professionals: in the spatial sector it is estimated that by 2025, there will be a shortfall of approximately 1,300 graduate or licensed surveyors and 300 geospatial specialists with university degrees. Looking at the sector make up, the spatial sector is currently male dominated, with only one quarter of the spatial workforce being female and with significant pay gaps between men and women. More broadly, there is limited evidence of cultural diversity, indigenous employment, or people with disability in the sector. Data for the nascent Australian space sector is scarce, however envisaged to be similar to the spatial sector, as skilled space professionals emerge primarily from STEM fields.

Opportunity for Growth

For the space and spatial sectors to be able to sustainably grow, innovate and deliver leading and useful research in the coming years, a diverse workforce will be needed. This will include diversity of background – starting with gender – but also diversity of thinking approaches. Peak bodies in both the space and spatial sector are strongly advocating for this change and making progress, either individually (e.g. Australian Space Agency having reached 50/50 gender balance) or in a coordinated fashion (e.g. the Space, Spatial and Surveying Diversity Leadership Network). For those efforts to be maximised and leveraged, coordination across both sectors is paramount and would result in increased benefits.

Actions

1. Establish a coordinating diversity and inclusion (D&I) group for the space, spatial and surveying sectors with the mandate to leverage, amplify and expand existing successful D&I initiatives and actions plans at sector level. The group should have representation from the peak bodies of each sector, and include a working party resourced to benchmark, monitor and report on the state of D&I in the sector on a regular basis.

5.10. Space as an Operational Domain for Defence Capability

Challenge

The July publication of the 2020 Defence Strategic Update and Force Structure Plan (FSP) outlined a number of strategic challenges in the Space Domain. Australia's growing security dependence on space and the increasing vulnerability of national security space capabilities create the need to rethink the scope and scale of Defence space capabilities. The FSP states the intent for sovereign space capabilities in both satellite communication and satellite imaging capabilities. As a result, there are now new opportunities for developing Australian industry content and sovereign capabilities for national defence and security. The FSP identified a number of capability investments in satellite communications, resilient PNT, space domain awareness and geospatial intelligence that represent out largest national investment in space and supporting systems. These are set out in Table 3:

Opportunity for Growth

Domain	Capability Investment	Start Year	End Year	Lower Cost ($m)	Upper Cost ($m)
Space	Satellite Communications	2020	2030	$4,600	$6,900
Space	Satellite Communications Assurance	2028	2038	$1,700	$2,500
Space	Terrestrial Operations in Contested Space	2027	2038	$1,400	$2,000
Space	Space Situational Awareness	2020	2033	$1,300	$2,000
Defence Enterprise	Satellite Imagery Capability (access)	2020	2032	$400	$500
Defence Enterprise	Sovereign Satellite Imagery Capability	2020	2034	$3,200	$4,800
Defence Enterprise	Additional Sovereign Satellite Imagery Capability	2032	2040	$1,200	$1,800
Maritime	Maritime C5ISREW (SATCOM Terminals)	N/A	N/A	N/A	N/A
Land	Battlefield Communications (SATCOM Terminals)	2025	2040	N/A	N/A
Total				**$13,800**	**$20,500**

Table 3: Planning funding for space and spatial initiatives in the 2020 Defence Strategic Update

This funding represents a strong opportunity for Australia's space industry to participate in the development and delivery of solutions that meet future national security needs.

- The scale of this investment and the stated goals of the government related to Australian Industry impact a wide range of space and spatial technologies and systems. Australia needs to position its industrial sector to ensure these important future capabilities can be delivered, sustained and operated in an increasingly contested space environment.
- The increased funding identified for acquisition and sustainment will require increased employment in a range as space and spatial disciplines related to operation of space systems and data systems supporting geospatial intelligence and space situational awareness.

Actions

1. Identify critical Defence space capability elements that require a high degree of nationally based development, operation and sustainment and ensure these areas are recognised as priorities for R&D investment and workforce planning.
2. This could be undertaken by setting up a joint working party with industry associations comprising SIAA, SIBA-GITA, FrontierSI, SSSI and Defence representatives.

5.11. Space Manufacturing in Australia

Challenge

Australia's capacity to manufacture critical elements of space systems is increasing but from a much lower base than countries with equivalent economies. Key issues for consideration include the focal areas for growth including sovereign capability, the balance of sourcing from domestic markets and international markets, the right size for Australia's space manufacturing and testing capability, and answering the question of how to sustain this capability in a globally competitive and often distorted market? Other countries use offsets to "protect" national capabilities, but Australia moved away from that policy some time ago. What mechanisms can be brought to bear to ensure Australian manufacturers can compete in international markets? Should a level of Australian content be mandated?

Manufacturing in Australia has been in decline for many years. However, it nose-dived with the collapse of the motor vehicle manufacturing industry in the last decade. In the context of the 2020 Commonwealth Budget a $1.5 billion fund was announced to kickstart manufacturing in Australia focused on six key sectors judged by Government to be areas of advantage or having potential for growth in new and emerging areas. One of these key sectors is space.

There are many challenges facing the overall manufacturing sector in Australia. However, the space and spatial sectors face some specific issues, discussed below.

Workforce

- Shortages of skilled and experienced staff;
- An age profile that is skewed to the young and the old, with a thin band of people in the 35-55 years age bracket;
- Women are grossly under-represented, although several space and spatial industry leaders are women;
- Indigenous people and other ethnic minorities are also under-represented.

Organisations

Universities shoulder a disproportionate proportion of the space sector workload. They also struggle to attract students in sufficient numbers into the disciplines associated with remote sensing. The extent to which the universities will be able to continue to shoulder this load is problematic, given the recent collapse in revenues to the sector and the severe belt-tightening occurring across the sector.

Much of Australia's space and spatial workforce is employed in government funded organisations, notably CSIRO, DST Group, BoM and GA.

Most private companies operating in the space and spatial sectors are SMEs and start-ups. Many of the start-ups are built around a technology that has been developed by the business owner. The small size of these companies, almost by definition, can limit the formality of many processes that governments and larger businesses sometimes insist upon. These include, but are not limited to:

- governance arrangements,
- adoption of and adherence to specific quality and other standards,
- cyber awareness and cyber security,
- business continuity and disaster recovery plans,
- IP protection policies,
- succession planning,
- business development and marketing strategies and capabilities.

Research and Innovation

When compared to nations of comparable size and wealth, Australia spends relatively little on research and development across the board. Successive governments have taken a view that if a company needs to invest in R&D to capitalise on a market opportunity, it will find the resources to do so. In recent months, R&D tax concessions policy has been overhauled, but the new model continues to attract more criticism than support from companies in most if

Export Potential

High wages, a relatively strong dollar and Australia's distance from markets in which its manufactured goods may be competitive combine to make the export of goods that are made in Australia difficult to sell overseas at competitive prices.

Opportunity for Growth

Three opportunities for growth are identified:

- Investment in sovereign capabilities. The Commonwealth Government has kick started the process with the $1.5 billion announced for manufacturing in the October 2020 Budget, however, more detail will be required to determine how the selected industries can be made more sustainable over time.
- Better informed users, leading to increased domestic sales.
- Increased exports – the many challenges already identified, notwithstanding.

Actions

1. Companies redouble their efforts to seek grant funding to improve their businesses, making them more competitive in domestic and international markets.
2. That industry associations encourage space and spatial companies to take full advantage of the services offered by the Centre for Defence Industry Capability (CDIC) and other industry grants programs within the Department of Industry, Science, Energy and Resources and in from the States and Territories.
3. That industry associations encourage and assist Australia's space and spatial companies to adopt a mindset of uncompromising quality, as a hallmark of Australian manufacturing – using Australian involvement in the JSF program as a model.
4. That industry associations devise ways and means to provide their SME and start-up members with affordable business skilling programs, as opposed to technical advice, in business development, marketing, IP protection, business strategy and planning.
5. That industry associations work together to improve and extend the programs that will emerge as a result of the Government's commitment to spend $1.5 billon on delivery of the Modern Manufacturing Strategy over the next few years.

5.12. Digital Engineering for Space

Challenge

Spacecraft launched to space require remote operation by their very nature. Simulation tools have been developed widely across the world over the past 50 years. These simulation tools can vary greatly and can present a computer aided design (CAD) of the spacecraft, simulated satellite models used for thermal and structural analyses through to operations simulation tools. Many different tools are also used to monitor and operate spacecraft on a daily basis, including simulation tools where manoeuvres and other events can be simulated prior to performing these activities on the assets themselves. Many of these simulation tools are very well developed and suitable for specific applications, however many are not well integrated (although some may not benefit from such an integration).

Australia is currently producing a small number of satellites, typically CubeSats, which are bespoke. Developing sophisticated and/or integrated simulation tools for a small number of bespoke satellites, where typical contract values are small (in comparison to the global sector) and customers do not yet see the value, is difficult.

Opportunity for Growth

Many simulation tools, such as “spacecraft digital twins” are starting to be developed by large organisations where they see value in these activities (e.g. constellations like OneWeb have developed a satellite digital twin, large satellite manufacturers have developed more sophisticated tools to aid in integration activities and NASA is performing research in the area).

Increased simulation tools to support activities such as on-ground integration and testing and on-orbit testing and the integration of the various existing simulation tools may provide value to Australia’s space sector as it grows and more satellites are manufactured here.

These simulation tools may also be useful to support other space activities.

Actions

1. research bodies and academia to investigate the value of “digital twins” within the space sector, when applicable with a priority given to bespoke manufacture of smaller satellites and its componentry, in conjunction with industry, with the investigation to be coordinated by SIAA, SIBA-GITA, FrontierSI and SmartSat CRC.

5.13. Launch and access to space

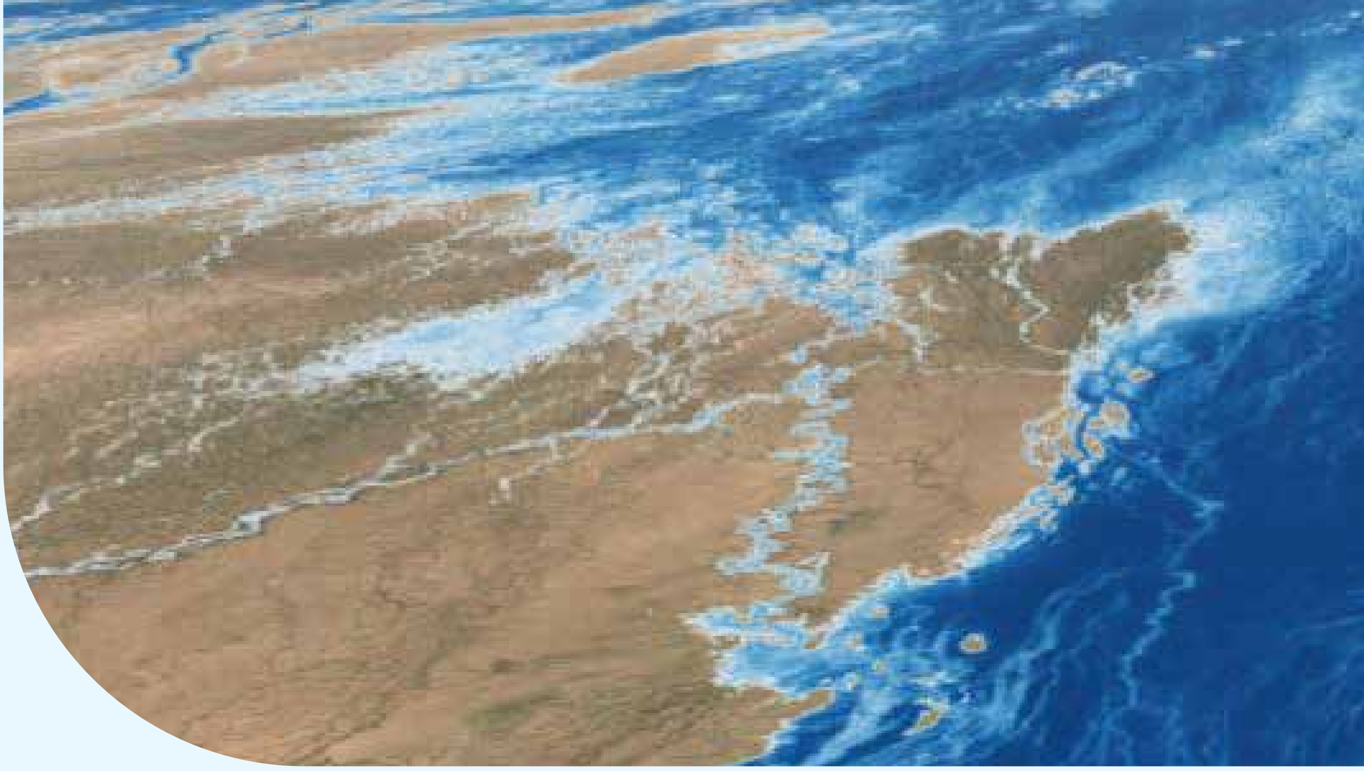
Challenge

Reliable access to space is critical to the growth of the Australian space sector – without sustainable and cost-effective avenues to launch Australian satellites the Australian space industry will be constrained. Australia needs to ensure that its companies and Government agencies have reliable and timely access to launch capability serving all orbits and launch inclinations to maximise the growth of the Australian space sector and to ensure the ability to maintain critical space-based services.

Historically across the globe launch vehicle manufacture and launch operations were a state controlled or state-funded activity with commercial payloads seeking opportunities from operators primarily serving the government market. Commercial services for non-state satellite operators were constrained by the capability (launch mass and orbital characteristics) and cost effectiveness of launch vehicles designed for government missions and their ability to get on the launch manifest. This is changing with the emergence of privately-owned commercial operators such as SpaceX, RocketLab and Blue Origin developing launch services to serve the commercial market. In spite of this trend towards commercial launch activities (even NASA now uses commercial services for human spaceflight) governments remain the largest purchaser of launch services by number of launches even though commercial satellites now outnumber government satellites due to the proliferation of large commercial satellite constellations (SpaceX has launched 829 operational Starlink satellites between May 2019 and October 2020).

The growth of the commercial launch market has expanded the range of launch operators and new innovations (such as first stage reusability) have reduced the cost to orbit. However, launch remains a potential bottleneck for the Australian satellite industry particularly at the small satellite end of the market (smallsats, cubesats) comprising most current Australian satellite activities. The improvements achieved by the launch industry do not necessarily scale directly to the small satellite market. Launch is typically the second largest cost in a large satellite program (after the cost of the satellite) but a dedicated launch can exceed the satellite build costs for a small satellite. Cheaper ride-share (shared launches) opportunities are available for small satellites but limit the orbit and the launch timeline to that of the primary payload. Satisfying the Australian regulatory requirements can also be a major issue for ride-share satellites which have little say in the key decisions regarding the launch.

In spite of the growing commercial launch industry the dual-use nature of rocket technology (ability to also be used as weapons) and the importance of space from a national security perspective continues to impact launch availability. In recent years China has emerged as the world leader in number of launches conducted per year yet Australian satellite operators are largely denied access to these launch vehicles due to a US ban on US parts and systems being launched from China. The recent tensions between Russia and Ukraine have effectively removed the highly effective Sea Launch program and Zenit-3 launch vehicle from the market. The launch market is susceptible to geopolitical forces which can lead to being bumped from a launch manifest to accommodate a military launch to denial of access to certain parts of the launch market. Australia needs to determine whether the current level of reliance on international organisations for launch meets our future needs including our sovereign needs for access to space.



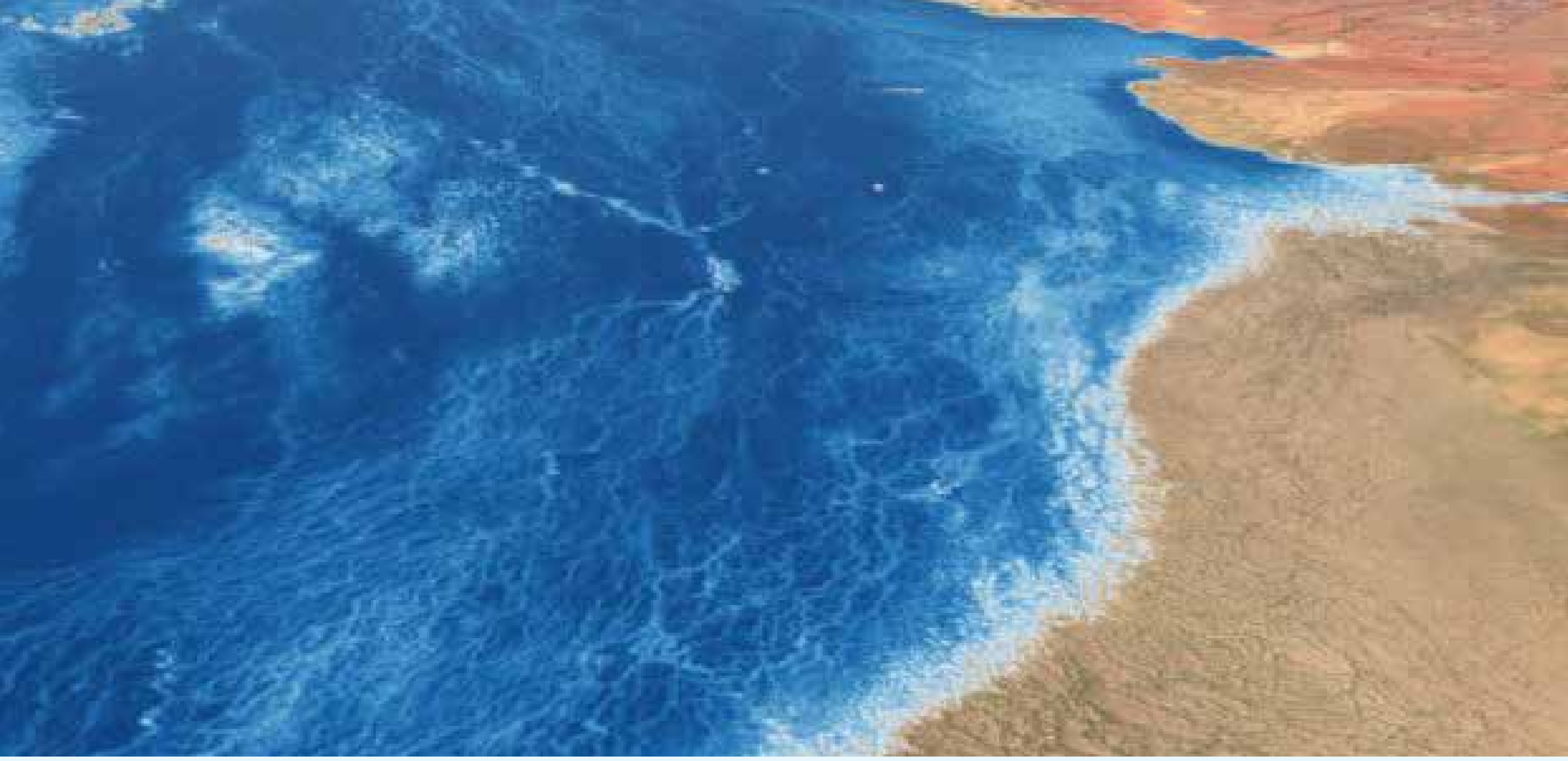
Opportunity for Growth

The launch market is dynamic with continual efforts to improve access to space with more reliable and cost-effective launch capability. A key target is the small satellite market where a race to develop cost effective access to space is underway including by Australian companies

Geography is a key factor for launch sites with proximity to the equator and ability to safely launch over open water or unpopulated areas to all launch azimuths from 0 to 98 degrees while minimising overflight of neighbouring countries. Australia is among the few nations that has this capability and is a good location for launch and testing of new vehicles. Australian companies are currently developing launch sites to capitalise on these advantages.

Another emerging opportunity is space tourism and point-to-point travel. Australia is well positioned to become the space tourism hub for Asia and be involved in the development of sub-orbital point-to-point travel, first for fast package delivery and subsequently for human travel around the globe in less than 90 minutes. SpaceX is well advanced with this concept with Australia considered a key initial location and the US military is now evaluating this as means of rapid supply and potentially troop movements globally. No country will benefit more from rapid intercontinental travel than Australia.

Finally, the US plans to return to the Moon, the goal being to harvest and transport space materials as well as the desire to reposition satellites to specific orbits are driving developments of orbital transport systems to move objects to and from LEO to MEO and GEO orbits, beyond GEO, Cis-lunar, Trans-lunar, the Lagrange Points and others. This includes the ability for subsystem recovery/re-use, space vehicle servicing, orbital transfer, orbital debris collection, and replenishment of consumables and expendables on spacecraft that cannot be recovered back to Earth (e.g., spacecraft inspection/servicing, refuelling, hardware maintenance, and technology upgrades) as well as on orbit assembly and sustainment of spacecraft. Australian companies are among many that are actively involved in these developments.



Actions

1. Access to space is such a critical component for the growth of the Australian space sector that the Australian space community and Australian Government should take active measures to ensure that Australia has reliable access to space. Actions could include:
2. Ensuring that the licensing regime for launching Australian payloads overseas is as streamlined as possible. The new Rules are an improvement and there is further scope to pre-qualify specific launch sites/launch vehicles which would greatly expedite the licensing process.
3. Ensuring that the licensing regime for domestic launch is no more onerous to Australian launch providers than that faced by their international competitors. The current system requires Australian launch operators to pay for safety analyses that are conducted by the government in other jurisdictions (US, NZ, Japan, China, Russia). These analyses are necessary and similar for both large and small launch vehicles but become a significant fraction of the total cost for small vehicles launching the smaller payloads which is the market entry point for Australian launch providers. These costs represent a significant hurdle for Australian competitors in this competitively priced market.
4. Ensuring that the Australian launch regulatory system is reviewed often to ensure that it is as streamlined as possible (while protecting public safety) and capable of supporting emerging technology. Australia could consider enacting legislation that enables human spaceflight from Australia to position itself to become the space tourism hub for the Asia Pacific and able to be involved in the development of suborbital point-to-point transportation.
5. Supporting the Australian launch providers by purchasing Australian rather than overseas launches wherever practicable. Historically national government support as a major customer/supporter has been a key factor in the success of most commercial launch suppliers.
6. Undertaking a detailed review of the importance and criticality of sovereign space launch capability. Is Australia's current reliance on the commercial launch market to supply its access to space sufficiently robust to ensure that Australia can launch its national security, weather & environmental monitoring, positioning and commercial satellites when it needs to? Can Australia withstand potential disruptions to the commercial launch market from geopolitical events (including bans on launching from certain countries), launch vehicle stand-down due to failure, supply chain disruptions and delays (including from pandemic health issues) and market saturation which prevents timely placement on a launch manifest? Would a sovereign launch capability provide more resilience for access to space while supporting

5.14. Space Domain Awareness and Congestion

Challenge

Over the last sixty years, humankind has launched thousands of objects into space and in the process has created large amounts of space debris in addition to defunct and operational satellites. The space debris ranges in size from rocket bodies the size of a bus through to hundreds of thousands of objects less than 10 cm in diameter. With orbital velocities exceeding 8 km/second, the kinetic energy in even small objects is sufficient to cause catastrophic damage to satellites. The orbital debris problem exists at all satellite orbits but is exacerbated at low orbits (<1200 km) due to the vastly larger quantities of debris objects at lower orbits. The challenge that this presents is significant as many of the new space projects under development are destined for these low earth orbits. These projects include constellations of thousands of communication satellites, earth observation satellites, academic research projects and remote sensing capabilities.

Currently Australia accesses information on objects in space through military organisations and relies upon the US Department of Defense to compile this data. Australia contributes to this knowledge through a range of sensors located within Australia and is party to a multi-lateral Space Operations Centre organisation that facilitates space domain awareness. With growing commercial interests in space and rising levels of orbital congestion, Australia needs to determine whether this arrangement is suitable for the future and whether additional sensors and data management capabilities within Australia will better assure space domain awareness and our understanding of risks and hazards to our space economy due to events occurring in space (including space weather).

Opportunity for Growth

By virtue of its geographic span from coast to coast and southern hemisphere location, Australia is uniquely placed to make valuable contributions to global efforts to better characterise objects in space (operational satellites as well as inactive satellites and space debris).

The establishment of a network of ground-based systems including optical (narrow field of view and wide field of view) sensors and radar (active and passive) systems which are tasked by a mission control system would be of real value. The observations would be stored in a unified data lake where they would be available for object characterisation, orbit determination and conjunction analysis.

This Space Domain Awareness (SDA) system would provide situational awareness for Australian space objects, allowing operators to manoeuvre satellites to avoid collisions with other resident space objects such as uncontrolled space debris. The network of sensors could form a dual use system which would meet Australian Defence and civil space requirements (thus addressing Australian space agency goals for SDA). Australia would also be able to contribute observations to international partners to assist with global efforts to improve SDA and contribute to efforts to better manage space debris.

Actions

1. Development of a roadmap for establishment of a network of Australian based sensors for detection and characterisation of objects in space. Capability is to include orbit determination and conjunction analysis to identify objects at potential risk of collision.
2. Establishment of a network of Australian based SDA sensors. The network will be controlled by a mission system and the observations stored in a unified data lake to enable characterisation of objects, determination of orbital parameters and predictions of orbital conjunctions.

5.15. Space as a Contested Domain

Challenge

Space is rapidly becoming a contested domain. This raises higher levels of concern that the competition and congestion which largely arises from commercial interests. The US Defense Space Strategy released in June 2020 states "China and Russia have each weaponized space as a means to reduce U.S. and allied military effectiveness and challenge our freedom of operation in space". This assessment has implications for Australia as a key member of the 'Five-Eyes' community and a leading regional security partner of the USA. A recent report from CSIS states "While discussions continue at the United Nations about preventing an arms race in space, the actions of some nations – namely Russia and China – are leading others to prepare for conflict." In a 2019 speech , the French Minister for the Armed Forces, Ms Florence Parly, stated "If our satellites are threatened, we will consider dazzling those of our opponents. We reserve the time and means of the response: this may involve the use of high-power lasers deployed from our satellites or from our patrol nano-satellites".

These public comments highlight the growing perception of risk from military actions to space-based assets. Technology developments aimed at reducing strategic advantage gained by use of advanced space systems may impact on non-military space assets. This is especially true given the dual-use nature of many space services and the heavy dependence on commercial systems by defence and national security agencies, including those in Australia.

As has been witnessed with cyber operations, targeting of commercial and civilian space infrastructure is possible from both state and non-state actors and this increasing risk may drive a need for increased investment in hardening critical national infrastructure, including supply chains, where that infrastructure relies on space-based systems. The 2020 Defence Strategic Update refers to increasing risk of "grey-zone" activities, actions contrary to our national interest that fall below recognised thresholds of conflict, with the growing risk of these actions targeting space and cyber-space. What emphasis should be placed on this issue in the RoadMap?

Opportunity for Growth

There are many adjacent defence industries in electronic warfare and cyber defence that are well positioned to enter the space sector with the required skills, knowledge and clearances to make an impact by developing solution to protection Australian space systems. This will require acquisition of additional skills in space systems and technologies, potentially leading to employment growth.

Growth opportunities are expected for industry in protecting commercial infrastructure in Australia and internationally arising from skills development in response to Critical Infrastructure Protection legislation update

The application of Artificial Intelligence, Machine Learning, Deep Learning and Data Analytics in detecting anomalous behaviours, modelling system resilience and predictive management of complex systems to mitigate "grey-zone" operations in space.

Actions

1. Determine the exposure of Australian critical infrastructure to defence operated space systems such as the US GPS constellation.
2. Continue Australia's legal and diplomatic efforts (e.g. Project Woomera) to define the application of international law to military uses of space and establish behavioural norms for space operations.
3. Conduct R&D into technologies that can enhance resilience of space services for civilian use at reasonable additional cost.

5.16. Ground Infrastructure and Spectrum Access

Note this issue is covered in part within the ASA Communication Technologies and Services Roadmap 2021–2030.

Challenge

The ability to communicate with satellites and downlink data is vital to the growth of the Australian space sector. Without sufficient spectrum and the capacity to downlink large amounts of data many of the emerging growth areas in the space and spatial domain will be significantly constrained. Australia needs to ensure that its companies have reliable access to spectrum and suitable ground infrastructure for data downlinks to maximise the growth of the Australian space sector.

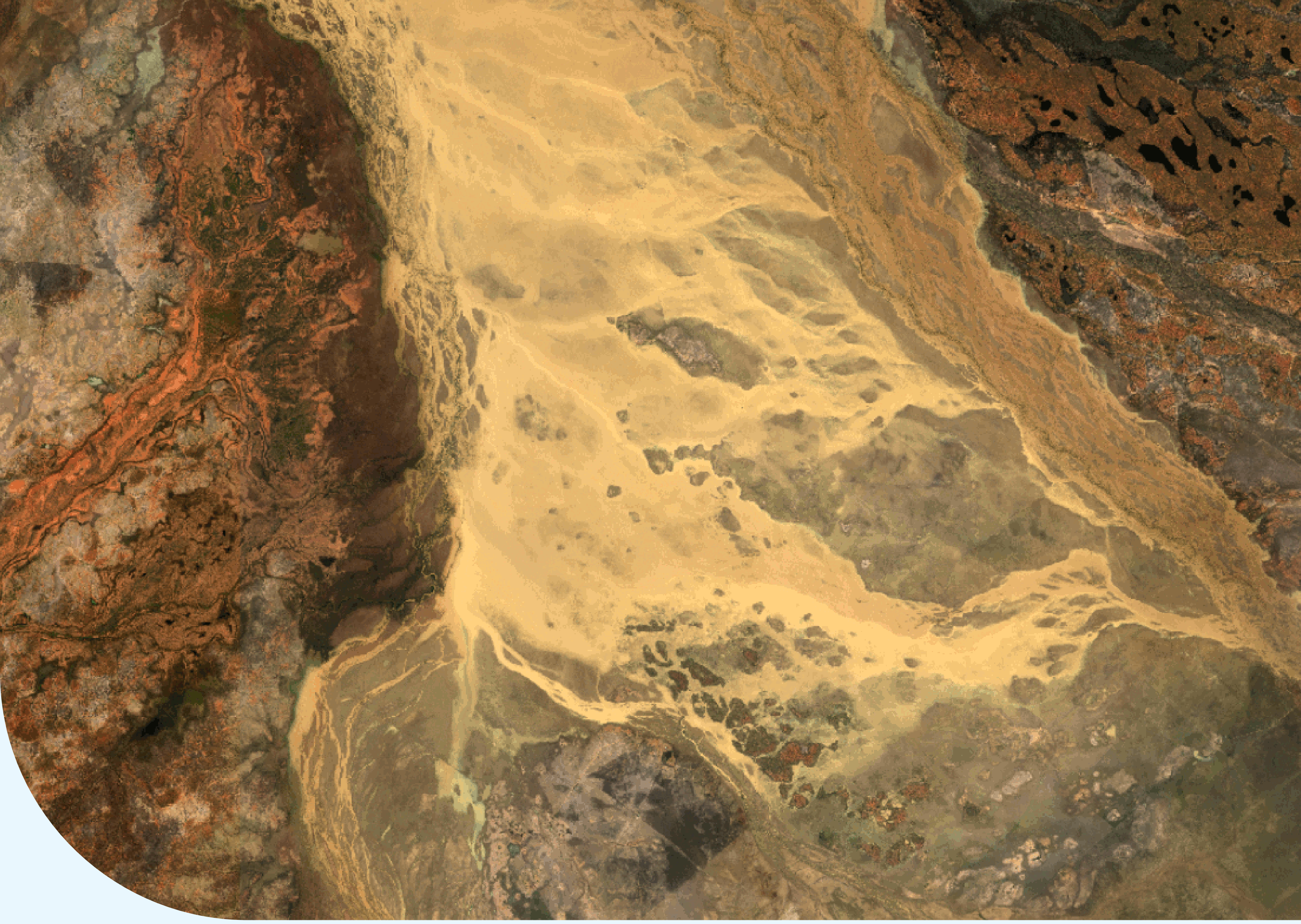
Space spectrum is an increasingly precious commodity that is being challenged on a number of fronts even as the demand for space spectrum is growing significantly. Atmospheric water vapour causes signal attenuation which generally increases with frequency requiring higher power transmitters and better receivers to maintain link margins. C-band spectrum was chosen for GEO satellite links as an optimum spectrum/power trade-off, but C-band is highly desired by the terrestrial mobile phone industry. The potential to generate high license fees from the mobile phone industry prompted the US FCC to move satellites out of most C-band spectrum in the US and the rest of the world is likely to follow. There is a growing issue of how to value satellite spectrum across all relevant satellite bands to ensure it is maintained for growing satellite services in the face of potentially higher spectrum license revenues available from the growing mobile phone industry.

At the same time the significant growth in satellites is creating challenges for new operators to find spectrum for their services without interfering with existing systems. This is particularly acute in LEO with ever increasing satellite constellations and has resulted in both ground and space-based systems which inhibit transmission at times to avoid interference such as when in line of site of GEO satellites. Another emerging challenge is finding spectrum to maintain communications with the growing bandwidth needs of spacecraft in cis-lunar and trans-lunar orbits associated with the return to the Moon without affecting the communications capability and growth of satellites in LEO, MEO and GEO orbits around Earth.

Spatial satellites are not only growing in number but also in sophistication of sensors which are producing increasing amounts of data. This higher fidelity data enables more sophisticated analysis but requires significantly more bandwidth to downlink the information. There is a risk that much of this useful data will be lost without the ground infrastructure and spectrum to enable these higher bandwidth downlinks.

Opportunity for Growth

The challenges of accommodating more satellite systems within existing satellite spectrum as well as finding spectrum for the increasing amounts of data to be downlinked is driving significant development activity. Australia has world class capability in ground infrastructure and has opportunities as a location for ground networks for high volume data downlinks. Australia is well located geographically as a downlink site for spatial data downlinks from LEO satellites passing over Asia as well as offering an alternate site for data downlinks from Europe and North America. Australia's wide geographic footprint offers the opportunity for eastern and western ground network sites that can capture more LEO satellite passes for downlinks. Spectrum congestion is leading to development of additional bands such as V-band as well as the use of optical links where Australia has significant capability. Development of new waveforms to enable shared spectrum and on-board satellite processing to minimise data downlink size are other growth areas where Australia has expertise.



Actions

1. Create strong information campaign to raise awareness across all government departments of the critical strategic importance of satellite spectrum for the space and spatial industry and how erosion of satellite spectrum will reduce the availability of space and spatial services for their department. This information campaign needs to be of sufficient size to counterbalance the ongoing appeals for access to satellite spectrum by the mobile phone industry.
   This awareness campaign needs to make a compelling argument that spectrum for the space and spatial industry is of critical importance even though it might not generate the type of revenue that the mobile phone industry might pay for spectrum licenses, at least in the short to medium term.
2. Australia should play an active role in international fora to preserve key spectrum for space and spatial activities including in higher spectrum bands and for optical links.
3. Explore all opportunities for Australia to provide high speed data downlink sites for space and spatial data particularly for high data downlinks from Asian, European and American satellites. Regional and international spatial fora as well as commercial operators should be made aware of the benefits of data downlink infrastructure in Australia.
4. Encourage and support Australian development of waveforms and spectrum sharing techniques as well as on-board processing techniques to maximise the downlinking of essential data.
5. Encourage and support Australian development of optical downlink capabilities and infrastructure as well as exploration of higher RF bands such as V-band (40–70 GHz) and E-band (70–90 GHz).

5.17. Earth Observation from Space

Challenge

Virtually all of Australia's EO capabilities are supplied by other nations or international companies. Australia's dependence on these satellites, the data they provide and the services that they support is growing rapidly and covers a very broad range of needs, both civilian and defence. Australia has developed a world class satellite imagery analytics and applications capability but has only nascent capability in the upstream supply chain areas of satellite and sensor design, build, launch, task and control. Australia is therefore highly dependent on the rest of the world to provide for its immediate and long-term needs.

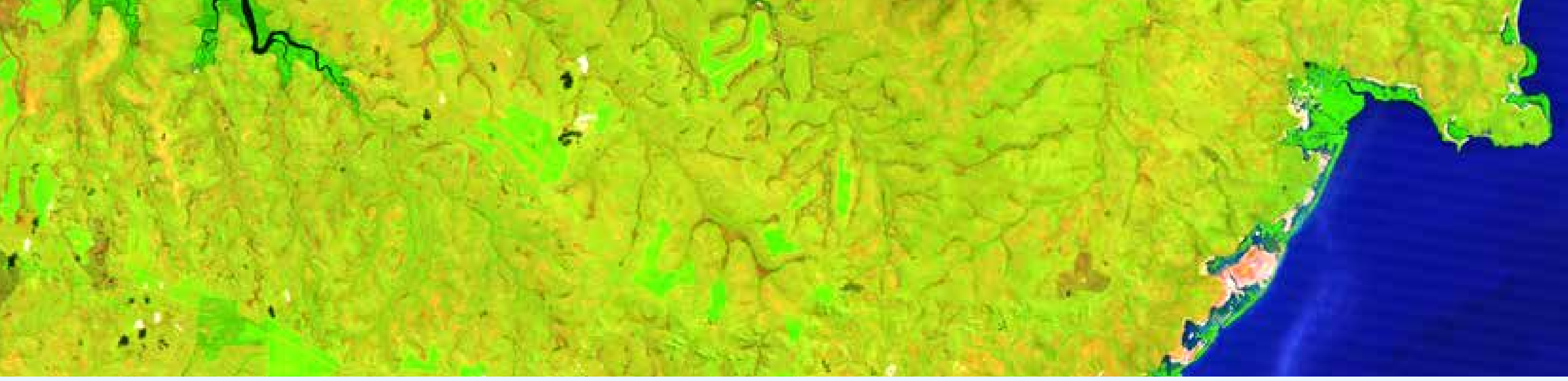
Opportunity for Growth

Australia currently relies on about 20-25 remote sensing satellites for its imagery and sensing needs from space. None of these are Australian owned. With the nascent but growing space start-up industry in Australia now comprising at least 80 companies and the Australia SME sector set for substantial growth there is the opportunity to facilitate a coordinated dual use (civilian – defence) approach to the strategic design and deployment of a constellation of satellites that are built up over the next decade to service the high priority, sovereign needs of Australia.

For example, what is the optimum combination of optical, Near- Infra red (NIR), mid infra-red (MIR) for fire detection and monitoring both now, based on current capabilities, and over the next decade? Continuous monitoring of fires, at operational resolutions, inter-jurisdictionally and nation-wide during catastrophic fire seasons has proven a challenge for Australia. Could this be addressed by a geo-stationary satellite with optical, NIR, MIR and hyperspectral capabilities, with sensor(s) of sufficient ground resolution and signal to noise ratios, coupled with next generation on-board and terrestrial analytics? This is but one of many examples that can be put forward to illustrate the opportunity before Australia of moving from an opportunistic user of the satellites that others choose to launch and operate to a nation of strategic, long term intent.

Actions

1. Australia to investigate the potential for a national approach to the long-term development and deployment of a constellation of satellites, and their supporting systems, to service high priority needs in both the civilian and defence sectors, including examining the role Australia could play at all stages of the space and spatial supply chain. This investigation could usefully be undertaken by a working group drawn from Defence, the Australian Space Agency, CSIRO, Geoscience Australia, SIAA, SIBA-GITA, EOA and SmartSat CRC.



5.18. Ubiquitous and Low-Cost Connectivity

Challenge

What is the potential benefits of a new class of service that provides low volume data connectivity at low cost (cost of terminal or cost of service, including IoT's)?

For decades Australia has pioneered the application of bandwidth and power efficient communications towards advanced satellite communications system. Historically this leading research has resulted in commercialisation by other nations.

Space is on the cusp of a new approach to delivery of satellite communications services with a shift away from television broadcast from geo-stationary satellites towards the provision of high-speed internet services from large constellations of smaller satellites in low earth orbit. This shift from "GEO" to "LEO" will change the dynamics of the satellite communications business and result in ubiquitous and low-cost connectivity.

Technology is also being developed to provide commodity connectivity (i.e. pervasive and low cost) for a range of new application built on the paradigm of Internet of Things.

Australian companies (both based here and listed here) are among the global leaders in this new class of service that could see the cost of short packet-based communication from anywhere in the world to centralised cloud infrastructure approach $0 dollars per message. This dramatic decline in price will fundamentally change the nature of global satellite communications away broadcast and fixed service as the main growth markets.

Opportunity for Growth

New market opportunities potentially exist in traditionally non-space sectors – e.g. agriculture, mining and mineral exploration, water management, energy markets, environmental management, emergency response amongst others.

The market potential for embedded low data connectivity could be speculated to approach the market volumes for embedded PNT devices. If this speculation is accurate then it is critical that this value be captured, where-ever possible, by Australian manufacturers and that Australia develop entrepreneurial and engineering skill in the downstream application of satellite IoT connectivity.

Actions

1. (TBD) to develop and deliver a space IoT awareness campaign to grow this sector. This could include innovation competitions targeted at industry, universities, research centres, maker communities etc.
2. (TBD) to ensure the Australian electronics manufacturing sector has a high awareness of the potential growth opportunity from capturing the emerging segment for low cost, embedded satellite messaging/IoT user devices.
3. (TBD) to fund studies aimed at identifying spatial sector and adjacent sector opportunities for space based IoT devices and services.

5.19. Resilient and Extreme Reliability Connectivity for Safety of Life

Challenge

The Cospas-Sarsat system has been operational for almost 40 years providing a global distress system to support and enhance search and rescue operations. The service is provided through a treaty-based, intergovernmental organisation with 45 signatories. Australian representation is through the Australian Maritime Safety Authority (AMSA) within the Department for Infrastructure, Transport, Regional Development and Communications. AMSA manages ground stations for the system in QLD and WA with a Mission Control Centre in the ACT.

The first-generation service was supported by a number of Low Earth Orbit satellites (LEOSAR) and geo-stationary satellites (GEOSAR) and supporting ground stations around the world. The second-generation system is currently deploying hosted payloads on a range of GNSS satellites in Medium Earth Orbit (MEOSAR) which will improve system performance, both in geo-location accuracy and latency of emergency beacon activation detection.

The Cospas-Sarsat systems uses a single 100kHz worldwide spectrum allocation at 406 MHz to support maritime, aviation and land-based search and rescue for safety of life.

Current limitations and issues with the current system include:

- Low powered beacon (user segment) combined with current satellite design severely limits communications performance, particularly during an emergency. Very little useful information content can be exchanged during the emergency.
- False alarms can result in unnecessary search and rescue operations that are expensive and high-risk to emergency and military personnel
- Beacon life and reliability can be uncertain
- Location accuracy can be poor – first generation systems provide a 1km CEP and second-generation systems offer 150m without access to GNSS. This inaccuracy limits applications
- High cost – low production quantities and beacon design result in higher cost per unit limiting market potential.
- Regional uptake is low – currently the USA and Australia represent the bulk of global ownership of beacons
- No integration – the beacon design limits the ability for value-added integration with contemporary personal devices such as smart watches, smart phones.

Opportunity for Growth

Australian expertise in reliable, power and bandwidth efficient satellite communication is contributing to new thinking about this legacy search and rescue system. The intent is to develop a new satellite communications protocols for a third-generation system featuring increased capacity, greater service reliability, two-way connectivity and improved location estimation. There are opportunities to explore utilisation of emerging Australian technology through existing Cospas-Sarsat infrastructure and extension to new satellite developments and safety of life for space exploration, in partnership with the Australian Space Agency and NASA.

For example, it was recently announced that Australian research into advanced search and rescue technologies would contribute to the NASA Artemis LunaNet architecture .

Future phases of the SmartSat CRC collaboration could support exploration initiatives like the Artemis missions, which will return humans to the Moon for the first time since Apollo. NASA will equip Artemis astronauts with second-generation beacons for use if needed for egress from capsule after splashdown or a launch abort scenario. The Search and Rescue team is working to extend beacon services to the lunar surface with the LunaNet communications and navigation architecture.

Developing a contemporary implementation of a safety of life personal device that can be mass produced at low cost and with high reliability will create scope for Australian industry to lead international production and supply regional countries with personal beacons. Increased capacity in the overall system will enable new applications for emergency services and remote workforce. The ability to integrate contemporary consumer devices could allow Australian developers to generate new business models and identify new markets/customers.

Actions

1. Open discussions with the Australian Maritime Safety Authority (AMSA) to explore the potential to advocate for the need to develop next generation search and rescue system to support adoption of Australian technology as a standard.
2. Scope and resource R&D project(s) to develop, prototype and demonstrate 3G beacon waveforms and networking protocols.
3. Support the Australian contribution to the NASA Project Artemis and the LunaNet architecture. This could lead to a highly visible Australian contribution to safety of life for all humans involved in lunar and planetary exploration under the Moon to Mars initiative.
4. Explore the potential for Modern Manufacturing Initiative support to develop advanced electronic manufacturing capabilities within Australia targeting satellite consumer devices for a global market

5.20. Augmented, Assured, Australian (AAA)-PNT

Challenge

The rapid and increasing uptake of PNT applications across multiple sectors of the Australian economy shows no sign of slowing, with PNT capabilities being integrated as an operational dependency for myriad applications, as well as critical infrastructure systems such as power utilities, financial services, mobile networks and transportation. Indeed, the augmentation of global constellations with regional systems such as SBAS has only led to greater reliance on PNT, as demonstrated by federal investment into GA's Positioning Australia program.

Consequently, to capitalise on these demands for a PNT system which is accessible, accurate and available for all Australian sectors, a major challenge will be developing an indigenous capability that ensures PNT across the nation by improving its resilience, robustness and trustworthiness over the long-term.

Opportunity for Growth

The importance of GNSS PNT capability to the success of Australia's future has been noted previously, for example in the Australian Civil Space Strategy, where it was identified as a high priority area for growth and investment, and the Australia Academy of Science's (AAS) 2017: A vision for space science and technology in Australia.

Positioning data derived from GNSS is considered by ANZLIC as one of Australia's fundamental data sets, and the AAS has commissioned a new working group for PNT. These all build on previous work started in 2012 to develop the Australian Strategic Plan For GNSS, which proposed a strategic direction for Australia's PNT that would lead to significant benefits including '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'.

Accordingly, the 2012 Strategic Plan set-out four strategic initiatives: (1) Ensure leadership for the Australian GNSS community; (2) Adopt a whole-of-nation approach to a sustainable, multi-GNSS-enabled positioning infrastructure; (3) Mitigate vulnerabilities in existing and future GNSS infrastructure; and (4) Capitalise on Australia's unique geopolitical and geographic advantages. While there has been significant progress within Australia since 2021 towards achieving these four objectives, there is still considerable opportunity from harnessing the future economic, social and environmental impacts of PNT, especially given the evolution of PNT applications, advances in GNSS constellations and their visibility across Australia, therefore it is felt that the time is right to renew the Strategic Plan.

Innovating new capabilities:

- Developing a sovereign capability to monitor and assess both the state of error sources affecting GNSS (as will be realised through the Positioning Australia program) and its inherent integrity is critical not only for positioning and navigation but also for the multitude of applications requiring the timing component currently supplied by GNSS.
- Delivering novel GNSS products that further contribute to our understanding of the dynamic atmosphere for weather forecasting, climatological studies, and the behaviour of the ionosphere and space weather. These products, such as GNSS derived models of atmospheric density, could afford greater resilience to our sovereign PNT capabilities. Additionally, the dynamic impacts of atmospheric effects on PNT are also experienced by other sectors within the growth pillars (Earth Observation, Satellite Communications and Space Domain Awareness (SDA)), so clear collaborative partnerships and knowledge exchange pathways are required to ensure that findings are benefitted across all industry sectors.

- Developing products and services essential for ensuring assured GNSS information for mission-critical and safety-critical PNT applications such as automated industrial machines, robotics, driverless vehicles, aircraft and infrastructure dependent on timing. Inventing, developing and delivering Australia-specific critical PNT integrity messages especially ones pertaining to high accuracy PNT services (such as RTK and PPP), could later become an industry-leading innovation to export regionally and globally further raising Australia's PNT reputation.

Improving infrastructure, mitigating vulnerabilities and assuring access:

- Development of assured PNT capabilities for Australia - meaning one that is suitably protected and secured (with authentication and possibly encryption) - to deliver the required PNT performances under adverse conditions. Assured PNT impacts all aspects of space (both downward and outward looking), and the growing spatial sector.
- Cultivating resilience across our PNT capabilities to better protect against both unintentional and purposeful interference and spoofing across all segments, including but not limited to known incidents such as solar flares, cybersecurity breaches, erroneous almanac uploads and unlikely 'black swan' events.

- Design and implementation of sub-metre (and even decimetre-level) accuracy GNSS systems based on low-cost mass-market GNSS receivers, enhanced via emerging terrestrial 5G telecommunications infrastructure delivering augmentation information for enhanced accuracy and integrity. Ideally, these GNSS products would be developed locally and be fully compatible with Australian PNT information and services.

- Developing and facilitating the integration of space-borne GNSS receivers aboard Australian satellites to support more applications of small satellites for communications, earth observation and PNT, and even on missions beyond Earth orbit, for so-called space service volume navigation.

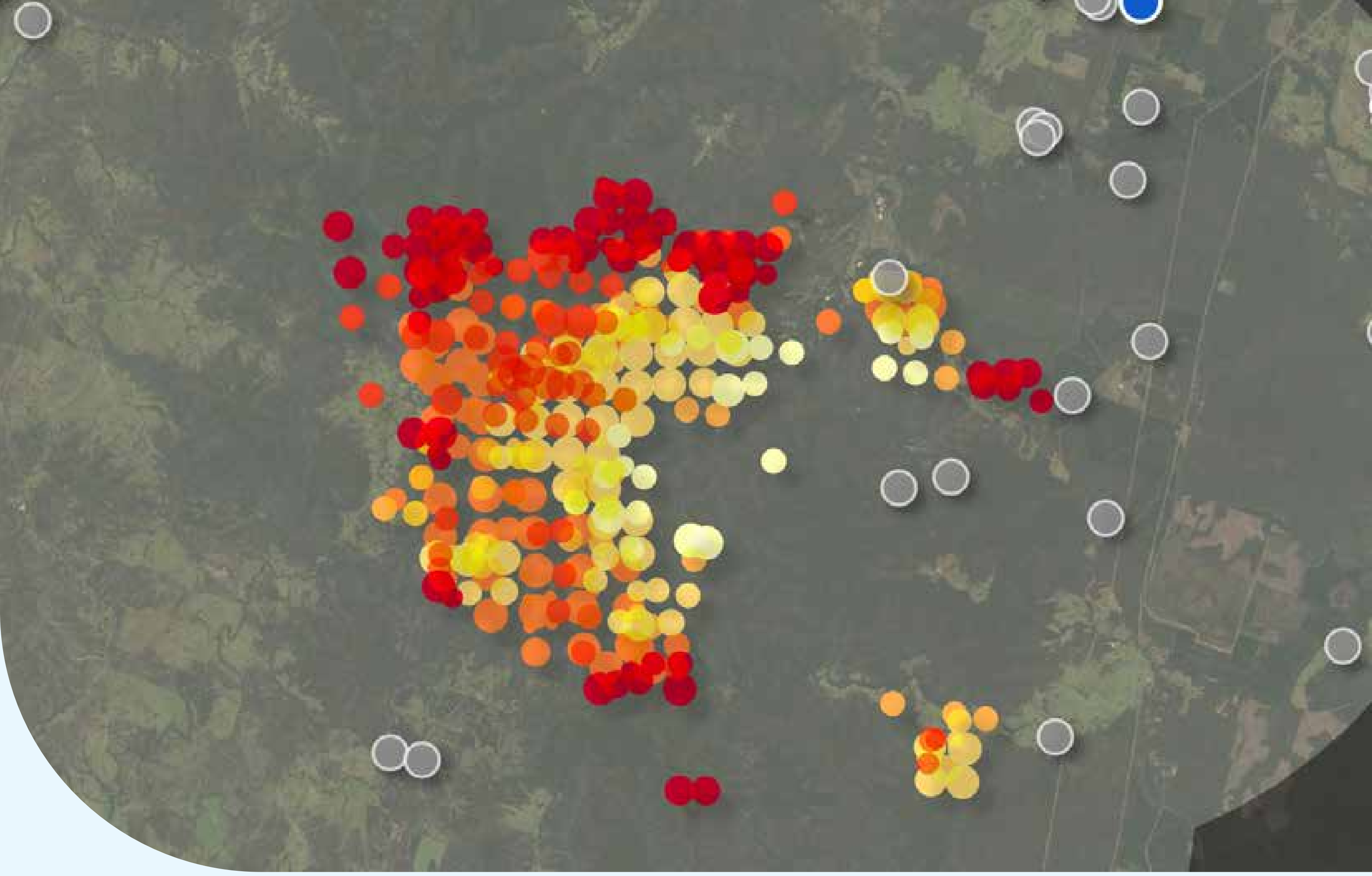
- Augmenting the GNSS space segment, for example using select LEO satellites equipped with appropriate payloads, could provide increased availability of the more advanced PNT techniques (RTK, network RTK, SSR and PPP-RTK). Indeed the provision of sovereign PNT integrity messages (determined for Australia by Australia) transmitted by Australian space infrastructure, must be complemented by simultaneous transmission through secondary terrestrial communications as a robust delivery method.
- Collaborating across federal and state governments to incorporate PNT infrastructure (terrestrial and orbital) and generated services (corrections, integrity, interference) within the Critical Infrastructure Network as part of an ongoing Risk Assessment and Mitigation program.
- Develop real-time capability to detect, measure, geolocate and ultimately mitigate sources of interference and spoofing to GNSS across Australia and realise it as a 'Nationwide GNSS Interference Monitoring Infrastructure'. Such an infrastructure could be hosted and coordinated between federal government and Defence, and report incidents of interference alongside ongoing integrity messages to the wider community, further facilitating the adoption and trust in PNT for Australia, by Australians.
- The successful augmentation of current GNSS with alternate (non-GNSS) PNT coming from emerging technologies promises even greater levels of resilience, robustness and trust around assured PNT for space and spatial sectors.

Actions

Several fundamental activities such as SBAS and NPIC are already progressing under GA's leadership of their Positioning Australia program; by leveraging these deliverables, opportunities exist for significant growth across industries and international borders, with several having potential global outreach/impact.

To capitalise on the numerous opportunities that PNT holds for Australia, a number of governance and policy recommendations are made to facilitate engagement and ensure adoption.

1. Developing an updated 'GNSS Strategic Plan for Promoting Enhanced PNT Capabilities across Australia' detailing industry strategy and aligned incentive mechanisms to facilitate development of high-tech GNSS-related products, services and workforce by local companies and organisations, which endeavour to adopt the new PNT capabilities that will become available across the nation. Leadership of this strategy development will require disciplined coordination across government, Defence, industry and education.
2. Forming a multi-industry group being responsible for monitoring, marketing and evangelising all strategic PNT plans developed and in action across Australia, and providing guidance where necessary, to provide consistency, ensure clarity and eliminate duplication through effective collaboration. Ideally, this could take the form of a 'Strategic Coordination & Engagement Group' or 'Task Force' comprising federal, academic and industry representatives, would be mandated to the new GNSS Strategic Plan, and be an official first point of contact for both Australian and international queries around the PNT innovations.
3. Sustained long-term investing in training and education, as well as research and innovation, to ensure that our industry sectors and workforce possess the capacity, competency and empowerment to take advantage of the opportunities offered by an assured, resilient and augmented PNT across Australia.
4. Mobilise the PNT ecosystem by boosting investments in the research, development, and commercialisation pathways for local companies and industry to create novel high-tech PNT products & services which complement and augment GNSS (connecting upstream space segments with the big primes through SBAS for example, with the downstream markets), ultimately creating new sectors and jobs. These innovations include new quantum sensors, terrestrial positioning systems, vision and imaging sensors, signals-of-opportunity, chip-scale atomic clocks, inertial measurement units and others, along with the sensor fusion engines required to successfully integrate all these measurements together with existing PNT. Mechanisms should also be created to leverage Defence's funding, IP and developments around assured and resilient PNT, into the civilian consumer marketplace through appropriate fast-track commercialisation pathways. New service industries utilising PNT should be fostered and encouraged to promote nationally and export internationally.
5. Encouraging international collaboration with key partners on prospective plans for new PNT capabilities – both space- and ground-based. Strengthen Australia's capability to understand, analyse and leverage strategic advantages and opportunities of partnering on emerging technologies.



5.21. Priority data stores

Challenge

Australia possesses many significant data stores within government agencies and research organisations (eg GA's DEA, the National Computational Infrastructure, jurisdictional agency systems, and NCRIS facilities to name a few) which have been created fit for a specific purpose. These have been or are in the process of being migrated to cloud environments, mostly owned and operated by multi-national private sector providers, some of which are located off-shore. The use of cloud infrastructures has increased exposure in terms of sovereignty, security, fragmentation, non-optimised critical mass, duplication, barriers to access, data currency, and the role of the private sector in public-private partnership. Optimising data storage and prioritising the custodianship and physical location offers the opportunity for improvement. It is timely to examine the risks to national spatial data stores, infrastructure, systems and analytics, including the physical location of the systems on-shore and off-shore.

Another key issue is to inventory data stores related to Critical infrastructure, ie. determine which of Australia's data stores need to be afforded special protection status, with increased governance and security, and overseen by formal data policy (including access protocols etc).

There is also an opportunity, once defined, to look at icon examples to build and use other nationally enabling infrastructure. A good example is DEA, which has increasing government and private use within Australia, and is also well regarded globally as a leading example of open data cubes. There are other examples of coordinated data collections and data stores, such as the square kilometre array, which is a next-generation radio telescope and will yield data volumes of approximately 300 PB per telescope per year during full science operations, and the data will be produced at a rate of approximately 0.5–1TB per second.

And what of the potential to create and manage datastores on-board in space?
Is this considered a priority?

Opportunity for Growth	Perhaps one recent and highly relevant example which illustrates a number of the issues outlined above is in the use of information in relation to preparing and responding to bushfires.
	The National Natural Disaster Arrangements Royal Commission (Bushfires Royal Commission) made the following recommendations in their report, primarily within the chapter on supporting better decisions:
	
	• Rec 4.1: Australian, state and territory governments should prioritise the implementation of harmonised data governance and national data standards.
	• Rec 4.4: The National Disaster Risk Information Services Capability should include tools and systems to support operational and strategic decision making, including integrated climate and disaster risk scenarios tailored to the various needs of relevant industry sectors and end users.
	• Whilst not a recommendation, the reports states that "Australian, state and territory governments should explore the feasibility and practicalities of developing and maintaining nationally consistent:
	  - Assessments of frequency, intensity and spatial distribution of natural hazards in Australia, and
	  - Projections of the frequency, intensity and spatial distribution of natural hazards in Australia."
	• The report also makes reference to GA's Australian Exposure Information Platform (AEIP) as a tool to support decision makers understand state based exposure to natural hazards but notes that this tools does not currently provide information through a geospatial mapping layer. This tools and the underlying database, the National Exposure Information System (NEXIS), ".. should be maintained and improved".
	• Rec 4.7: Australian, state and territory governments should continue to develop a greater capacity to collect and share standardised and comprehensive natural disaster impact data.

Actions	1. An audit and prioritisation of critical data priority stores that underpin national decision making. One example is Bushfire response. 2. Development of secure data stores with appropriate collaborative infrastructures that facilitate data access, with appropriate privacy and ethics requirements. This should also encompass appropriate governance including legal mechanisms, regulation frameworks, and ethics guidelines which facilitate collaborations between government, universities and industry in relation to data ethics, transparency, autonomy, and replicability. 3. The importance of standards and common frameworks for collection, storage and delivery of spatial data and that appropriate metadata needs to be emphasised to underpin management and discovery of the data and for users to determine how the data can be used and reused. 4. Consideration should also be given to required private data stores as well as shared infrastructures driven by citizen contributions. 5. Coincident computational information processing capability will need to be developed in tandem with appropriate sharing frameworks that allow researchers to collaborate and innovate.

5.22. Critical (Foundational) Spatial Data

Challenge

It is timely to consider redefining and expanding the existing list of Foundation Spatial Data Framework themes and the systems that support their creation and use to ensure they are optimised for three and four dimensional needs for a future sensor and information powered world. Migration of thought from the more traditional spatial data infrastructure concepts of data storage and access, to more advanced capabilities including automatically creating, sharing, curating, delivering, and using knowledge (not just data or information) in support of the emerging digital economy and the rise of spatially-aware and equipped citizens must occur. It advances the thinking from information product generation to the production of insights. It also embodies the provisioning of predictive analytics capacity in real-time for any user in any location whilst mobile.

ANZLIC defines Foundation Spatial Data as the authoritative geographic information that underpins, or can add significant value to, any other information; and supports evidence-based decisions across government, industry and the community. These data can be described as base spatial layers required by most users and are generally not derived from other spatial layers. They are authoritative, accurate, and easily discoverable and accessible. Traditionally these data are held and maintained by Government although this is changing. In Australia these tend to be maintained by state governments and aggregated to a national level through the foundation spatial data framework (FSDF) which provides a common reference for the assembly and maintenance of these data to serve the widest possible variety of users. The FSDF aims to deliver a national coverage of the best available, most current, authoritative source of foundation spatial data which is standardised and quality controlled. The data themes are: Address, Administrative Boundaries, Positioning, Place Names, Property, Imagery, Transport, Elevation and Depth, and Land Cover and Land Use.

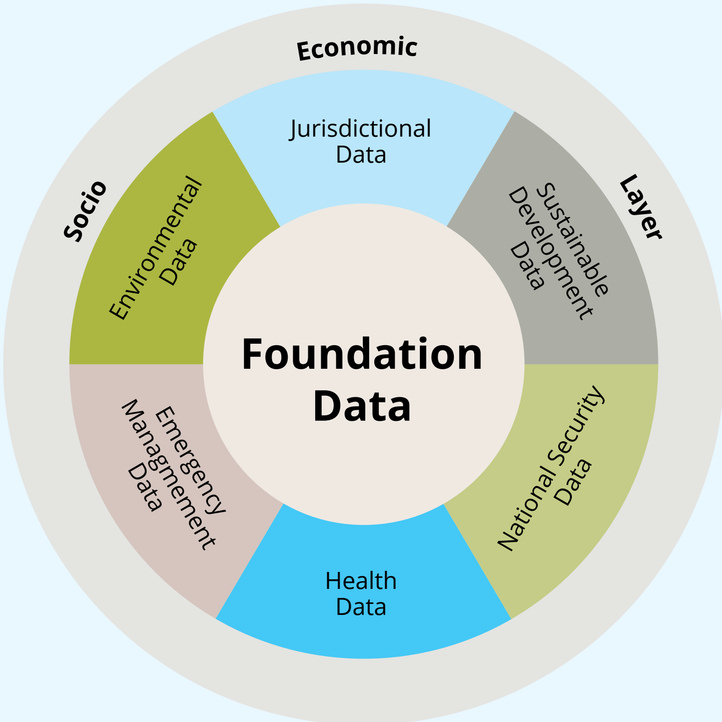


Figure 8: Conceptual View of Foundation Spatial Data Framework (Source: ANZLIC)

They are managed as a suite of datasets by custodians across government, coordinated through ANZLIC.

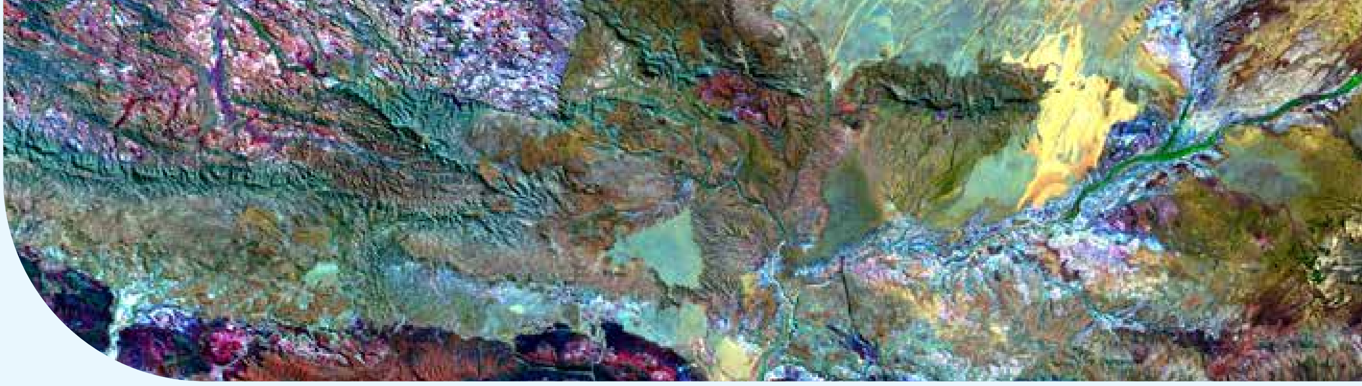
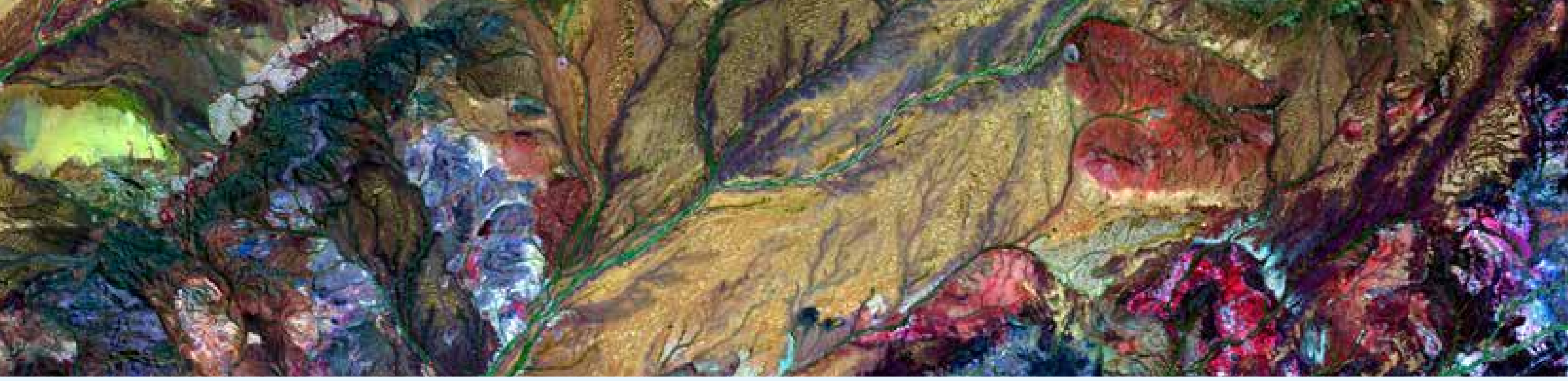


Figure 9: FSDF Defined Themes and Datasets (Source: ANZLIC)

However, the ten FSDF themes listed above were established about a decade ago. There has been subsequent work at a global level towards the Sustainable Development Goals (SDG's), by the United Nations Committee of Experts on Global Geospatial Information Management (UNGGIM). In 2018 they determined the global fundamental geospatial data themes as: Global Geodetic Reference Framework; Addresses; Buildings and Settlements; Elevation and Depth; Functional Areas; Geographical Names; Geology and Soils; Land Cover and Land Use; Land Parcels; Ortho-imagery; Physical infrastructure; Population Distribution; Transport Network; and Water.

It is timely to consider redefining and expanding the existing list of FSDF themes to align with those of the SDG's, and consider those which will provide for future challenges of three and four dimensions. Several jurisdictions already have work underway, however this has not yet had national agreement. ANZLIC has identified as one of its 2020-24 strategic priorities the modernisation of the FSDF and specifically:

- Modernise foundation spatial data to 3D and 4D (time) digital formats.
- Streamline processes to collect and supply spatial data to users across the full data lifecycle: capture, procure, access, standardise, maintain and value-add.
- Enable better data management practices, focusing on governance, privacy and cyber security, discoverability and accessibility.
- Drive development and adoption of open spatial data standards that align with and inform international standards.



Whilst fundamental to Australia the FSDF needs to be further considered against future needs, and their expansion to include critical datasets that will be critical for the future, or their ability to be easily combined for future use needs to be taken into account. Whether they conceptually should be expanded to include datasets including health, banking and finance, telecommunications and energy, or be made to more easily integrated needs to be reviewed. Other areas of potential improvement include geocoding the Australian Business Register to define essential service companies (pharmaceutical, PPE, cleaning, etc) for use in times of national or international crisis (e.g. COVID19), or geocoded location and construction of all residential and commercial properties to rapidly speed up assessment of catastrophic damage after fires, or for flammable cladding identification. Near real time and continuous updating for many of the dynamically changing datasets may also add substantial utility.

Opportunity for Growth

- Future proofing the FSDF data themes by expanding them to account for a future with operating digital twins and applications which will be built on emerging technologies such as edge computing.
- Expanding the FSDF to be able to operate in real or near real time and service digital twins and related priority applications. This will include improving processes which automate the collection, distribution and display of data. This also includes factoring in the development of analytics onboard satellites to optimise near-real time processing and availability
- Flexible governance frameworks and IT infrastructures which authenticate private and community data providers. Government will need to be inclusive of trusted private data providers, such as utilities.
- Building community awareness to further enable FSDF like data sets currently locked up and not being used, to enhance utility of current data sets.
- Ensuring that ML/AI, and other new technology developments are optimally used in the creation of FSDF.

Actions

1. Establish a working group to further explore the opportunities for growth comprising GA and FrontierSI.
2. Map needs of sectors and organisations that service Australia’s critical infrastructure and systems of national significance (as defined by the Department of Home Affairs) against what the FSDF can provide in its current and in future forms. To be undertaken by the Space Cross-sectoral Interest Group under the guidance of the Department of Home Affairs and the Australian Space Agency.

5.23. Spatial Digital Twin

Challenge

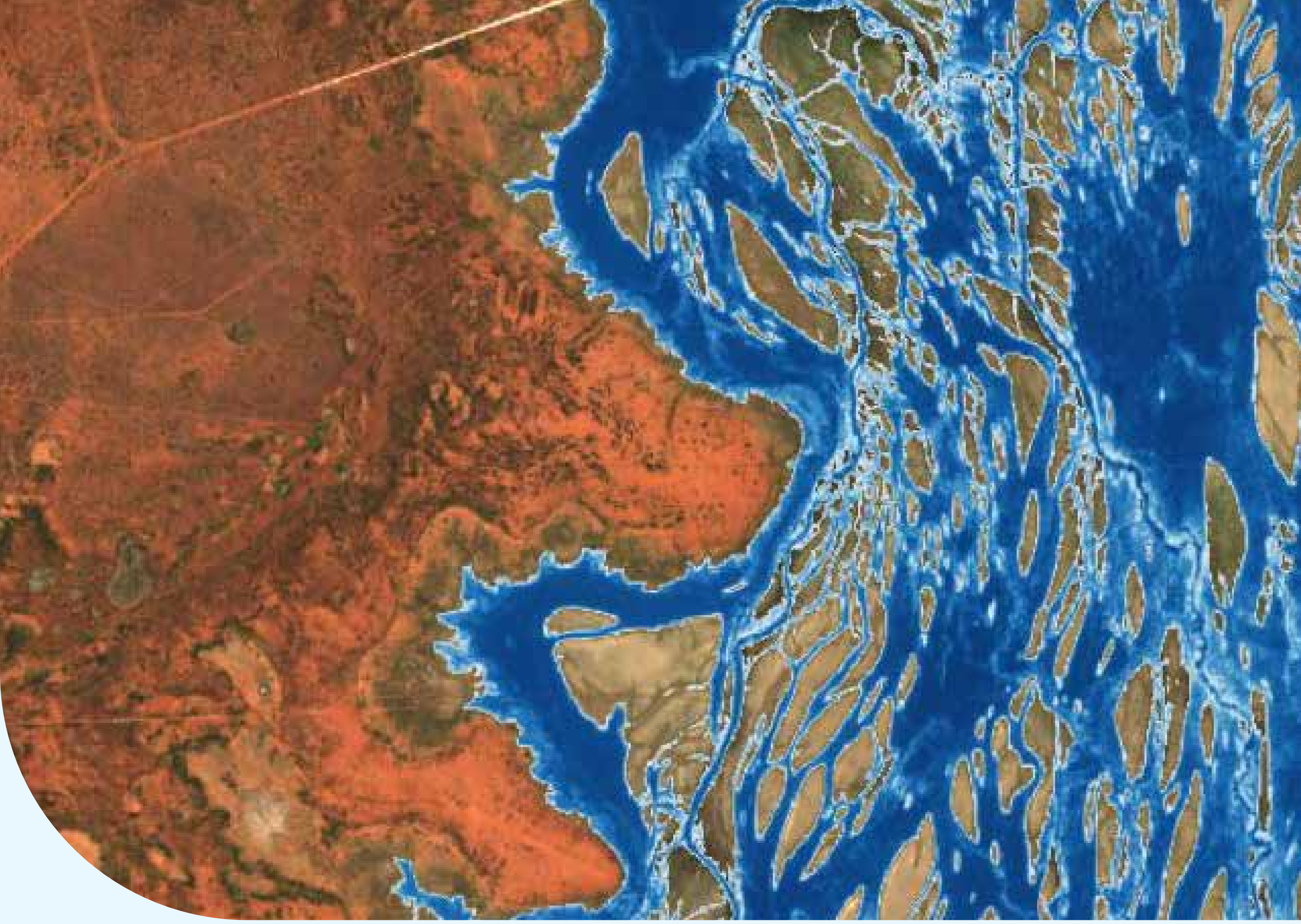
Spatial Digital Twins are an advanced spatially accurate digital representation of the real world and are emerging as a powerful tool to help people improve their understanding of our physical environment, make better-informed decisions, build predictive capability, and offer just-in-time analytics and products which should lead to improved outcomes and benefits. Digital Twins assume that the value of data is vastly improved when it is aggregated and then distributed and shared for decision making. Conceptually digital twins can mean a model of an object, a physical asset, a process or a complex environment such as a city, but in this section we are referring to the built and natural environments. Today Spatial Digital Twins are operating at various levels of maturity and complexity from individual built structure both above and below ground, through to the development of an accurately positioned city model across most major sectors of the economy. However Spatial Digital Twins are recognised as being at a relatively early stage of maturity right now, with much more potential value to be unlocked as their use cases mature. The challenge is in understanding the complexity of applications across industry sectors, the level of maturity of the digital twins in terms of quality and value, and the frameworks which enable data sharing and governance.

The drivers for Spatial Digital Twins include, aging infrastructure, resource distribution, connected and autonomous transport, mandatory digitalisation of cadastral information, and a critical need to address urban risks such as changing climate and rising inequality.

To drive a consistent approach to digital twins in the built environment, ANZLIC has developed the Principles for Spatially Enabled Digital Twins of the Built and Natural Environment in Australia which describe high-level principles, benefits and use cases for spatially enabled digital twins in the Australian context. The principles also outline the vision of a federated ecosystem of securely shared spatial digital twins and their value for the Australian economy.

Opportunity for Growth

- Spatial Digital Twins are an essential component of the overall digital transformation agenda across government and industry, which is advancing rapidly
- Spatially-enabled Digital Twins can be designed to better plan, manage, and maintain resources in urban environments.
- Place based or spatially accurate digital twins are driving the need for better access to high quality data to allow advanced visualisation and analytics.
- As data availability increases, along with compute power and cloud infrastructures this will enable the development of models or digital twins and the increasingly complex simulations of the built environment, whether it be city models or transport networks, or fine element method (FEM) based process models or designs.
- In 2009, the number of people living in urban areas (3.42 billion) surpassed the number living in rural areas (3.41 billion), and since then the world has become more urban than rural.
- Currently the UN Sustainable Development Goal #11 for sustainable cities and communities cannot be achieved without significantly transforming the way we build and manage our urban spaces
- The key opportunity is that while data frameworks are in their infancy (relatively speaking) and offer potential to integrate, current and future data streams to bring together different models we are a long way from the vision of Spatial Digital Twins are available as open data and simulations using open standards at all levels of governments



Actions	•	It is essential that Australia collaborate with the local and global initiatives to develop the use of this technology. These organisations include Open Geospatial Consortium (OGC), International Standards Organisation (ISO), the US based Digital Twin Consortium and The Smart Cities Council. The Australia and New Zealand chapter of The Smart Cities Council is stewarding the development of a Digital Twin Strategy for Australia and New Zealand. Their goal for the Strategy is to create the conditions for a thriving Digital Twin market place in the region. OGC is working closely with ISO on standards development with active working groups, while the Digital Twin Consortium is still in its formational stage, but given its membership it has the potential to have a powerful influence on the way forward.
	•	There has been a fundamental shift in data science from data to models as the knowledge of the world increases which includes digital twins. A key part of the solution is increasing model interoperability and integrated modelling with related technologies including BIM, underground assets AI and ML to enable new forms of visualization, learning, and reasoning. Within Australia, while participating in the above initiatives, it is essential to identify the principles, data frameworks and data governance, including standards which will enable data sharing and use.

5.24. Turning environmental monitoring into environmental management

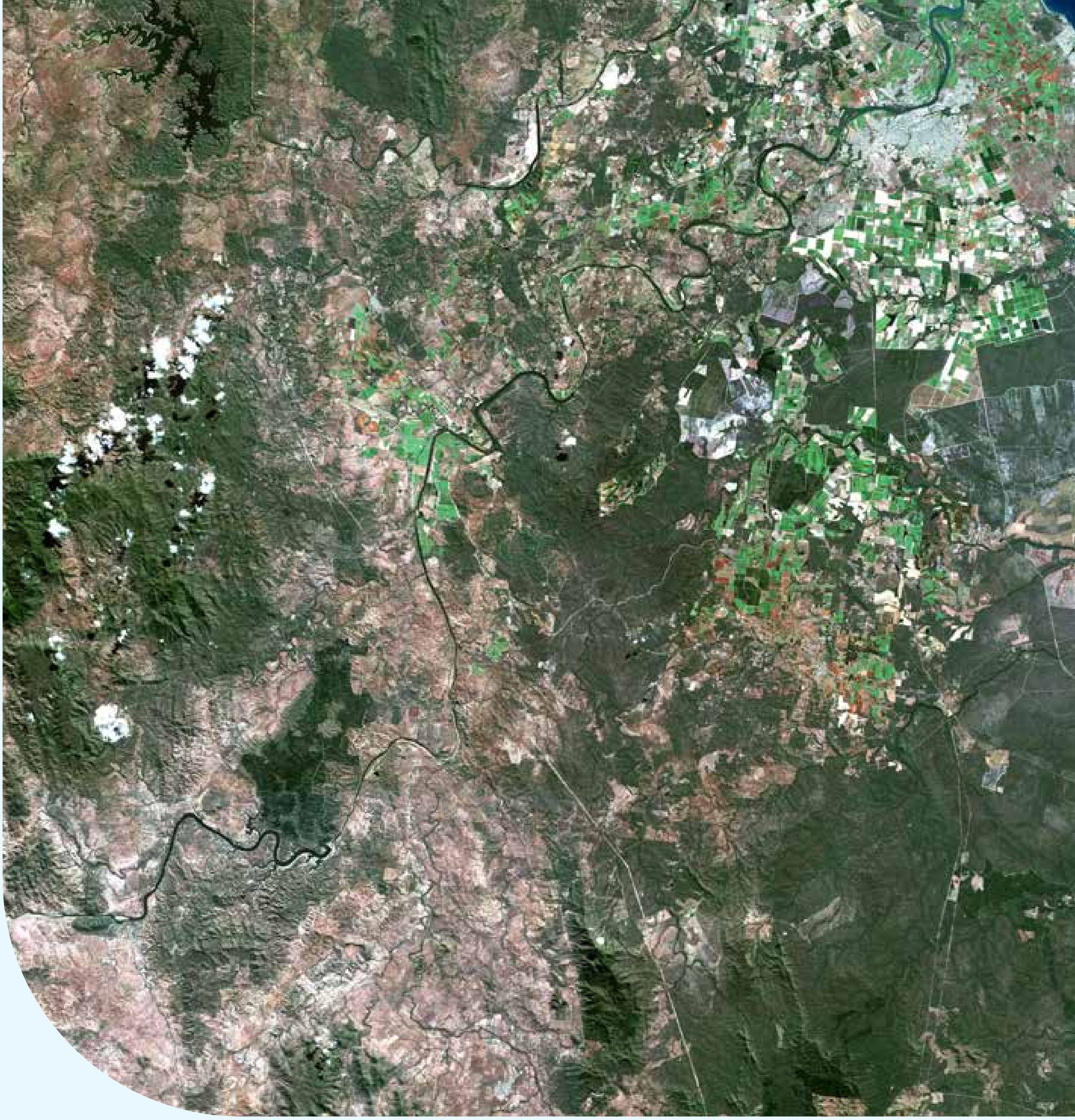
Challenge

The current paradigm for earth observation systems involves data collection to monitor ecological/ environment systems with data analysis informing decision makers on actions that may deliver certain outcomes. Moving to a management focused approach requires access to a wider range of data with better data governance, coupled with advanced analytics/machine learning techniques for sense-making and greater use of spatial digital twins. The key is to develop phenomena-specific systems purposely designed to respond to (societal, environmental and economic) pressures to produce the highly valuable information products that end users ideally want, rather than just creating more low value data. This will enable the introduction of prognostic/ predictive capabilities supporting better, more timely decision making and intervention. It includes identifying what technology developments and investments is required to enable this evolved approach. Critical priority issues include responding to the effects of global climate change, urbanization, population growth and building a circular economy model (including reducing system wastage).

Fundamental and essential environmental information is required for citizens and communities to make decisions. One example is monitoring beach water quality which is affected by a number of factors including storm water run-off. Monitoring the water quality of vulnerable beaches improves government and community planning and decision-making processes. To turn environmental monitoring into environmental management and help with the decision-making process, a multidisciplinary data collaboration is needed to collect and integrate diverse types of datasets from many organisations, often where data is acquired and used in silos with respect to data collection, management, analysis and dissemination. The Victorian State of the Environment 2018 Report, which is an environmental report card that measures the health of Victoria's environment, has identified a similar trend. The Report has recommended that the Victorian government develops their spatial information capability and database to inform decision-making across the environment portfolio. Similarly, in the Australian Space Agency report on the role of space-based earth observations to support planning, response and recovery from bushfires, they have also identified the need for an easy-to-use directory of satellite imagery for use by all stakeholders including emergency management for better use of earth observation data.

Systemic integration of spatial datasets from various jurisdictions and fields will provide insights that can lead to smarter decisions and the construction of more comprehensive strategies. Advanced computing power, cloud computing and big data analytics such as artificial intelligence and machine learning technologies can demonstrate how faster and better, decision making can be done Australian Energy Market Operator CEO, Audrey Zibelman reflected on ''What I have learned in Australia is how important advanced computing and the application of artificial intelligence (AI)and machine learning is to our industry to navigate to greater electrification of the economy and a diverse, decarbonised power system.'' (AFR 1/10/20)

Opportunity for Growth	Identified opportunities relate to technology and while land and land use planning are traditional domains for the spatial industry, in terms of application of spatial to environmental monitoring and management, the opportunity is vast from application to bays, waterways, marine and coastal environments to air quality management and green-house gas reduction by decarbonization of the energy and transport systems for example. • Data governance, accountabilities and a systematic approach to data management for spatial data collection, integration, storage and ongoing management across government and portfolio agencies. Currently, there is limited accountability for data management and integration from multi-agencies and the requirement to maintain high-quality datasets that lead to enabling sophisticated analyses. Data governance should be established and clearly articulate roles and responsibilities for relevant agencies. • Long-term earth observation information: Various satellites have different temporal scales with varying levels of image resolutions. Integration of data from those satellites to create decades of information for various environmental themes with analytic applications such as machine learning will be highly useful for environmental management and decision-making processes. One example is Landsat Surface Reflectance statistics for land cover mapping developed by DEA. For example Victorian government use these statistics to map the dynamic changes in land cover through time in Victoria (from 1985 to present). They model land cover across Victoria, including native vegetation (herbaceous, woody and wetlands), intensive agriculture and recreation, forestry and the built environment, including urban areas. Time-series of spatial optical data have demonstrated high capacity for characterisation of environmental phenomena, describing trends as well as discrete change events. • Higher accuracy positioning systems: SBAS is currently in development in Australia and New Zealand and expected to be operational in 5-10 years. SBAS can improve positioning accuracy from a meter level to a centimeter level. This has very strong implications for enhancing environmental and disaster preparedness and management and protecting life and assets – environmental and physical infrastructure – as well as for industries such as forestry and quarries where accuracy is key to ensure boundary management and species protection during operations to maintain a social license to operate. • Measuring three-dimensional structure of Australian forests using satellite: Currently, three-dimensional mapping of forest structure has been performed by LiDAR technology using aircraft. This mapping exercise is important for forest biomass and structure monitoring, leading to enabling a solid estimation of time-series forest carbon storage from the ground. However, this is time-consuming and labor intensive. Satellites harnessed with LiDAR technology will provide a significant impact on responding to the effects of global climate change. In 2018, NASA launched two sensors into space that will play a prominent role in monitoring forest biomass and structure over the next decade: the Global Ecosystem Dynamics Investigation (GEDI) now attached to the International Space Station, and the Ice, Cloud, and Land Elevation Satellite-2 (ICESat-2).These two satellites, which in combination provide complete coverage of the planet, are equipped with LiDAR sensors that record forest structure in 3D, contributing to an ongoing wave of large-scale forest ecosystem measurements. This technology also has the potential to monitor climate impacted environments such as coastal settlements - to manage coastal inundation and erosion due to sea level rise and storms from climate change.



Actions

1. Ongoing- and cross-agency collaboration across industry and governments is key to improving spatial information capability and datasets to inform decision-making across the environment portfolios of government/s. In addition, data governance and clearly defining accountability for data collection, storage, management and integration across agencies could provide a systematic approach to ensure high quality data capture to empower analytic methods such as artificial intelligence and machine learning.
2. It is important that end users of spatial technology are regularly informed of megatrends in spatial technologies so current information and understanding can be applied to their land and environmental monitoring, management and decision-making processes and diminish the barriers to adopting new technologies for sustainable environment management.

6. GLOSSARY

Term	Description
Accuracy	The accuracy of an estimated or measured position at a given time is the degree of conformance of that position with the true position, velocity and time (from RNP)
Availability	The availability is the percentage of time that the services of the system are usable by the user (from RNP)
Continuity	The continuity of a system is the ability of the total system (comprising all elements necessary to maintain user position within the defined area) to perform its function without interruption during the intended operation (from RNP)
Integrity	The measure of trust that can be placed in the correctness of the information supplied by the system (from RNP)
DFMC	Dual-Frequency Multi-Constellation (DFMC) - a PNT technique enabled through next-generation SBAS capability
EO	Earth Observation
GNSS -	Global Navigation Satellite Systems including GPS, GLONASS, Galileo and BeiDou
NPIC	National Positioning Infrastructure Capability
PNT	Position Navigation & Timing, typically using GNSS
PPP	Precise Point Positioning - a PNT technique enabled in part through next-generation SBAS capability
RNP	Required navigation performance (RNP) specifications - https://gssc.esa.int/navipedia/index.php/GNSS_Performances
SATCOM	Satellite Communications - providing a data pathway between ground stations using orbiting satellites connected using a number of International Telecommunications Union (ITU) allocated frequency bands covering Broadcast, Fixed Service, Mobile Service and others.
SBAS	Space Based Augmentation Systems such as WAAS, EGNOS
SSA	Space Situational Awareness

ANNEX 1: RESOURCES

Key References

Document Name	Description
ANZLIC Strategic Plan 2020-24	Driving spatial excellence and place-based intelligence across Australia and New Zealand
Australia's Space & Spatial Industry Growth RoadMap 2030	Refers to this body of work. Still in development
The Value of NSW Spatial Information	Prepared by Acil Allen consulting for CRC SI and the NSW Government. The report assesses the value of spatial information in 2017 and estimate the expected value in 2022.
SIBAIGITA Strategy	Current strategic plan covering 2017-2020. "Positioned for Growth" addresses three focus areas for SIBAIGITA; Advocacy, Growth and Services.
SSSI Road Map 2018-2021	SSSI strategic Plan defines actions for deliver a vision for the organisation in 2021 with goals linked to growth, reputation, collaboration and connectedness, certification and governance.
Cadastre2034	ANZLIC document setting out a national strategy to reform and innovate in the provision of cadastral spatial services.
The Value of Spatial Information for Tasmania	
Location Information Strategy for Western Australia	
SA Geospatial Insights	
GeoScience Australia Strategic Plan 2028 v2	Geoscience Australia strategy published in 2019 identifies 10 year target to improve delivery of geographic and geological information to all Australians.
The Australia and New Zealand Foundation Spatial Data Framework	
Digital Earth Australia Program Roadmap 2020 (March)	
2020 Defence Strategic Update	Updates the 2016 Defence White Paper. Includes coverage of strategic national security implications for space.
2020 Force Structure Plan	Australia Defence capability plans to address strategic changes outlined in the Defence Strategic Update. Provides an overview of capability needs for Space and Geospatial Intelligence
2026 Spatial Industry Transformation and Growth Agenda	A series of documents with the most recent release 2019 Action Plan
Advancing Space Australian Civil Space Strategy 2019-2028	Extant Australian Civil Space Strategy

Australia's Future in Space: A Strategic Plan for Space Science	Australian Academy of Science work to develop Space Science decadal plan. Unpublished as of Feb 2021.
Australian Earth Observation Community Plan 2026	
Building Queensland's Space Economy	
Defence GEOINT 2030: A Strategy for Defence's GEOINT Capability	Updates the 2010 Strategy and identifies five strategic goals to deliver Australia's future geospatial intelligence capability
Defence Industry Capability Plan	The DICP is a key part of the Government's commitment to achieve an Australian defence industry that has the capability, posture and resilience to help meet Australia's defence needs over the decade to 2028.
Defence Industry Policy Statement	Part of the 2016 Defence White Paper, outlines required industry development objectives to meet the needs of the Integrated Investment Program that enables our national security. Includes a revised approach to supporting innovation with the Defence industrial sector
Defence Science and Technology Strategy 2030	This strategy seeks to ensure the national S&T enterprise is nurtured and leveraged to achieve scale in the resources that are applied to research problems.
Digital Earth Australia Roadmap	
Economic Value of spatial information in NSW	
NSW Space Industry Development Strategy	NSW Government Space Industry Strategy
QLD Space Industry Strategy 2020-2025	QLD Government Space Industry Strategy
Space - A Roadmap for unlocking future growth opportunities for Australia	Part of CSIRO Futures Roadmap portfolio
Space Industry Capability in Western Australia	
Space Innovation and Growth Strategy (South Australia)	
Australian State of Space Report 2019	Australian Space Agency annual report covering the fiscal year 2018/19
Protecting Critical Infrastructure and Systems of National Significance - Consultation Paper August 2020	The Australian Government is committed to protecting the essential services all Australians rely on by uplifting the security and resilience of critical infrastructure.
Communications Technologies and Services Technology Roadmap	The Australian Space Agency Communications Technologies and Services Roadmap provides a 10 year plan and sets the strategic direction to support the growth of the industry. The first of a number of space technology roadmaps to be released.
SmartSat CRC Strategy 2021-2025	(Not Publicly Released) Sets out the initial strategy for SmartSat CRC to deliver impact across Australia's space and spatial sectors

Additional Resources

Document Name	Description
geoBuiz 2018	
GeoSpatial Report 2017-September	
India Geospatial Strategy Document 2019	
Location Matters Roundtable Summary	
UNGGIM - IGIF Overarching Strategic Framework 2018	
The Value of NSW Spatial Information	Prepared by Acil Allen consulting for CRC SI and the NSW Government. The report assesses the value of spatial information in 2017 and estimate the expected value in 2022.
CRCSI Global Outlook Report 2016 (November)	
CRCSI Global Outlook Report 2018	Report examines the market size for many component parts of the spatial industry and its technologies drawing mostly on previously published material.
The Value of Spatial Information Australia 2008	
The Value of Earth Observations from Space to Australia	
UK National Geospatial Strategy	
SA Geospatial Insights	
Canadian Geomatics Environmental Scan Value Study 2015	
Canadian Geospatial Strategy	
Malaysia NGMP Executive Summary	
US Geospatial Data Act of 2018	
Singapore Geospatial Master Plan	
UNGGIM DRAFT Future Trends report - 3rd Ed	
Implications of Dynamic Datum on Cadastre	
GeoScience Australia Strategic Plan 2028 v2	
Draft Report of GEO-XVI	
Deloitte's Geospatial Ecosystem	
Full report Determining the Future Demand, Supply and Skills Gap for Surveying and Geospatial Professionals - 2018-2028	
DELWP Core Spatial Data Strategy 2018	
CRCSI Towards Spatial Knowledge Whitepaper 2017 (May)	

3D QLD Roadmap	
A First Pass Analysis of Risks Associated with Australia's Dependencies on Space-Based Assets	A risk analysis of Australia's dependency on space assets. In Progress.
Australia 2030 Prosperity through Innovation	Strategy to drive innovation across Australia's economy. Developed in response to the 2015 National Innovation and Science Agenda.
Australian Ecosystems Models Framework	Aus Eco Models framework can be used to evaluate strategies to assess the impact of disasters such as catastrophic bushfire events, on environmental asset
Australian inquiries into natural hazard events: Recommendations relating to urban planning for natural hazard mitigation (2009-2017)	An assessment of major Australian post disaster and emergency event inquiries and reviews from the past 10 years (2009-2017) in terms of recommendations relating to the integration of urban planning and natural hazard mitigation.
Australian Space Industry Capability	Analysis supporting the Expert Reference Group, led by Megan Clark, reviewing Australian Space Industry
Australia's Cyber Security Sector Competitiveness Plan - 2019 Update	An example of the industry growth plan from the Australian Government's Industry Growth Centres
Building Queensland's Space Economy	
Defence Surveillance and Intelligence Industry Plan	Industry plan developed for the Sovereign Industry Capability Priorities outlined in the Defence Industry Capability plan. This plan addresses sovereign industry needs for surveillance and intelligence capabilities, including Space Domain Awareness and Space-based Surveillance.
Defence Surveillance and Intelligence Implementation Plan	Provides details on the implementation of the "Industry Plan".
Current and future value of earth and marine observing to the Asia-Pacific region	
Cyber Security - A Roadmap to enable growth opportunities for Australia	Part of CSIRO Futures Roadmap portfolio
Decarbonisation Futures	Decarbonisation Futures provides a guide for Australian government and business decision- makers on priority technologies, deployment pathways and benchmarks for achieving net zero emissions.
USA Defense Space Strategy	Through the strategy, the US Department of Defense will advance space-power through the pursuit of three objectives: maintain space superiority; provide space support to national, joint, and combined operations; and ensure space stability.
Deloitte Access Economics (online reports)	Deloitte Access Economics is united by a passion for economics and a belief that it can create a better future for all. Our deep economic rigour comes with practical commercial advice to help shape public policy, deliver business insights and inform investment strategy.

Food and Agribusiness - A Roadmap for unlocking value-adding growth opportunities for Australia	Part of CSIRO Futures Roadmap portfolio
Future Trends in geospatial information management: the five to ten year vision	Draft Version of the 3rd edition report on future trends in geospatial information management by the UN.
Global Space Industry Dynamics	
Growing Australia's Quantum Technology Industry - Positioning Australia for a four billion-dollar opportunity	Part of CSIRO Futures Roadmap portfolio
India's future plans through the Indian Space Research Organisation (ISRO)	
Investment in the Australian Space Sector	KMPG report from Feb 2020
Market & Technology Trends - Edition 1 (2020)	Sharing the latest developments in Asia, including info on: Upstream Developments – satellite and satellite augmentation systems, ground equipment, policy initiatives and more Market Trends – trends seen in the downstream applications domains across different markets Macro Technology – trends involving advances in key technology areas considered as potential GNSS enablers, such as robotics, digitalisation and AI, as well as big data
Priorities for natural hazards emergency management research	Bushfires and Natural Hazards CRC national research priorities. The first reference to provide national priorities to guide research efforts into natural hazard management.
Report of the Committee on the Peaceful Users of Outer Space	
Review of Australia's Space Industry Capability: Issues Paper - August 2017	
Review of Australia's Space Industry Capability: Issues Paper - March 2018	Report from Expert Reference Group
UK Space Innovation and Growth Strategy 2014-2030	Space growth action plan developed by UK Industry Growth Centre
EU Space policy for a sustainable economy	Council of the European Union conclusions on 'Space for a sustainable Europe'
CSIS Space Threat Assessment 2020	US National Security think-tank annual report on threats to space capabilities
Australian State of Space Report 2019	Australian Space Agency annual report covering the fiscal year 2018/19
State of the Canadian Space Sector Report 2019	Report provides factual information about the Canadian space sector in 2019.
Australian State of the Climate Report 2018	This fifth BoM report draws on the latest monitoring, science and projection information to describe variability and changes in Australia's climate. Observations and climate modelling paint a consistent picture of ongoing, long term climate change interacting with underlying natural variability.

Low Emissions Technology Investment Roadmap - Discussion Paper	A key goal of this Roadmap is to ensure Australia remains at the forefront of the global low emissions technological innovation. Driving down the cost of deploying low emissions technologies to a point where they are competitive with existing alternatives will deliver meaningful reductions in global emissions.
The Economics and Impact of Victoria's Start-Up Ecosystem	Detailed assessment of the impact of start-up on the economy of Victoria. Includes forecasts of economic impact over 20 years under two scenarios (moderate growth and high growth).
The Global Startup Ecosystem Report (GSER) 2020	The New Normal for the Global Start-up Economy and the Impact of COVID-19
The Space Economy - How Space Contributes to the Global Economy	Fourth in a series of OECD publications the space economy (previously published 2007, 2011 & 2014). In a little more than a decade, the space sector has experienced considerable development throughout the world, with greater impacts on the larger economy boosted by both globalisation and digitalisation. It is also on the verge of significant changes, with new commercial space systems – from satellite broadband constellations to spaceflight – becoming operational.
Unlocking the power of location: The UK's geospatial strategy	Sets out a coordinated approach to unlock economic, social and environmental value from geospatial data.
USA State of the Space Industrial Base 2020	Summary Report - A Time for Action to Sustain US Economic & Military Leadership in Space. This report assesses the current health of the space industry and to provide recommendations for strengthening that industrial base.
Value of science and technology	Opportunities for Australia to overcome innovation challenges and realise greater value from innovation investments
Asia-Pacific Plan of Action on Space Applications for Sustainable Development (2018–2030)	The Plan of Action is a regionally-coordinated, inclusive and needs-driven blueprint that harnesses space and geospatial applications, as well as digital innovations to support countries, particularly those with special needs, to achieve the 2030 Agenda.
National Space Policy of the United States of America	The National Space Policy also directs the United States to continue to adapt its national security strategy to defeat aggression and protect national interests in space. As part of this effort, the newly created sixth branch of our Armed Forces, the Space Force, will enhance the capabilities of our Armed Forces to protect our freedom of operation in, from, and to space.
The economic impact on the UK of a disruption to GNSS	Like all modern economies, much of everyday life in the UK is reliant on Global Navigation Satellite Systems (GNSS). It is sometimes called the invisible utility. GNSS provide signals from satellites orbiting in space to give us accurate information on positioning, navigation and timing. These systems have a large range of uses but, until now, the economic benefits haven't always been well understood. It is not clear what the economic impact of a GNSS outage would be on the UK. This report looks at what would happen to the UK economy if GNSS were unavailable for 5 days.

SBAS Test-bed Demonstrator Trial Economic Benefits Report	SBAS Test-bed Demonstrator Trial Economic Benefits Report: provides assessment of the economic benefits of SBAS across Australia and New Zealand
SBAS Test-bed Project Report	SBAS Test-bed Project Report: provides detail on the technology, signals, completed projects, equipment and environment tested as well as the main challenges, findings and recommendations
SBAS Test-bed Technical Report	SBAS Test-bed Technical Report: details performance results from a testing campaign of the SBAS services by FrontierSI
Space, the Final Frontier for Cybersecurity?	Report from 2016 Chatham House workshop on vulnerability of space based systems and the cyber technology that underpins them
The Economic Benefits of Commercial GPS Use in the U.S. and The Costs of Potential Disruption	This 2011 report, sponsored by the commercial mobile telephony Lightsquared, was prepared by NDP Consulting. It reviews the possible impacts of a terrestrially based GPS augmentation system but include detail on economic impact of GNSS usage.
Economic Benefits of the Global Positioning System (GPS)	A 2019 report sponsored by the US National Institute of Standards and Technology (NIST) was prepared by RTI International. It was supported by the National Society of Professional Surveyors. The analysis aimed to estimate the economic benefits of GPS to the US private sector. The scope of the study included an attempt to estimate the impact of a 30 day GNSS outage (all space systems are equally affected).
Denmark's economic vulnerability to a loss of satellite-based PNT	A London Economics study has analysed Denmark's dependence on GNSS through two measures - PNT and a through case study analysis of 8 distinct areas of society. The case studies have evaluated the scenario of 'an instantaneous and complete loss of all GNSS services for a consecutive period of five days after which time all GNSS services are fully and instantaneously re-instated'.

ANNEX 2: 2030 GROWTH ROADMAP – GOVERNANCE

To support development of the 2030 Space and Spatial Industry Growth RoadMap, a governance structure has been established. This comprises a Steering Committee of senior leaders from stakeholder organisations and a Working Group that draws upon expertise from across the two sectors.

The 2030 Steering Committee has provided oversight of this Consultation paper with the Working Party undertaking the development of the paper. Membership of these bodies is shown below.

A small operating fund has been created to support procurement if additional resources/expertise as required.

Steering Committee Membership

Dr Peter Woodgate	Chair
Mr David Ball	Deputy Co-Chair and Chair SIAA (May to Dec 2020)
Dr Tim Parsons	Deputy Co-Chair and Chair SIAA (From Feb 2021)
Mr Glenn Cockerton	Deputy Co-Chair and Director SIBA-GITA
Ms Sandy Carruthers	Council Member ANZLIC
Dr Jackie Craig AM	Board member SmartSat CRC (joined Nov2020)
Dr Rosalind Dubs	Board member SmartSat CRC (joined Nov 2020)
Ms Mehrnoush Ghorbani	vice Mr Cockerton, Director SIBA-GITA
Mr Chris Hewett	AS GEOINT Department of Defence (until Dec 2020)
Ms Linda McCann	AS GEOINT Department of Defence (from Jan 2021)
Dr James Johnson	CEO, Geoscience Australia
Mr Andrew Kiley	Assistant Secretary Department of Home Affairs
Prof Andy Koronios	CEO, SmartSat CRC
Ms Julia Mitchell	vice Mr Ball, Board member SIAA
Mr Peter Nikoloff	Chair Industry Advisory Board, SmartSat CRC
Dr Zaffar Sadiq Mohamed-Ghouse	Immediate Past President SSSI
Mr Todd Settle	Australian Geospatial Intelligence Organisation
Mr Anthony Murfett	Deputy Head ASA
Dr Sarah Pearce	Deputy Director CSIRO Astronomy and Space Science
Prof Stuart Phinn	President Earth Observation Australia
Ms Alison Rose	vice Dr Johnson, Chief Space, Place and Communities, GA
Dr Gillian Sparkes	Chair Frontier SI

Working Group Membership

Mr David Ball	Chair SIAA (from May to December 2020)
Ms Alison Bowman	Communications Manager SmartSat CRC
Mr James Brown	CEO, SIAA
Mr Glenn Cockerton	Director SIBA-GITA
Prof Allison Kealy	Deputy Director Sir Lawrence Wackett Centre, RMIT University
Dr Ryan Keenan	Principal Consultant Positioning Insights
Dr Graeme Kernich	CEO, Frontier SI
Mr Peter Kerr	2030 Director, Coordinator Defence and National Security SmartSat
Mr Peter Nikoloff	Chair Industry Advisory Board SmartSat CRC
Ms Eva Rodriguez	Strategy Manager Frontier SI and EO Program Manager SmartSat
Ms Alison Rose	Chief Space, Place and Communities, GA
Mr Tony Wheeler	CEO, SSSI
Dr Peter Woodgate	Chair

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SPACE & SPATIAL ROADMAP 2030

We want your opinion – 2030spaceandspatial.com/feedback/