A discussion paper towards the development of a

SPACE+SPATIAL INDUSTRY GROWTH ROADMAP 2030 EXTENDED VERSION

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

Acknowledgement of Country

First Nations people have long looked to the night sky for guidance and knowledge. For thousands of years, First Nations astronomers have recorded the movements of the stars, planets and moon, developing a deep understanding of the cosmos. This knowledge has played a vital role in First Nations culture and traditions, helping to shape everything from agriculture to architecture. First Nations people have also made significant contributions to Western science. Today, First Nations people are still playing an important role in scientific discovery and the advancement of the earth observation industry. First Nations science is a rich source of knowledge and discovery, and its importance cannot be underestimated. As such, we pay our respects to Elders past and present from all Nations across the lands and waters, also known as Australia, and all First Nations peoples who continue to contribute to the vibrancy of the space and industries.

In Memorium Dr Peter Woodgate

Dec 1957 – Dec 2022
Chair, Steering Committee
2030 Space + Spatial Industry Growth Roadmap

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This paper is auspiced by the following industry bodies: Aurora Space Cluster, Earth Observation Australia, FrontierSI, SIBA, SmartSat CRC and SSSI.

The companion document to this Executive version of the Roadmap is the Extended version which includes a thorough summary of the many issues and suggestions provided in the detailed submissions and through the workshops and website in response to the Consultation Paper (June 2021, 100 pages) (https://2030spaceandspatial.com/key-issues/)

Attribution
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2030 Space and Spatial Industry Growth Roadmap, August 2022

Foreword

Australia's space and geospatial industries have reached a pivotal moment in their development. Both are small by OECD standards. Neither has yet created a multi-national commercial enterprise. Without additional and specific actions, neither is likely to meet the rapidly growing needs of Australia's civilian and defence sectors over the coming decades.

Australia needs to significantly strengthen, integrate and coordinate these two vital sectors so that they can innovate, grow and deliver at pace, and position Australia to join the digital age's global leaders.

Australia is fundamentally reliant on space and geospatial-based information flows for economic productivity and management of critical issues including climate change, security, and environmental management. As a nation, Australia must decide if it is going to keep pace with global developments in space and geospatial industries. Will Australia choose to make sufficient investment in areas including satellite manufacturing, Spatial Digital Twins, artificial intelligence, machine learning and data reception and become an active player in these markets or will Australia miss the opportunity to fully participate strategically and economically?

This roadmap is the product of extensive and industry-wide consultation led by a Steering Committee comprising peak industry bodies for both the space and geospatial industries as well as expert representatives from the civilian and defence sectors, government, publicly funded research sectors and ably assisted by an expert Working Group. The consultation process engaged many space and geospatial user communities over nearly twelve months through a series of national workshops and a dedicated interactive website to collect submissions and feedback.

The result is an in-depth view of the challenges, threats, opportunities and growth potential of these intertwined industries and a direction set to promote significant industry growth. This Comprehensive Version provides the context and detail of how industry growth can be achieved. The roadmap sets out nine high-priority objectives that, if undertaken, will help ensure Australia's interlinked space and geospatial industries maximise their growth potential, and deliver critical services to Australia's governments, commercial and defence sectors, and the wider community.

These objectives are designed to inform government policy and support industry. They will strengthen and integrate the space and geospatial sectors. They advance and champion space and geospatial industry expertise for:

- Climate change resilience, weather, and climate forecasting
- Natural disaster preparation and response
- Telecommunications including broadcasting, telephony and internet access
- Positioning, Navigation and Timing (PNT) for all forms of transport and logistics operations
- Timing signals for financial transactions
- Critical infrastructure
- Defence

A competitive advantage for Australia

A wide range of space and geospatial roadmaps, plans and strategies already exist. This study acknowledges these important contributions. However, the nine priorities in this paper do more than complement these previous works. They are a call to action.

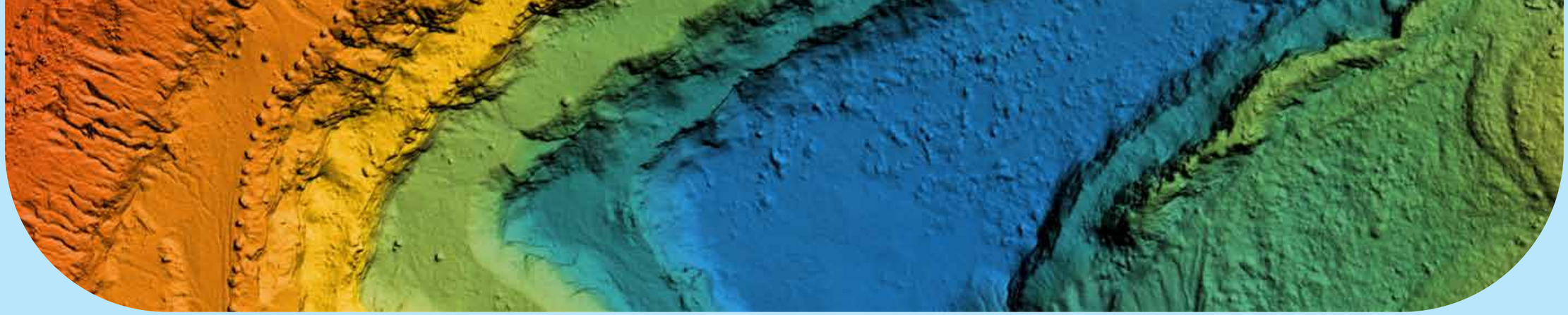
A golden opportunity

Australia's future prosperity and security will rely heavily on our space and geospatial industries. Productivity gains and management of critical issues including climate change, security and environmental management are now all fundamentally reliant on space and geospatial-based information flows. This is only going to increase.

The synergies of the space and geospatial industries working together creates enormous benefit. Optimising and enhancing their combined ecosystems will create significant competitive advantage for Australia. This will drive significant economic growth and lead to new businesses and job opportunities and export revenue. This will also play a critical role in managing the environment and improving our national wellbeing and will also greatly strengthen our sovereign capabilities in terms of defence and security.

Australia has a golden opportunity to establish new and deeper relationships with our emerging sovereign space industry as well as with the established players in the geospatial industry. Australia must think long term and do so with foresight, planning and ambition. If Australia collectively seizes this opportunity, it can accelerate the rate of growth of both industries and realise critical mass far more quickly. Building Australia's space and geospatial capabilities is mission critical to the future of this nation.

Dr Peter Woodgate
Chair, Steering Committee
2030 Space and Spatial Industries Roadmap



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Executive summary: The right place and the right time

When Australia's peak bodies in the space and geospatial industries came together to undertake this major work of consultation and collaboration, it was history in the making.

It stimulated a national conversation revealing a wealth of support and acknowledgement of the vital importance of the space and spatial sectors.

Australia is at a point in time when it can lay the foundations for what the nation could look like in 2050. Space and geospatial have a synergy able to drive the Australian economy to success in a digital world underpinned by the seamless flow of information.

As the nation's geospatial industries press ahead with world-leading innovations, the space sector is increasingly relevant to the broader community experiencing critical concerns around environment, sustainability, and economic resilience.

Australia's leaders and experts in the field, emerging professionals, engaged stakeholders and a diverse array of individual voices, have had their say in bringing together this Industry Growth Roadmap.

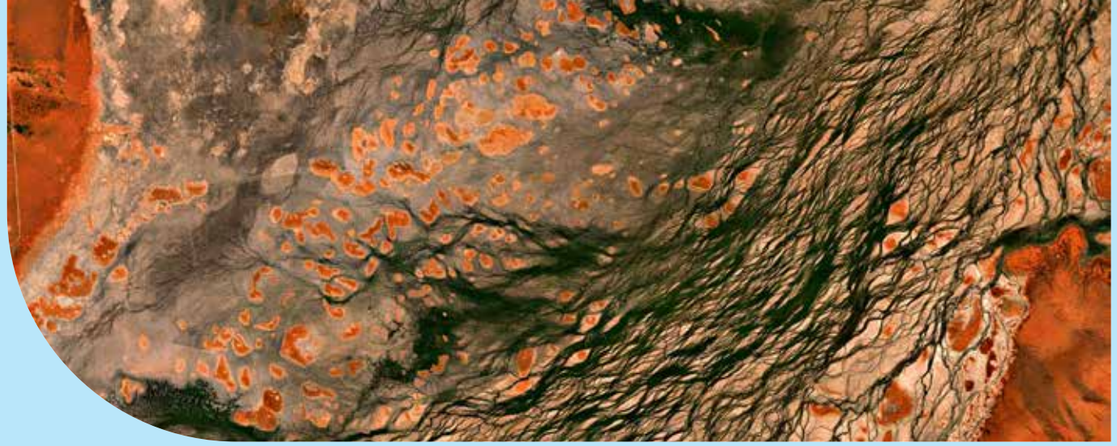
From golden opportunities to risk mitigation, and economic imperatives, the Roadmap brings to life a compelling case for Australia's next steps in the new space era.

The collaboration

The 2030 Space + Spatial Industry Growth Roadmap represents a collaboration by Australia's space and geospatial industries. It identifies the challenges and major opportunities for the industries over the next decade, which will see significant technological change.

Three growth scenarios are presented: From high-growth with appropriate capital investment through to a modest, business-as-usual approach. 'Actions' and 'Action Champions' for each of the nine priority objectives are identified. The goal is to ensure that the Australian space and geospatial industries can contribute their full economic, social, and technological potential.

The Roadmap is the result of extensive industry-wide consultation led by industry peak bodies including the Space Industry Association of Australia (SIAA), the Spatial Industries Business Association - Geospatial Information & Technology Association (SIBA-GITA), the Surveying and Spatial Sciences Institute (SSSI), and Earth Observation Australia (EOA). SIBA-GITA and SSSI have recently merged to become the Geospatial Council of Australia. Government agencies including the Australian Space Agency (ASA), the Australia and New Zealand Land Information Council (ANZLIC), the Department of Defence, Geoscience Australia, Bureau of Meteorology and CSIRO were also consulted, and the authors are grateful for their contribution.



Key findings

The development of the Roadmap was framed by key findings from the industry consultation process:

- Space and geospatial technologies are essential enablers for industrial development and environmental management and can lead to better decision making across many sectors that in turn will drive productivity.
- It is time to gain consensus on national priorities for space and geospatial investment.
- Australian Government Agencies, especially the Department of Defence, underpin the viability of Australia's space and geospatial industries. Their procurement policies are critical for industry development and to secure sovereign capabilities.
- Australia needs to become a supplier of satellite services, not just a consumer, if we are to realise the full benefits from growth in these industries.
- Greater recognition of the threat environment around space and geospatial assets is needed.
- The cost of launching commercial space assets is rapidly reducing.
- National Space Missions are a key driver for developing space capabilities.

Recommended actions

This Roadmap for growth recommends actions aligned to nine thematic areas:

- Establish a blueprint with ongoing National Space Missions
- Drive industry growth
- Coordinate research
- Increase capability
- Advance Spatial Digital Twins (SDT)
- Upgrade Position, Navigation and Timing (PNT)
- Enhance sovereign capability
- Grow Australian capabilities to support Defence
- Enhance national mapping base and its foundation geospatial data

Continuing action by government at all levels, organisations and their representative associations and researchers is required to achieve the ambitions set out in the Roadmap. The Government's role is particularly important as a major procurer, a source of funding and as a model user of geospatial data to drive the many productivity improvements that are available from these technologies.

Looking beyond 2030: Australia's place in the trillion-dollar space and geospatial economy

Analyses by a number of leading financial institutions project that the global space economy will grow to as much as USD2 trillion by 2040.

Australia has the potential to be a major player in this wave, with the potential to achieve significant economic and productivity outcomes and secure access to critical data streams essential to Australia's future.

Those reports also make the point that much of that growth will come from new segments of the space-related marketplace and not from traditional areas such as communications, Earth Observation (EO) and Position, Navigation and Timing (PNT). Developments in areas such as Space Based Solar Power (SBSP), utilisation of space-based resources, development of products in microgravity, and point-to-point transportation are expected to open new realms of space-related economic activity. Some of these developments will be both transformative and disruptive in a global sense. Yet they also represent new arenas where no single nation holds the high ground or has embedded experience.

Australia does not face the same barriers to entry as it does in mature space markets. It has particular capabilities and attributes which position it well to be able to capture a major share of these new markets.

A geospatially-empowered future

Globally, geospatial is one of the fastest growing sectors with compound average growth rates of 15% and this growth is expected to accelerate towards 2030. The current global geospatial market is estimated to reach USD520 billion in 2022 and this is expected to be USD1.44 trillion by 2030, enabling a further USD10.2 trillion of economic activity[1].

Australia's geospatial capability is well respected internationally and Australia is recognised as a very sophisticated and technologically capable geospatial player. However, Australia is currently not seeing this level of growth in its geospatial sector (currently estimated at around one-third of the international growth rate). Geospatial data and applications will be a key technological source that drives productivity in the world's economies post 2030. With Australia's geospatial capability, appropriate industry policy settings and targeted investment can unlock Australia's local geospatial potential and substantially lift productivity and the direct economic impact delivered to the Australian economy.

Routine access to space and the evolution of satellite platforms will enable the collection and consumption of enormous flows of data about our planet and how we navigate around it. Already the pathway is emerging to having a high resolution, persistent, temporal view of the Earth and every activity on its surface.

By 2050 it is expected that we will be sensing a multitude of changes on the surface of the planet, manage global traffic flows in three dimensions across land sea and air, manage the flow of driverless vehicles, aerial taxis, unpiloted drones, aircraft, and spacecraft in a global movement of people and freight and products being delivered everywhere from across a city to beginning a journey off-Earth. Australia in 2050 will be awash with highly automated craft being guided and managed through massive flows of data communicated across the continent.

Facing the challenges of climate change

By 2050, Australia will have needed to confront and manage the onslaught of more intense and pervasive bushfires, increasingly severe floods, cyclones and droughts that climate change will produce. We will have braced ourselves for disaster cycles that will be roughly twice as intense as that experienced at present. Disaster management, national supply chains, and agricultural communities will rely ever more on data from space to predict, manage and respond to natural disasters and keep our population and environment safe, and the wheels of the economy turning. Constellations of satellites will be monitoring indicators such as soil carbon and moisture, crop growth, water levels, land clearing, and urban growth and helping prepare for each season as new crises emerge. Australia will use thousands of satellites in orbit to capture data about the changing face of the continent, with data processing and analysis in cloud-space powered by AI onboard satellites.

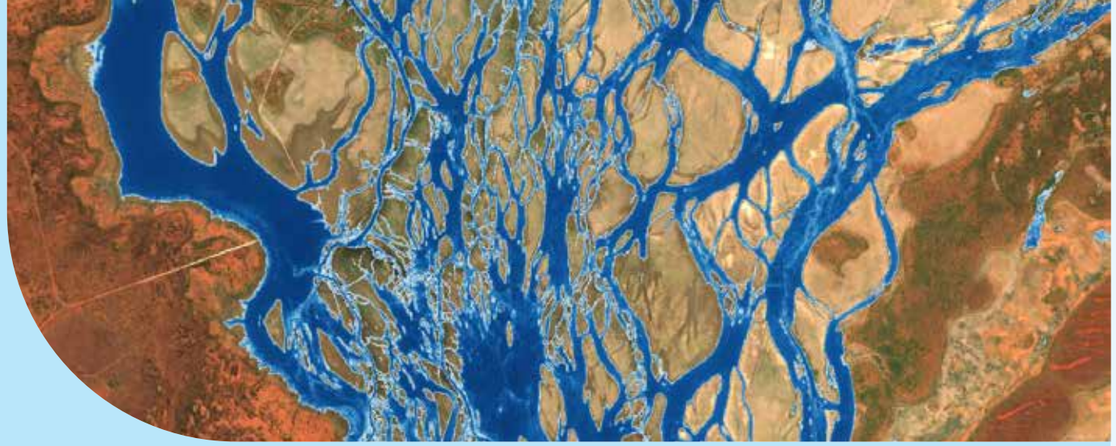
Resilience in a globally connected world

Australia will be connected to the world via thousands of satellites in orbit that do not belong to any one country, but are operated by corporations. Data flows of currently unimagined proportions will underpin businesses, entertainment, health, agriculture, transportation and every facet of daily life. Every Australian will be consuming or accessing data flowing through satellite-based infrastructure.

National security

Australia will rely on a suite of space-based platforms to provide surveillance, communications, navigation and intelligence gathering to keep threats to Australia's security further from our shores. Australia will need to have its own responsive space capabilities with Australian companies designing and building sensors, small satellite platforms and domestic launch capabilities, ready to respond to rapidly changing security challenges and support Australia's military forces.

[1] GeoBuiz 2022 Global Geospatial Industry Outlook - https://www.geospatialworld.net/consulting/reports/geobuiz/2022/



Clean energy from space

By 2050, Australia could be receiving significant amounts of its energy beamed from massive solar arrays in space supplied by new energy providers.

Space-based solar power could be one of the cleanest and most economical sources of energy and the question will be *who* will control those assets. One Australian company has already taken the first steps to develop this technology. So has one other leading nation in Asia.

If Australia embraces this t*echn*ology at the early stage of its development, it could be Australian companies supplying the energy needs of the region including our regional and Pacific neighbours. An alternative scenario is one where Australia is reliant upon energy beamed from power satellites controlled by other nations.

Securing supply chains

It is foreseeable that reusable spacecraft powered by SCRAM jets will join points all around the world, Australian companies will be able to export products with limited shelf-life to new global markets; specialised or key components may be delivered rapidly anywhere in the world ; and from a practical point of view, Australia will be no further away than any other supplier.

A global transportation network

The same transportation technologies that enable global fast package delivery would also enable high speed passenger transport, providing more efficient travel for people to move around the globe without the attendant issues that current long distance travel involves. The ability to attend a meeting anywhere in the world and be home by evening could be a game-changer for how Australians view their ability to act on the global stage or marketplace.

The highways of space

In its quest to settle Mars, SpaceX is building a transportation system that is expected to return humans to the Moon and establish a permanent presence there; fuel economic activities through cislunar space; send settlers to Mars; and provide the backbone of a network of point-to-point transportation spanning the globe. All of this becomes possible by combining reusability with space flight rates akin to airline operations. As the tempo of flights increases, the cost to get into orbit will fall and an increasing pool of people, companies and organisations will find reason to conduct activities and operations in space or off-Earth.

By 2050, it is probable there will be manufacturing and research labs in space, tourism will embrace facilities in orbit, on the Moon and the equivalent of passenger liners travelling around the Earth and the Moon. The settlement of space will have begun, with every type of worker required to support the people working and living off-Earth.

As humanity expands its reach off-Earth, the needs of everyday society will follow. In building the current nation of Australia, Australians have demonstrated their ingenuity in conquering the challenges of a harsh environment. Our sparse population, wide open spaces, relatively clear airspace, political stability, proximity to the equator, access to southern polar orbits, and other geographic advantages for launch make Australia an ideal location to host regular and frequent space flights.

1 Space and geospatial: Jointly accelerating growth

1.1 A vision for Australia's space and geospatial industries

Becoming a global leader in space and geospatial systems and services will:

- Provide essential tools to drive productivity improvement across the economy
- Provide the nation with its sovereign space and geospatial needs
- Enable the local execution of complex space projects and make substantial technical operational and management contributions to international missions
- Create market opportunities in adjacent and emerging disciplines including data-driven decision-making, artificial intelligence, precise positioning in real time, remote operations, artificial intelligence, machine learning, SDTs, and optical communications and quantum technologies
- Assist Australian firms to capture a larger share of the rapidly growing global space and geospatial markets
- Promote Australia as a destination of choice for space and geospatial specialists and companies and space and geospatial start-ups
- Enhance Australia's reputation as a provider of research, education and training in space and geospatial sciences and technologies
- Provide the enabling technologies for critical supply and value chains across the economy delivering substantial productivity gains to our national economy.

1.2 Space and geospatial industry synergies

The space and geospatial sectors are increasingly interdependent and share a symbiotic relationship, increasing efficiencies in a data-driven world. The nature and strength of the interdependent relationship is illustrated in Figure 1.

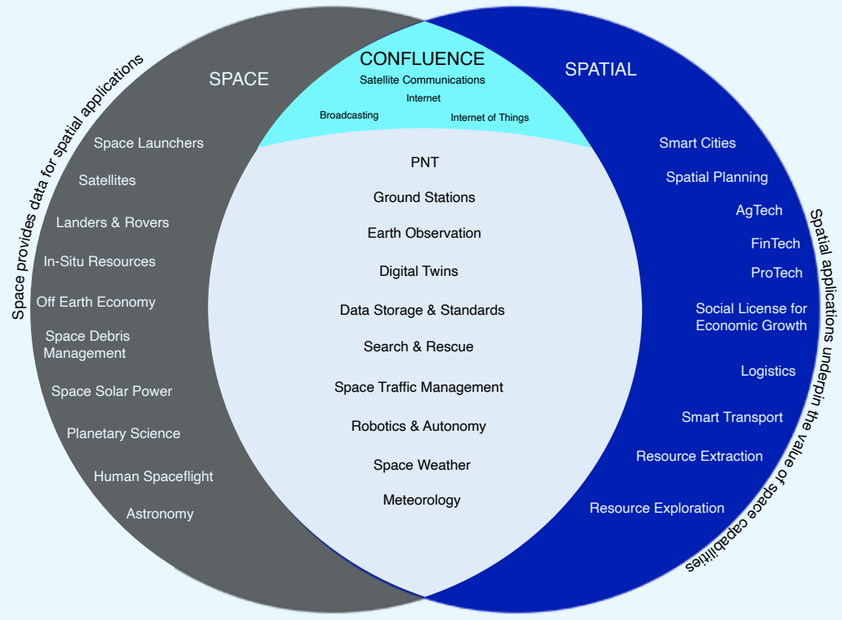


Figure 1: Illustrating the close and synergistic relationship between the space and spatial industries.

The geospatial sector is dependent on three critical space-based capabilities for production of high value geospatial information products;

- Earth Observation (EO)
- Position, Navigation and Timing (PNT)
- Telecommunications.

By 2030, demand for space data-derived products will be a primary driver of commercial space activities[2]. Broad area and niche sensors will offer customer-driven data and derived information products from satellite constellations which will target specific geographic areas.

Precision positioning at centimetre-level accuracies has the potential to increase productivity in areas such as agriculture, water usage, construction and mining. The need for increasing detail will lead to new geospatial infrastructure including the development of SDTs of physical systems that will ingest vast amounts of data and provide insights and decision-support systems in ways that are only just becoming apparent.

A convergence of the value chains for space and geospatial will emerge from new ways of thinking about commercial opportunities for space-derived data.

Unless action is taken now, the Australian geospatial sector will remain an importer and consumer of information and services generated elsewhere and, as a result, remain a market follower. By developing our space and geospatial industry sectors jointly, they can become leading producers and customers for space data and related geospatial applications and services and derive first-mover competitive advantage within global markets. However, the window to exploit this opportunity will close as others recognise and move to realise the benefits of a holistic space and geospatial approach.

1.2.1 Synergies

The synergistic relationship between the space and geospatial industries is illustrated in Figure 1. Some areas are defined as in the space sector, others in the geospatial sector. But many aspects rely on interactions between them, illustrating their inter-dependent and synergistic relationship.

This interdependence is increasingly evident in the uses of these technologies. Applications such as Search and Rescue illustrate the importance of the integration of space-based systems with geospatial services. Without satellite-derived positioning technology and global satellite communications, it would be impossible to coordinate rescue missions.

Weather and climate forecasting and prediction is an essential community service as well as critical to a range of activities from aviation to climate change monitoring. Longer range weather forecasts would not be possible without space-based Earth observation data which accounts for about 75%[3] of input to weather prediction models globally, and possibly closer to 90-95% for the Southern Hemisphere.

Satellite communications is included in the intersection as it allows space and geospatial functions to be integrated and delivered to decision makers.

[2] See Appendix 1

[3] Eyre, J. R. ; Bell, W. ; Cotton, J. ; English, S. J. ; Forsythe, M. ; Healy, S. B. ; Pavelin, E. G. “Assimilation of satellite data in numerical weather prediction. Part II : Recent years”, Quarterly Journal of the Royal Meteorological Society, vol. 148, issue 743, pp. 521-556; January 2022.

Case study: How geospatial data enables climate adaptation in agriculture

Powerful forces are driving change in Australian agriculture. Aside from a changing climate, these include new markets and altered trade arrangements, changing socio-demographics, and competition for natural resources like land and water. It is against this turbulent context that the agriculture sector in the north-east of Victoria strives for long-term sustainability.

There are limited avenues to access practical climate change information, water balance impacts and agricultural production predictions. However, interactive geospatial web applications provide an effective decision-making tool for farmers.

The foundation of climate and agricultural data visualisation is, appropriate geospatial data. Current climate information is available through the SILO data repository and climate change data can be sourced from CSIRO to create a Global Climate Change Model and emissions scenario.

In this case study, both were furnished a five square kilometre grid for the study area. Agricultural production and water balance were modelled through a Catchment Analysis Toolkit and validated by workshops with local producers and relevant industry bodies. This allowed relevant climate parameters, contextual information and productivity performance metrics relating to anticipated climate impacts on commodities to be customised.

Geospatial tools were developed to report impacts of climate change and the critical factors impacting the performance of six agricultural sectors under current and projected climate change. Information presented included the results of agreed modelling showing the impact in terms of commodity productivity.

Benefits included:

- Increased capacity of agriculture systems, related communities and local governments to adapt to significant changes in regional climatic conditions
- Increased knowledge and awareness of climate change scenarios and effects for agricultural enterprises
- Enhanced ability of land managers and councils to have regionally specific climatic data available supporting strategic planning.

1.3 Defining the space sector

The Australian Space Agency has defined the space sector as a set of activities along the space value chain that are part of the broader space economy. The space economy includes the full range of activities and the use of resources that create and provide value and benefits to human beings while exploring, understanding, managing, and utilising space. It includes all public and private actors involved in developing, providing and using space-related products and services, ranging from research and development, the manufacture and use of space infrastructure ([such as] ground stations, launch vehicles and satellites) to space-enabled applications ([such as] navigation equipment, satellite phones, meteorological services and other data services based on space-derived data) and the scientific knowledge generated by such activities.

It follows that the space economy goes well beyond the space sector itself, since it also comprises the increasingly pervasive and continually changing impacts of space-derived products, services and knowledge on economy and society[4].

The space value chain segments broadly include:

- Manufacturing and core inputs (ground and space segment manufacturing and services)
- Space operations
- Space applications
- Enablers (such as regulation and essential service delivery, infrastructure and capabilities, research, development and engineering, and specialised support services).

[4] https://www.industry.gov.au/data-and-publications/definition-of-the-australian-space-sector/defining-the-australian-space-sector

While the space sector captures the provision of space-related goods, services and applications to broader industries, it does not include subsequent value-adding activities enabled by space activities such as food production using precision agriculture technologies.

The Australian space sector's revenue was estimated at AUD$4.6 billion[5] 2018-19. There are no estimates of value-added and obtaining current data is a priority action.

1.4 Defining the geospatial sector

Geospatial information comprises all information with a location. The geospatial sector describes the organisations and professionals that acquire, integrate, manage, analyse, map, distribute, and use geographic, temporal and geospatial information and knowledge. The industry includes consulting knowledge professionals, fundamental and applied researchers, technology developers, educators, and the applications developed and used to address the planning, decision-making, and operational needs of people and organisations of all types. Many of these activities are carried out by members of the wider geospatial information 'sector', which includes numerous government or semi-public agencies, universities and other not-for-profit institutions as well as private sector actors.

The geospatial sector is critical to the economy. Few, if any, industry sectors are not using geospatial technologies in their operations. Government is one of the biggest users of geospatial products, supporting critical activities including biosecurity and emergency management; defence; environmental and natural resource management; planning and property development approvals; all forms of primary industry; space, air, sea and land transport; aspects of the retail sector; finance and insurance; many forms of health, education and community services; and virtually all aspects of public administration. Geospatial information is at the heart of big data, and it is considered that about 80% of the world's information can be depicted and or analysed spatially.

There are no current estimates of the value added to the Australian geospatial sector and obtaining current data is a priority action. However, a dated estimate from 2006-07 estimated GVA of AU$12 billion[6].

1.5 Space and geospatial enablement in the Australian Public Service

All sectors of the Australian workforce benefit from a better understanding of how the space and geospatial sectors drive productivity across the economy as well as provide essential services and national security. The Australian Public Service (APS) has a major role to play in this regard. The Thodey report into the APS pointed to the benefits of leveraging the full potential of digital systems and data analytics.

Some Commonwealth agencies (e.g. Australian Space Agency, GA, BoM) and operational arms of State and Territory agencies understand the potential of space and geospatial, but this is lacking elsewhere. The Thodey review recommended an ambitious transformation program. It is crucial that space and geospatial be included explicitly in this transformation program. This could start with greater space and spatial awareness, aiming to enhance understanding of policy, technological and regulatory implications of space and geospatial systems and services across Australia's society and economy.

The advantages of enhanced space and spatial awareness extend to state and local governments which can also significantly benefit from applications and data available from the space and spatial sectors.

The case studies provided in this section illustrate some examples of the benefits available from increased use of space and geospatial data.

[5] "Economic snapshot of the Australian Space Sector 2016-17 to 2018-19", Australian Space Agency, Feb 2021. https://www.industry.gov.au/topic/data-and-publications/australian-space-agency

[6] Acil Tasman (2008), 'The value of Spatial Information', https://www.crcsi.com.au/assets/Resources/7d60411d-0ab9-45be-8d48-ef8dab5abd4a.pdf accessed 19/12/2021

CASE STUDY: Victorian Government digital transformation through space and spatial data and infrastructure

To accelerate whole-of-government digital transformation, the Victorian Government invested $37.4 million over four years in the Digital Twin Victoria (DTV) program. For the first time in Victoria, high-quality datasets, intelligent analytics and future-ready infrastructure, have come together in a single statewide program.

Within this program, the Advanced Earth Observation (EO) workstream focuses on filling the data pipeline with remotely sensed spatial data. Victoria is also investing $45 million over three years to deliver a highly accurate, digital representation of the State's authoritative map base through the Digital Cadastre Modernisation program (DCM). A spatially accurate cadastre supports more than one million annual transactions of land and property; planning and development including record investment in infrastructure; smarter farming and agriculture; and the provision of emergency services in Victoria.

Both of these investments have been made to prepare Victoria for a high-precision and digital future, through an uplift of foundational spatial datasets, three and four dimensional spatial analytics and the rapid integration and visualisation of emerging spatial data sources. Together, these digital investments are expected to deliver costs savings and monetised benefits of $19 million per annum to government.

CASE STUDY: Satellite-based IoT ground water monitoring generating efficiencies and improving management practises in South Australia

In 2020 the South Australian Department for Environment and Water (DEW) implemented a two-year pilot using 64 Internet-of-Things (IoT) sensors and low cost telecommunications nano-satellites. This system provided an end-to-end means to transmit and aggregate, in near real-time, automatically collected information from groundwater bores. Like other state and territory authorities, DEW is responsible for the operation and management of an extensive network of groundwater monitoring bores.

Currently, only 6% of their 3500 bores are instrumented and bore observation information is generally collected infrequently by field-visits, often only a few times a year, due to the bores being located in remote and harsh environments. The research project has enabled information to be collected daily, with the bores being fitted with sensors able to automatically measure and record water levels, pressure, salinity, temperature and flow; and for this information to be sent to DEW via satellite, without the need for additional infrastructure. In addition, a data visualisation application was developed that enabled users to see statistics and the status of the bores monitored in a map-based interface.

The project, funded by SmartSat CRC and involving FrontierSI, Myriota, NGIS and the University of South Australia, is already yielding benefits to end users who are able to quickly examine retrieved data alongside a range of other observations.

The improved availability of spatial data coverage (i.e. covering larger areas) and temporal frequency is expected to allow greater understanding of groundwater systems, more detailed impact assessments and resource management responses and their monitoring as well enabling optimisation of the underlying groundwater observation asset base at significant cost savings.

2 Where we are today

The list of critical technologies published by the Australian Government recognises sensing, timing and navigation as one of the seven thematic areas. This category largely comprises space and geospatial technologies. These technologies underpin four of the other six categories:

- Artificial intelligence, computing and communications
- Energy and environment
- Quantum
- Transportation, robotics and space.

Strategic economics consultants AlphaBeta estimate the technologies of space and geospatial underpin around 75% of all economic activities[7].

2.1 Australia's global position in space and geospatial

Today, Australia has a relatively small space and geospatial ecosystem comprising a diverse yet vibrant collection of companies comprising mostly SMEs, some foreign-owned primes (large multi-national companies), and a growing number of start-ups.

However, while the geospatial industry has been developing a reputation for innovation over the past five decades, the Australian space sector is languishing.

Despite early engagement in the 1950s and 1960s supporting North American and European missions and steady growth in the telecommunications sector, efforts have only recently resumed to grow Australia's space capability.

And while there is a desire to grow Australia's space capabilities and evidence of industry growth, there are large gaps in planning. Government procurement (particularly Defence) has been a key driver for the development of sovereign space capability internationally. It is just as critical to the growth of both industries in Australia. However, Australia's space and geospatial industries have formed the view that unless there are changes to procurement policies, local SMEs are unlikely to successfully compete against multinational corporations in the global marketplace for the multi-billion dollar programs planned by the Department of Defence.

Australia lags behind many other nations with smaller economies and is not capturing a proportionate share of the space market. Rather, Australia is dependent on international partners for the delivery of space capability and its imported intellectual property and assets. In 2016, Australia's share of the global economy was 1.8% while it only captured 0.8% of the global space market[8].

A recent report by Euroconsult[9] on global space expenditure shows that as a proportion of GDP, Australia ranks 21st despite having the 13th largest economy – see Figure 2. The Australian Government spent less on space in 2021 than Belgium, a nation with a smaller GDP. When compared to nations with equivalent national economic outputs, the Australian government spent one tenth that of the Russian Federation and about half that of South Korea. Compared with peers, the Australian Government is a relatively small customer of the space industry. Perhaps of greater importance is that much Australian government expenditure goes offshore even when capabilities exist in Australia that could be nurtured in a similar fashion to those in other countries. This lack of government support leads to the loss of industry capability and an unwillingness from industry to invest and innovate stifling economic and employment growth. Commitments to National Space Missions, procurement policies which build local capability, coordinated and targeted research expenditure which achieve better results would be part of the mix.

[7] AlphaBeta 2016 - The economic impact of geospatial services: how consumers, businesses and society benefit from location-based information
[8] Advancing Australia in Space: SIAA White Paper, Space Industry Association of Australia, March 2017, page 4
[9] Government space budgets driven by space exploration and militarization hit record $92 billion investment in 2021 despite COVID, with $1 trillion forecast over the decade, Euroconsult, 6 January 2022, accessed 8 May 2022.

Photo courtesy of Geoscience Australia

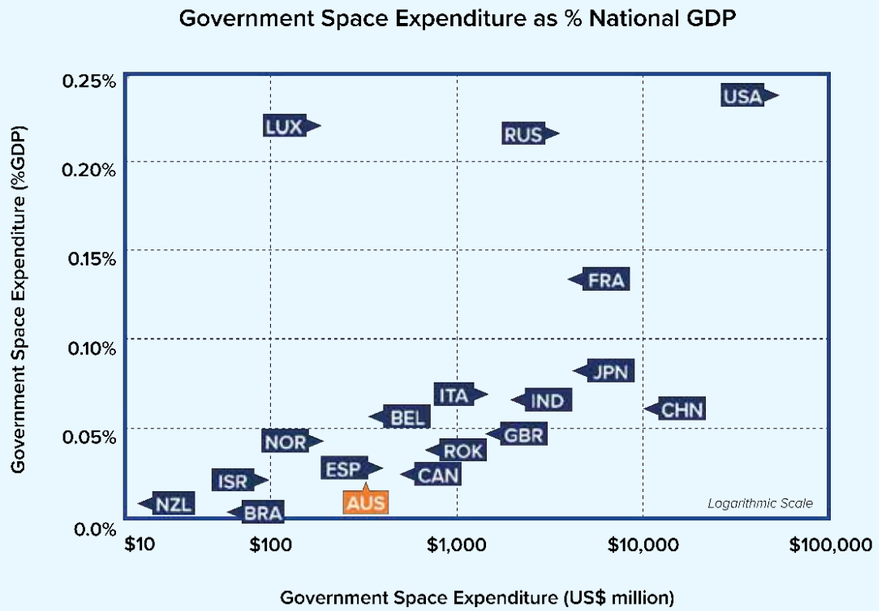


Figure 2: Australian Government Space Expenditures vs Comparator Nations
Note the expenditure axis is logarithmic so that each rectangle to the right is ten times the amount of its neighbour to the left, thereby highlighting the proportionally very large expenditure of those nations to the right of the figure.

2.2 'The Now Frontier'

In November 2020, the then Minister for Industry, Science and Technology requested a House of Representatives committee inquiry into developing Australia's space industry. After 15 public hearings and 89 submissions, *'The Now Frontier: Developing Australia's Space Industry'* report was produced with 38 recommendations. The current government responded to this report in December 2022.

We reviewed this report and assessed that these bipartisan recommendations align with the *Space + Spatial Industry Growth Roadmap 2030*, with six of our nine objectives directly supporting recommendations from the inquiry.

Both bodies of work place a strong emphasis on:

1. Creating an **overarching vision and long-term priorities** for the space sector, the review of procurement policies, as well as whole-of-government coordination with industry to oversee the development of the space industry as a whole (Obj. 1; Rec. 1, 2,4,5)
2. The **importance of aligning civil and defence space priorities and investment** (Obj. 8, Rec.3)
3. Increasing the visibility and **enablement of space (and geospatial) across the public service**, to leverage the full potential of digital systems and data enabled by space and geospatial technologies and facilitated by skilled people (Rec.7)

4. Focusing on Australian sovereignty, linked to the development of a **national space capability** that can be promoted and protected and focusing with industry on developing areas that can designed built and delivered in Australia (Obj.3,4; Rec. 9,10)
5. The need to include **space as a key infrastructure priority area** (Rec. 14), assessing risk analysis of the critical dependencies of each of Australia's recognised critical infrastructure areas on space assets and services, geospatial infrastructure, data and services (Obj. 7)
6. The development of a specific **ABS ANZSIC classification for space** to provide a more accurate picture of the size of the Australian space (and geospatial) industry and to help track its value and growth. (Obj. 2; Rec. 16).
7. Fostering the **growth of Earth Observation from space and data processing capabilities** that benefit each sector of the economy (Rec. 17), using **Spatial Digital Twins** as a critical national capability to provide accurate digital representation of the real world with 3D and 4D (time) dimensions (Obj. 5).
8. The need to identify **off-Earth opportunities, beyond the next decade**, that can provide Australia with a strategic advantage, such as space solar power technology (Rec. 18).
9. The need to **coordinate science and research** as fundamental to innovation and growth and to review the model for research and industry collaboration (Obj. 3; Rec. 30, 31).
10. Focusing on **increasing national capability, through education and outreach**. This includes embedding STEM education at all levels and focusing on diversity; showcasing and improving the number of employment and career options and pathways to industry; attracting a broader and diverse range of groups to the sector, including attracting international workers and commercial enterprises (Obj. 4; Rec. 33, 34, 35, 38).

This alignment highlights the confluence of interests between industry and government in growing Australia's space and geospatial sectors.

As the 2030 Space + Spatial roadmap focuses not only on the space industry but encompasses the overall space economy – through integration with the geospatial sector - the potential benefits of this alignment go beyond estimates for the space sector and open a myriad of opportunities for growth and national prosperity.

3 A Roadmap for growth

We propose nine key national objectives to achieve the vision for accelerated growth and increased capability for the two industry sectors to 2030, through to 2040 and beyond. Each objective has one or more actions with identified 'action champions' to drive progress and change.

3.1 Growth scenarios

The degree of action on these nine objectives will determine the growth trajectory for Australia's space and geospatial industries.

Three potential growth scenarios have been identified:

3.1.1 Scenario 1 - Transformational growth

This scenario assumes all nine objectives are met and proposed actions undertaken, transforming Australia's space and geospatial industry sectors to be globally competitive and relevant, with an increased share of the global space and geospatial economies. This will see:

- The emergence or creation of at least one large-scale Australian space company of sufficient size to successfully compete as a prime in the delivery of large defence, government or international contracts
- Broadening of sovereign capabilities to include regional data connectivity and the ability to provide Earth observation requirements and greater self-sufficiency in areas including defence and weather forecasting
- Strengthening and consolidation of the SME base
- A much larger pipeline of start-ups.

Policy settings will help drive innovation, build global competitiveness, and deliver a range of 'public good' national capabilities. The compound annual growth rate (CAGR) of about 8.6% p.a. is the only scenario that delivers the 2030 goal of a tripling of the value of the space industry, as outlined in the Australian Civil Space Strategy, Figure 3. In this scenario, Australia increases its share of the global space economy from 0.8% to 1.7%.

3.1.2 Scenario 2 - Medium growth: Tracks to the forecast global space industry growth

This scenario assumes that only some of the objectives set out in this Roadmap are met. It assumes that Australia matches the forecast global space sector growth of 5% CAGR to 2030. As a result, Australian industry is unlikely to achieve sufficient scale and capability to satisfy defence capability programs, regional data connectivity and Earth observation requirements, including greater self-sufficiency in weather forecasting. There will be continuing reliance on foreign companies to deliver such needs. Under these assumptions, Australia's share of the global space economy remains at 0.8% by 2040.

Photo courtesy of Geoscience Australia

3.1.3 Scenario 3 - Modest growth: Tracking to the forecast for Australian GDP growth

In this scenario – a business-as-usual approach – it is assumed that few of the actions are implemented and few, if any, of the nine objectives are met. This scenario tracks current national long-term GDP growth forecasts of 2.6% and assumes current policy settings. There will be continuing high reliance on foreign suppliers with attendant sovereignty risks and a failure to capitalise on the commercial potential presented by the fast-growing global industry. Australian industry will continue to struggle to translate world-class research into commercial opportunities and to compete in global markets. Under this scenario, growth will not be sufficient to maintain Australia's already small share of the global space and geospatial economies due to falling industry competitiveness and capability. The result will be continuing reliance on foreign providers except in a diminishing number of niche areas including Earth observation analysis and precision positioning. The Australian space industry will only capture 0.5% of the global market by 2030, a significant reduction from 0.8% in 2016.

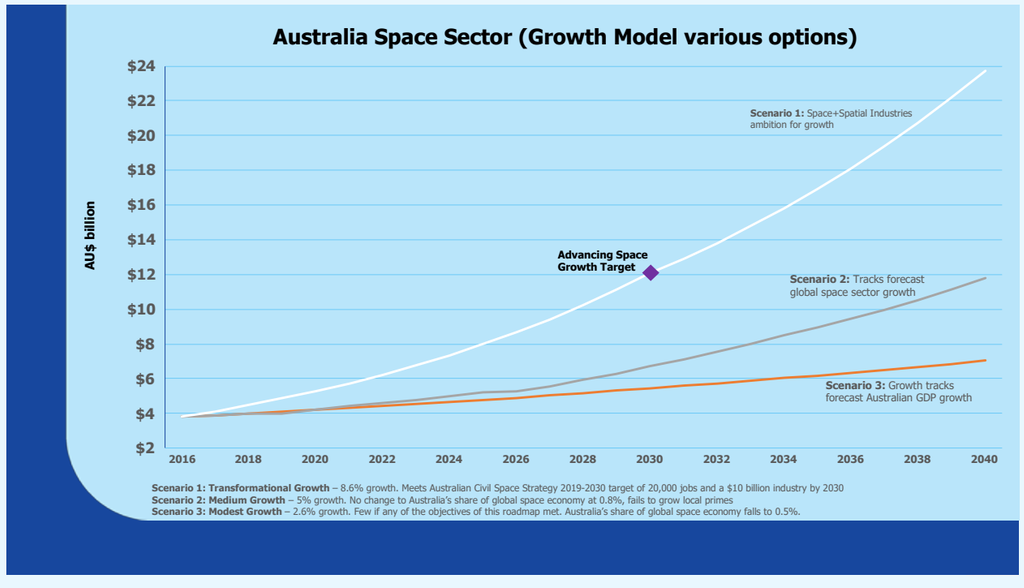


Figure 3: Three Australian Space Industry Growth Scenarios[10]

[10] Note that these are aspirational scenarios for illustrative purposes only. In developing a blueprint for growth, Australia needs better data to understand the baseline figure for future growth and this should be determined by Gross Value Added, not revenue. Most economic forecasts estimate growth based on revenue and this can be misleading as outlined in the IDA report. (Source: Bryce 2019 Global Space Economy at a Glance)

3.2 Roadmap in detail: Key objectives, actions and action champions

This Roadmap sets out:

- Nine key objectives to accelerate the growth of the space and geospatial industries
- Actions that will progress each objective together with organisations that will be the action champions and will play a lead role in driving the actions forwards.

These are summarised in the table below:

Objective 1: Establish the Blueprint with ongoing National Space Missions
Action 1.1 Australia needs a single guiding national space and geospatial strategy and detailed Blueprint that sets out in detail the priority space and geospatial capabilities needed by the nation. It will incorporate major National Space Missions that address critical national challenges, and civil and defence applications of space and geospatial capabilities across all sectors of Australian society, the environment and the economy. *[ASA, ANZLIC]*
Action 1.2 Australia needs to develop a clear investment strategy to sustain both commercial and defence industry supply chains. The Blueprint will provide a clear strategic direction for government and industry and needs to be underpinned by an investment strategy — including National Space Missions — which will concurrently inform and grow our space industry with a stable pipeline that is competitive both nationally and internationally. Formulating and funding National Space Missions that drive development of high priority sovereign capabilities that are globally competitive will also play an important role. *[ASA, DoD, SIAA, GCA, EOA]*
Action 1.3 Government procurement programs must be reviewed to ensure that critical components of the Blueprint can be delivered. *[ASA and DoD to collectively determine the best national approach to aligning government policy across all jurisdictions at Commonwealth, state and territory levels]*
Action 1.4 A new governance mechanism be found that enables regular dialogue and coordination on strategy formulation by the jurisdictional lead bodies in both space and geospatial, civilian and defence, to synchronise their goals, and the consequential planning and road-mapping that drives the achievement of these goals in the Space and Geospatial Strategy and the capabilities set out in the Blueprint. *[ASA, ANZLIC , DoD , convene a group of industry and research peak bodies]*
Objective 2: Drive Industry Growth
Action 2.1 Acquire data to understand existing industry structure and identify current Australian presence in relevant segments. *[SmartSat CRC, ASA, GSA]*
Action 2.2 Agree 2030 and 2040 growth targets across each segment of the space and geospatial industries. *[SmartSat CRC, EOA, industry peak bodies and government]*
Action 2.3 Undertake a full ABS stocktake of the industry including reviewing the ANZSIC system with respect to the treatment of space and geospatial. *[ABS, prompted by the SmartSat CRC and GCA]*
Objective 3: Coordinate Research
Action 3.1 Consideration be given to establishing a standing body for guiding priorities for publicly funded R&D in the space and geospatial sciences which could include a process for providing advice to the National Science and Technology Council (NSTC). This body would be part of the new governance mechanism suggested under Action 1.4. A key role would be to determine the Technology Readiness Levels (TRL) for nationally agreed research and development priorities (focussing on TRLs 1-4). A body of this kind could also support the identification of how the space and geospatial industries can support the agenda setting for the NSTC. *[SmartSat CRC, Office of Australia's Chief Scientist and FrontierSI]*
Action 3.2 Improve the alignment of existing funding (particularly ARC, ITRP, ARC linkage, CRC-P, NCRIS, Critical Technologies Fund and Defence) across space and geospatial to specifically target prototyping activity and advanced technology demonstration in space. This could be structured in some instances as grants requiring co-investment from industry with the co-investment ratio recognising technical risk and commercial risk and rewards. *[SmartSat CRC, Australian Chief Scientists and EOA]*
Objective 4: Increase Capability
Action 4.1 The challenge of meeting the jobs growth target needs a systematic approach including:
4.1.1 Establishing an agreed national taxonomy of skill sets for space and geospatial
4.1.2 Extending the 2021 SmartSat-ASA skills gap study to cover other geospatial skills that are dependent on space and that support the growth targets.
4.1.3 Undertaking an audit of the existing suite of courses at the tertiary level in Australia covering both the university and vocational education and training sectors, including the current size of the pipeline of graduates from micro-credentialing through to the doctoral level.
4.1.4 Publication of an analysis of the estimated shortfall in skill sets against the taxonomy in order to better inform education providers to help with forward planning, investment and expansion of degree and training options.
4.1.5 Sourcing additional resources for the Space, Spatial and Surveying Diversity Leadership Network (SSS-DLN) and allied activities including Traditional Owners to significantly strengthen the diversity outcomes for space and geospatial
4.1.6 Creating an inventory and profile of the companies that generate space and geospatial services and the companies that rely on these capabilities.
4.1.7 Examination of micro-credentialing programs to rapidly grow the space workforce to meet the immediate as well as long-term needs of industry.
4.1.8 Establishing a regular flow of space missions to attract space-qualified individuals back to Australia as well as attracting other space-qualified personnel from other countries to migrate to Australia.
4.1.9 Embedding skills training and career pathways in space across primary through to tertiary education.
4.1.10 Developing a coherent and integrated approach to space and geospatial education programs in Australia that better meets the needs of government, Defence, academia, and industry.
[SmartSat CRC supported by EOA and GCA]

Objective 5: Developing Spatial Digital Twins
Action 5.1 Australia needs a single guiding national space and geospatial strategy and detailed Blueprint that sets out in detail the priority space and geospatial capabilities needed by the nation. It will incorporate major National Space Missions that address critical national challenges, and civil and defence applications of space and geospatial capabilities across all sectors of Australian society, the environment and the economy. *[ASA, ANZLIC]*
Action 5.2 Australia needs to develop a clear investment strategy to sustain both commercial and defence industry supply chains. The Blueprint will provide a clear strategic direction for government and industry and needs to be underpinned by an investment strategy — including National Space Missions — which will concurrently inform and grow our space industry with a stable pipeline that is competitive both nationally and internationally. Formulating and funding National Space Missions that drive development of high priority sovereign capabilities that are globally competitive will also play an important role. *[ASA, DoD, SIAA, GCA, EOA]*
Action 5.3 Government procurement programs must be reviewed to ensure that critical components of the Blueprint can be delivered. *[ASA and DoD to collectively determine the best national approach to aligning government policy across all jurisdictions at Commonwealth, state and territory levels]*
Objective 6: Upgrade Position, Navigation and Timing (PNT)
Action 6.1 Facilitate the compilation of an overarching updated 'GNSS Strategic Plan for Promoting Enhanced PNT Capabilities across Australia' building on existing documents (e.g. the PNT Roadmap, due for release from the ASA mid-2023, and the Australian Academy of Science Decadal Plan for Space released in 2022) 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. *[ASA, Geoscience Australia and FrontierSI]*
Action 6.2 Form a multi-stakeholder 'Strategic Coordination & Engagement Group' responsible for monitoring and advocating for the updated GNSS Strategic Plan (see Action 6.1) and providing guidance where necessary, to provide consistency, ensure clarity and eliminate duplication through elective collaboration. Ideally, this would comprise government, academic and industry representatives. *[ASA and Department of Industry, together with support from Geoscience Australia and FrontierSI]*
Action 6.3 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 and services which complement and augment GNSS, ultimately creating new sectors and jobs. These innovations to 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. *[ASA, Department of Industry and SmartSat CRC (with its partners)]*
Action 6.4 Mechanisms to utilise Defence investments in technology for assured and resilient PNT should be explored as appropriate. This includes the use of quantum PNT and systems to detect and mitigate denial-of-service, interference and spoofing within the consumer marketplace. *[DoD, with others to be determined through consultation with stakeholders]*
Objective 7: Reduce Sovereign Risk
Action 7.1 Undertake a thorough risk analysis of the critical dependencies of each of Australia's recognised critical infrastructure areas on space assets and services, geospatial infrastructure, data and services, the threats faced, the consequences and likelihood of damage, the mitigating actions and the residual risk using the ISO 31,000:2018 Risk Management standard and the ISO 27,000-Series on Information Security Standards. *[The Space Technologies Sector Group within the Trusted Information Sharing Network of the Australian Critical Infrastructure Advisory Council, supported by the Department of Home Affairs, the DoD, ASA and EOA]*
Objective 8: Grow Support for Defence
Action 8.1 Align Defence Priorities and Civil Space National Priority Areas with 10-year and 20-year goals as part of an Integrated National Civil-Defence Space Industry Growth Policy. Industry peak bodies to lead the development of a strategy that gives Defence confidence that it can provision the majority of its allocated $17 billion forward space and geospatial expenditure on Australian sovereign capability, including proactive industry formation of consortia of critical mass, granting programs of scale and procurement that are agile and build to the Blueprint. *[DoD and ASA supported by industry groups]*
Action 8.2 Develop a project plan outline that could lead to an integrated National Joint Civil-Defence Disaster Response space and geospatial capability with strong links to Action 7.1. This should include consideration of the Australian Climate Service and key customers in Emergency Management Australia and the National Recovery and Resilience Agency. *[Department of Home Affairs, ASA and DoD with support from SmartSat CRC]*
Objective 9: Enhance National Mapping Base and its Foundation Spatial Data
Action 9.1 Adequately resource ICSM and ANZLIC to coordinate the upgrade of the Australian Geospatial Reference System. *[ANZLIC and ICSM]*

3.2.1 Objective 1: Establish the Blueprint supported by ongoing National Space Missions

Australia has space and geospatial capabilities. However, its businesses lack critical mass and government expenditure lags behind its Organisation for Economic Co-operation and Development (OECD) peers.

Australia's geospatial sector growth of 5.5% CAGR, less than half the rate of the global average, is a massive, missed opportunity. The average growth of geospatial services and technologies globally is running at more than 13% CAGR, and the Asia Pacific region is growing at nearly 18%.

Australia's space sector has been growing at the rate of 3.3% averaged over the last between 2017 and 2019 according to the State of Space Report published by the Australian Space Agency in 2022, but this report sets a target for our space sector to grow at 8.5% between now and 2030.

Australia risks missing out on the tremendous economic growth and efficiencies that these industries offer unless a more active approach to industry development is adopted. It is imperative that the Australian Space Agency's planned National Plan for Space and accompanying Blueprint incorporate not only space capabilities but also the full suite of geospatial capabilities to ensure the highest value supply chain of space-derived geospatial information products.

Moreover, the creation of the ASA in 2018 with a goal of developing the Australian space industry, has highlighted the absence of an equivalent body responsible for assisting the geospatial industry to flourish.

Given Australia possesses advanced geospatial capabilities, with strong government policy and some targeted investment, the growth potential is equally as exciting as the space sector.

Moreover, a new national governance mechanism with space and geospatial working together would greatly facilitate coordination, policy formation, strategic planning and aligned investment across the industry, civilian government, defence, research and academic sectors. Australia would be operating with a single vision.

Action 1.1
Australia needs a single guiding national space and geospatial strategy and detailed Blueprint that sets priority space and geospatial capabilities. It will incorporate major National Space Missions that address critical national challenges, and civil and defence applications of space and geospatial capabilities across all sectors of Australian society, the environment and the economy.

Action Champion 1.1
The ASA in collaboration with ANZLIC.

Action 1.2
Australia needs to develop a clear investment strategy to sustain both commercial and defence industry supply chains. The Blueprint will provide a clear strategic direction for government and industry and needs to be underpinned by an investment strategy — including National Space Missions — which will concurrently inform and grow our space industry with a stable pipeline. Formulating and funding National Space Missions that drive development of high priority sovereign capabilities that are globally competitive will also play an important role.

Action Champion 1.2
The ASA and Department of Defence, supported by the Geospatial Council of Australia and Earth Observation Australia (EOA).

Action 1.3
Government procurement policies need to ensure that critical components of the Blueprint can be delivered.

Action Champion 1.3
The ASA and the Department of Defence to collectively determine the best national approach to aligning government policy across all jurisdictions at Commonwealth, state and territory levels in order to achieve a truly 'whole of Government' response to space and geospatial industry growth.

Action 1.4
A new governance mechanism be found that enables regular dialogue and coordination on strategy formulation by the jurisdictional lead bodies in both space and geospatial, civilian and defence, to synchronise their goals, and the consequential planning and road-mapping that drives the achievement of these goals in the Space and Geospatial Strategy recommended in Action 1.1, and the capabilities set out in the Blueprint, Action 1.2.

Action Champion 1.4
The ASA, supported by ANZLIC and the Department of Defence, convene a group of industry and research peak bodies.

"Smarter, more coordinated government procurement optimised for local and export capability growth will lift SMEs, larger corporate space efforts, and startups, creating a globally competitive Australian space ecosystem sooner." *Tim Parsons, Chair of the Board of Directors, Space Industry Association of Australia and Chair, SmartSatCRC AURORA Start Up Cluster Steering Group*

"Make Australia's space investments even more explicitly about benefits to Earth, i.e. society and the economy, linking in to critical concerns such as food (agriculture), environment (water, air, weather), and sustainability (economic resilience in the face of climate change) (...) add in the much deeper, bigger impact on day-to-day lives that space has. There's now a perfect opportunity to talk about how space can support the environment, but the public is not hearing that." *Troy McCann, CEO Moonshoot*

"More work is needed to make space relevant to people's everyday lives, rather than be perceived as toys for billionaires to play with." *Conrad Pires, CEO Picosat Systems*

Rationale and consultation input

The feedback received in the consultation highlighted that the many related strategies and roadmaps need to be aligned. Any new work needs to define its relationship to existing work and what additional value it creates. In particular, there is a need to generate greater awareness across government of the critical and embedded nature of space services and products towards supporting investment in space systems, especially those based on sovereign need.

In relation to investment, the link between data and decisions, and how this can benefit Australia, needs further exploration. The focus should be on outcomes, not technology. This is the focus of Action 1.2, which needs to take a short, medium and long-term view on required investment/support and how this will meet future national needs and address supply chain and operating risks for critical national capabilities.

The Australian Civil Space Strategy, developed by the Australian Space Agency shortly after its creation in 2018, highlights the opportunities for Australia in the growing space economy and areas of competitive advantage. This has catalysed the sector. Now there is a need to bring the civilian and defence requirements together in a single national strategy. This can be delivered with a focus on 'National Space Missions' that detail 'must have' capabilities and articulate the seamless relationship with the geospatial sector to ensure that the range of current, planned and future activities optimise industry growth while developing sovereign capabilities.

The consultation process for this paper found that there are at least 25 strategies, roadmaps and plans have been developed by Australian entities covering the space and geospatial sectors (see Figure 4). They have varying durations, often overlap, and taken together represent a valuable collective body of planning. However, awareness of the existence, contents and intentions of the others is incomplete, leading to gaps. This disparate landscape of plans is insufficient to drive the industries forward into a significant growth phase.

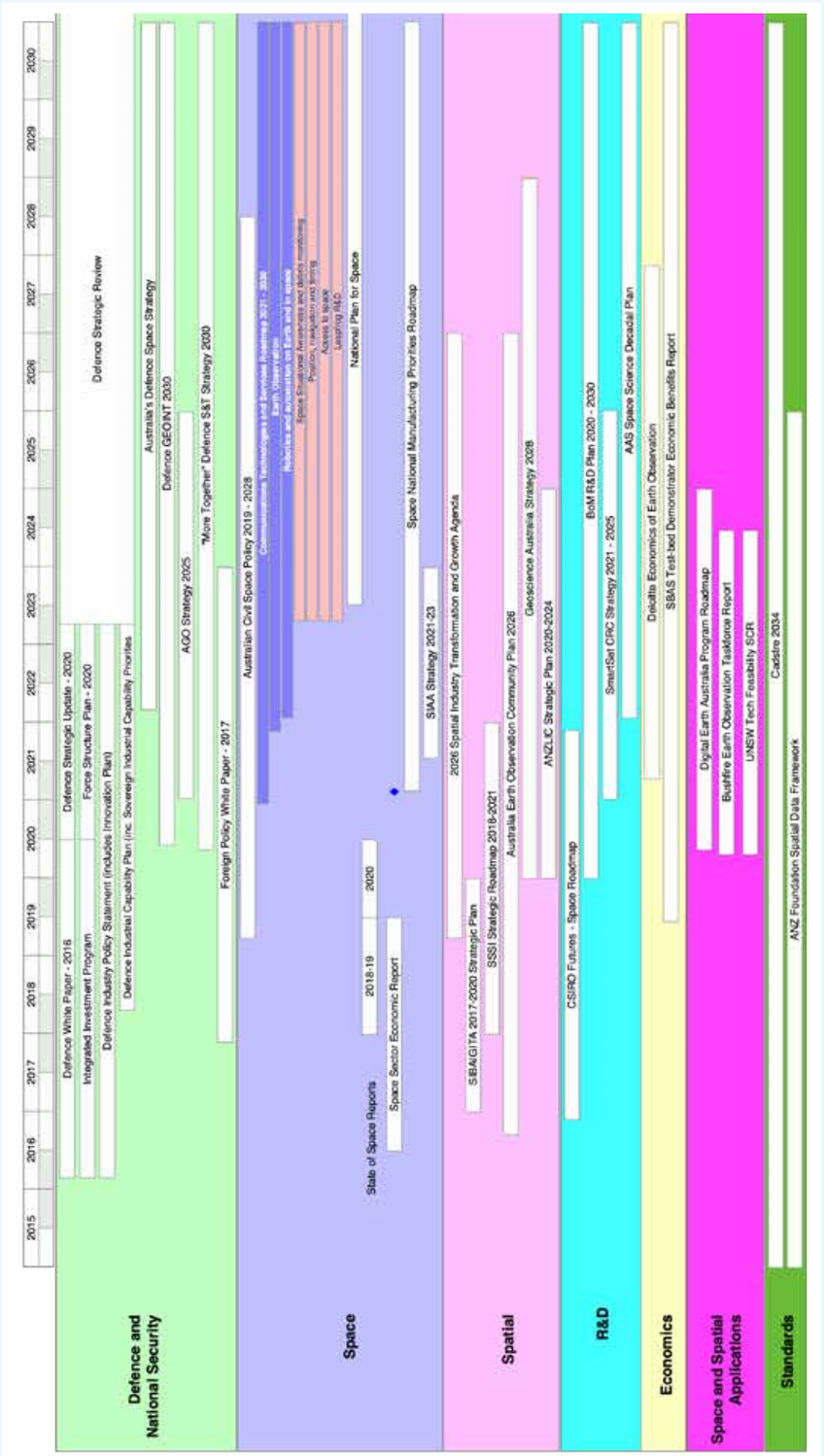


Figure 4: Timeline of Australian strategies and roadmaps

Procurement

Government procurement policies and practices will play a critical role in the growth of the space and geospatial industries. Intermittent government procurements and grant programs do not provide the sustained workflow required as growth pathways for start-ups and SME's and access of patient capital. The result is a hand-to-mouth existence for smaller companies that heightens the risk of stagnation or failure and an inability to compete with multi-nationals whose parent governments take a more strategic approach to space systems development.

Procurement, especially for defence, is used in many countries to build indigenous capability. Australia's procurement policies must be modified to prioritise Australian companies and build critical mass as well as enabling direct contracting with Australian SME's rather than foreign primes. It is not satisfactory to hide behind claims that Australia's trade obligations cannot be met while pursuing such policies.

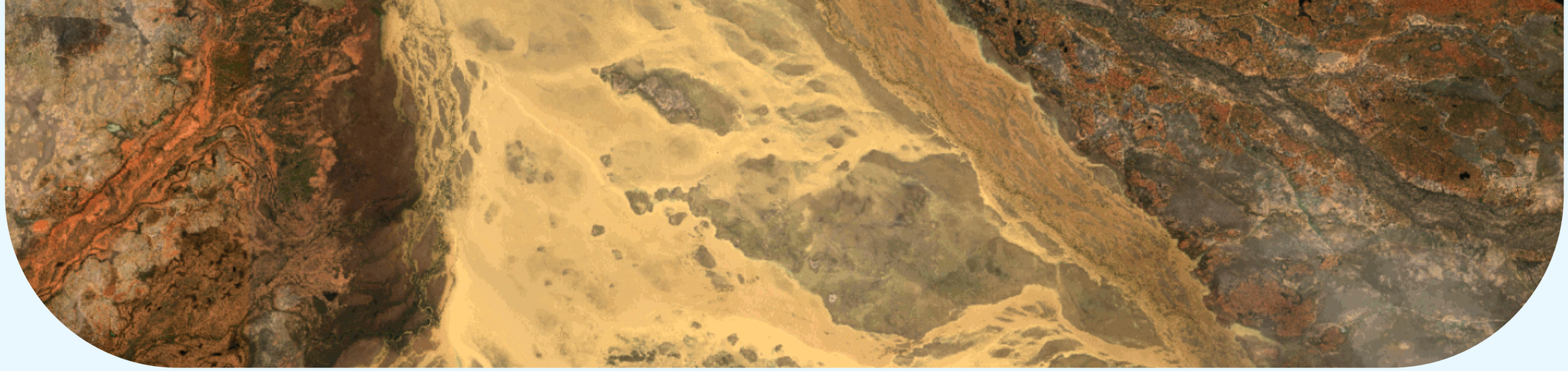
There should also be a goal to grow Australian space industry capability through a stable pipeline of National Space Missions. Appropriate procurement along with tightly coupled collaborative relationships with public R&D organisations, and a clear understanding of sovereign capability development goals by 2030 and beyond will play a vital role in developing the industry.

Aligned sources of funding

Fragmented and uncoordinated space and geospatial investment in recent years has resulted in an Australian space industry sector that is small and disjointed with isolated pockets of capability. Australia needs to maximise its investments in the right capability acquisitions to create the strongest possible value chain. This can be achieved through complex collaborative partnerships embracing the full supply chain from ideation to end use, guided by the next generation of national governance, funded by a full portfolio of sources (procurement, venture capital, grants, and R&D awards). The National Reconstruction Fund (NRF) is a welcome development for providing support at the firm level. This is however only one of the areas needing attention if the industry is to achieve its potential.

Sovereign capabilities

Supply chain disruptions and geopolitical tensions have raised awareness of the importance of sovereign capabilities for critical industry sectors such as space and geospatial. With prudent procurement policies and ongoing support, the Australian space and geospatial sectors are capable of achieving significant elements of sovereign capability. Growth in the space and geospatial industries will benefit significantly from an articulation of these sovereign capabilities together with an understanding of those which need to be domestically based. This will enable Australian space companies to plan and develop these sovereign needs.



3.2.2 Objective 2: Drive industry growth

Drive sustainable long-term growth through development of a robust industrial ecosystem of space and geospatial companies.

Development of growth strategies for specific segments of the space and geospatial industries for 2030 and 2040 will result in a robust space and geospatial industries ecosystem helping to capitalise on the long-term global economic growth opportunities.

Morgan Stanley forecast that in 2022 the global space industry is worth USD $411 billion per annum and is expected to grow to USD $1.1 trillion by 2040, representing one of the key global growth market opportunities of the coming decades. Critical to establishing growth strategies is the need to understand the existing industry structure and composition by company and capability. This data needs to be collected and maintained to underpin planning and monitor progress towards goals. Growth targets by industry sub-sectors to 2030 and 2040 can then be set. Government procurement using local supply chains will be critical to growth.

Action 2.1
Acquire data to understand existing industry structure and identify current Australian presence in relevant segments.

Action Champion 2.1
SmartSat CRC (which has around 100 partnering companies, including 70 start-ups) will undertake a first phase study, drawing on support from the Australian Space Agency (ASA) and the Geospatial Council of Australia (GCA).

Action 2.2
Agree 2030 and 2040 growth targets across each segment of the space and geospatial industries.

Action Champion 2.2
A first pass set of 2030 growth targets to be developed by SmartSat CRC supported by EOA, by industry peak bodies and government (e.g. ASA).

Action 2.3
Undertake a full ABS stocktake of the industry including reviewing the ANZSIC system to enable the identification of data relating to space and geospatial.

Action Champion 2.3
ABS, prompted by the SmartSat CRC and GCA.

Rationale and consultation input

Global market: Strong growth anticipated

Globally the space and geospatial industries have exhibited strong growth, which is projected to continue – see Table 1. This has been accompanied by increasing private sector initiatives in the space component, supplanting previous public sector dominance in many areas.

Table 1: Global space industry sales, 2021-2040[11]

	2021 US$m	2030 US$m	Growth 2021-2030	2040 US$m	Growth 2021-2040
Consumer TV	$93,546	$102,305	9.4%	$117,226	25.3%
Consumer Radio	$6,679	$8,535	27.8%	$10,060	50.6%
Consumer Broadband	$10,932	$46,266	323.2%	$94,852	767.7%
Fixed Satellite Services	$17,847	$18,315	2.6%	$17,254	-3.3%
Mobile Satellite Services	$7,292	$11,123	52.5%	$16,899	131.7%
Earth Observation Services	$3,250	$8,247	153.8%	$25,273	677.6%
Ground Equipment	$142,863	$178,070	24.6%	$196,092	37.3%
Satellite Manufacturing	$22,652	$19,838	-12.4%	$26,333	16.3%
Satellite Launch	$4,996	$10,109	102.3%	$9,794	96.0%
Non-Satellite Industry	$82,980	$97,349	17.3%	$127,566	53.7%
Second Order Impacts	$1,921	$99,369	5072.8%	$411,502	21321.2%
Total	$394,958	$599,526	51.8%	$1,052,851	166.6%

[11] Haver Analytics, Morgan Stanley, https://www.morganstanley.com/ideas/investing-in-space

According to an estimate by Morgan Stanley, the projected demand for Earth observation and consumer broadband services is particularly strong. The report suggests the most significant growth prospect is satellite broadband services driven by increasing demand for data to currently unserved areas. Other areas of opportunity include IOT, artificial intelligence, virtual reality, video and autonomous vehicles. The challenge is to identify areas where Australian industry can establish a competitive advantage.

Economic objectives of an industry strategy/blueprint/plan: Unlocking great potential

In economic terms, the objective of an industry strategy is to accelerate the industry's rate of growth beyond that which would otherwise have been expected. The strategy may also seek to capture specific market positions for Australian companies based on particular competitive advantages.

An industry growth strategy needs to be predicated on an accurate understanding of the size, composition and characteristics of companies and strengths and deficiencies in the overall industry and innovation ecosystem. Data is needed to provide information about the extent and nature of these elements, to enable a well formulated growth initiative, to understand the drivers of innovation, the impediments of growth, the opportunities for improved policy, the skilled capacity and labour needs, the role of public investment in research and development, the size of the start-up community and its growth pipeline among other issues.

Published industry data for the present size and characteristics of the Australian space and geospatial industries is incomplete. However, the renewed interest and emphasis on Australian space has attracted many new organisations to the sector including many start-ups. SmartSat CRC alone has around 70 space start-ups and industry experts generally agree that there are at least 100 space start-ups in this ecosystem as of 2022.

According to the Australian Space Agency, global space industry revenue was worth US $350 billion per annum in 2019, which is expected to grow to US $1.1 trillion by 2040 . This presents a golden opportunity for sustained growth in a growing global sector given the many advantages Australia's geography and technological resources provide.

Australia's space and geospatial industries are characterised by a relatively large number of SME's, more recently start-ups, a very small number of larger Australian-based companies, some of which have an international presence, and a small number of multi-national primes. The absence of Australian primes means that there is usually reliance on foreign multi-nationals to lead major contracts. These primes often have established supply chains which reduce opportunities for local companies. Smaller companies face common obstacles and constraints with technology companies in all sectors – issues accessing capital, limited capabilities across the broad range of technical and internal business competencies needed for success, and the need to establish new global market links. A concerted plan to develop and grow these firms can overcome these challenges and take advantage of the emerging global opportunity.

Towards a detailed understanding of the structure of the Australian space and geospatial industries

A fundamental requirement is to have an accurate and detailed picture of the companies within the industries. This involves understanding their capabilities, growth aspirations, critical linkages, key opportunities and perceived obstacles to growth. Appropriate policy or other responses can then be recommended as appropriate.

The key preliminary task is to identify the companies active in each segment and to gain as much relevant information about as many of them as possible. Ideally this would include the types of information outlined in Table 2 below. Realistically it will not be possible to obtain all this information from all of the companies in scope because of resource constraints and the reluctance of some companies to share some types of information. Therefore, a strategy will need to be designed which produces as much of the critical information as possible.

[12] Australian Space Agency (2019), Advancing Space: Australian Civil Space Strategy 2019-2028, Canberra: Commonwealth of Australia, April; available at: https://www.space.gov.au.

Table 2: Indicative company-level information

Company information	Turnover
	No of staff
	No of offices
	Turnover range (may not wish to disclose)
	Competencies
	Technical expertise?
	Internal business expertise?
	International experience?
Product and service offering	Key products
	Key services
	Product and service innovation ambitions
Internationalisation status	Exporter?
	Overseas agents/partnerships?
	Offshore offices/factories?
Linkages: Key suppliers	Key Australian suppliers
	Key offshore suppliers
	Desirable development of Australian supply sources?
	Supply problems/issues?
Linkages: Research and industry	Proportion of turnover invested in R&D and innovation
	Any linkages with PROs?
	What benefits do these linkages provide?
	Access to infrastructure for testing etc available?
	Obstacles to developing linkages?
	Memberships/linkages to networks?
Growth plans and trajectory	What does the company look like in five years?
	Obstacles/constraints to achieve?
	What does the company look like in ten years?
	Obstacles/constraints to achieve?
Market development goals	Five-year goal
	Obstacles/constraints to achieve?
	Ten-year goal
	Obstacles/constraints to achieve?
Capability development	Capital investment priorities
	Human capital development priorities
	Training needs and skills gaps
Intellectual property	IP protection strategy?
	Patents?
Ownership	Sole/family/multiple ownership?
	Foreign equity?
Accessing external sources of business ideas/mentoring advice	Use of consultants?
	Advisory Board?
	Constraints in accessing external advice?
Engagement with government programs	Participation in government programs
	Identify programs
Reasons to stay based in Australia	Why would the company remain based in Australia (if appropriate)
Reasons to move offshore	What would cause the company to move offshore?
Main constraints	Main constraints on company's growth?
Industry development	One most important thing that would benefit the industry's development
	Three top impediments to growth

3.2.3 Objective 3: Coordinate Research

Improve coordination of publicly funded research for the space and geospatial industries.

Publicly funded research will play a crucial role in achieving sovereign space and geospatial capabilities as well as capturing a larger share of the global commercial space and geospatial sector. Australia already conducts significant research in the space and geospatial sectors (spanning the publicly funded research sector, the private sector and the defence sector) and has a growing international reputation for providing significant space and geospatial research. In recent years, Australian governments have implemented several programs to accelerate the translation of the outputs of research into commercial ventures.

Australia also has research strengths in potentially disruptive technologies which could be combined with space and geospatial capabilities, potentially leapfrogging into world leadership roles generating competitive advantage and the potential to capture significant market share.

Australia has several publicly funded programs that provide investment for space and geospatial research and development at the national and state level (some specific to space and geospatial but others open to the broader range of high technology sectors). There is little strategic direction or coordination of space and geospatial investment and projects across these programs.

Building enduring new space and geospatial capabilities through technological innovation requires sustained investment programs over the long term with repeated investment cycles, especially in areas of science that require significant capital investment at the early stage and that are deemed to be needed sovereign capabilities.

Action 3.1
Consideration be given to establishing a standing body for guiding priorities for publicly funded R&D in the space and geospatial sciences which could include a process for providing advice to the National Science and Technology Council (NSTC). This body would be part of the new governance mechanism suggested under Action 1.4. A key role would be to determine the Technology Readiness Levels (TRL) for nationally agreed research and development priorities (focussing on TRLs 1-4). A body of this kind could also support the identification of how the space and geospatial industries can support the agenda setting for the NSTC.

Action Champion for 3.1
SmartSat CRC to develop options for the development of this standing body, supported by the Office of Australia's Chief Scientist and FrontierSI.

Action 3.2
Improve the alignment of existing funding (particularly ARC, ITRP, ARC linkage, CRC-P, NCRIS, Critical Technologies Fund and Defence) across space and geospatial to specifically target prototyping activity and advanced technology demonstration in space. This could be structured in some instances as grants requiring co-investment from industry with the co-investment ratio recognising technical risk and commercial risk and rewards.

Action Champion for 3.2
SmartSat CRC to develop options for an appropriate mechanism in consultation with the group of Australian Chief Scientists and EOA.

"Knowledge, research, innovation... these words are bandied about as if "space + spatial" is just another tech area, like biotech. It is not. We do not just work in "labs" or "start-up hubs". We need "sand pits" or "testbeds". An example is the evaluation of augmented (DFMC) GNSS of the Positioning Infrastructure GA has been working on. There were many real-world tests, at an application/sector level, e.g. transportation, construction, agriculture, marine, etc. I would suggest we need permanent testbeds, appropriately equipped with check, calibration, alternative tech so that researchers (from industry and academia) could evaluate new tech". Anonymous e-mail via web site.

Rationale and consultation input

Australia has several significant publicly funded programs that provide investment for space and geospatial research and development at the national level including the Cooperative Research Centres Program, funding to the Defence Science Technology Group and the proposed Australian Strategic Research Agency, the Australian Research Council and CSIRO, among others. Other funding programs are available through various State and Territory funding programs. Taken together they represent expenditure in excess of $12 billion out to 2030. The opportunity exists to encourage coordination across these programs, especially in areas of science that require significant early-stage capital investment and are identified as required sovereign capabilities. Embedding enduring new space and geospatial capabilities requires sustained investment over a decade, such as is offered by the CRC and NCRIS programs which act as anchor programs for the achievement of longer-term goals.

"Another challenge, probably a fundamental one, is for SMEs to have a chance to participate in Proof-Of-Concept demonstrations of new systems and technologies. By proactively engaging SMEs that operate in the downstream markets, the PoCs can help them meet their business development goals while also ensuring that the research has the best possible commercialisation pathway" Anonymous e-mail via website.

Australia has research strengths in several potentially disruptive technologies which could be combined with space and geospatial capabilities. Relevant areas include:

- application of artificial intelligence, robotics, and big data analytics to space-derived information
- application of next-generation communication technologies, including optical and hybrid optical radio
- quantum communications to enable secure, space-based broadband communication
- innovative sensors, antennae and instrumentation
- constellations of miniaturised spacecraft for communications, Earth observation, and the Internet of Things (IoT)
- next-generation rocket and spacecraft propulsion systems (hypersonics).
- Capability gaps which inhibit innovation and commercialisation include:
- Ability to rapidly prototype and demonstrate research outcomes to enable industry to understand technical risk and identify market opportunities
- Scale of companies versus capabilities and risks involved in tender bundles
- Procurement policies which inhibit growth of Tier 1 and 2 companies to achieve enduring scale.

"The Australian space industry should be encouraged to draw on the experience, expertise, technologies and infrastructure of all sectors of the Australian economy including Australian Government agencies and research organisations. Most of the existing infrastructure and analytical tools described in the Space and Spatial Roadmap Consultation Paper have been produced through collaborations amongst Australian Government agencies (including CSIRO, Geoscience Australia and the Bureau of Meteorology). We suggest highlighting the potential additional benefit that could be achieved through a closer, more collaborative approach between industry, the public sector and research agencies to improve Australia's position in the global space sector and industry growth. (...) Currently the vast majority of existing space and spatial data infrastructure is used and operated by Government research agencies (federal and state), and innovation is provided by the academic and research sector in addition to the spatial 'value-add' industry sector. While ensuring that start-ups can build on these data sets and sources, developing a properly collaborative model for industry to engage with Government and public sector research and academic agencies will ensure the best outcomes for Australia" CSIRO

3.2.4 Objective 4: Increase Capability

Drive high-value employment opportunities through a technologically capable workforce by building capacity in space and geospatial skills.

Technology requires a capable workforce. Increasing the supply of space and geospatial skills will underpin the potential of space and geospatial industries to capitalise on growth opportunities.

Action 4.1
The following actions would assist in expanding the space and geospatial workforce supporting industry growth:

4.1.1 Developing a more coherent and integrated approach to space and geospatial education programs in Australia that better meets the needs of the public sector, academia, and industry

4.1.2 Establishing an agreed national taxonomy of skill sets for space and geospatial

4.1.3 Extending the 2021 SmartSat-ASA skills gap study to cover other geospatial skills that are dependent on space and that support the proposed growth targets

4.1.4 Audit the existing suite of university and vocational education and training courses. This would include examination of micro-credentialing programs to rapidly grow the space workforce to meet the immediate as well as long-term needs of industry

4.1.5 Publication of an analysis of the estimated shortfall in skill sets against the taxonomy to better inform education providers and assist in planning, investment and expansion of degree and training options

4.1.6 Sourcing additional resources for the Space, Spatial and Surveying Diversity Leadership Network (SSS-DLN) and allied activities including Traditional Owners to significantly strengthen diversity outcomes

4.1.7 Creating a profile of the companies that generate space and geospatial services and identifying expected sources of demand

4.1.8 Establishing a program of National Space Missions to attract experienced individuals to return to Australia as well as attracting other relevant personnel as migrants.

Action Champions for 4.1
SmartSat CRC supported by EOA and GCA to develop a detailed plan for each of the issues identified under 4.1 that includes the identification of specific organisations to take responsibility for key elements of the action plan.

STEM is crucial: talent is going to be a key constraint on growth if we don't support it. Start-ups rely on students and recent grads to help them meet their needs and development. We have two students, and we believe in the importance of de-mystifying space. *Tony Scoleri, Founder and CEO AICRAFT*

(...) the issue of low-level (computational infrastructure) skills, capability, and capacity in state and local governments to deliver the data, services, and analytics that the roadmap is calling support for. For example, jurisdictions have been greatly challenged with resourcing the delivery of spatial data in GDA2020; a significantly higher resource requirement is anticipated to address the needs set out in the roadmap for a digital future. Whole of Government (Federal, State and Local) must be funded and resourced in this aspect - ANZLIC

Missing is the need to train industry, not just government, to understand the international standards and associated international expectations. The innovation can only be realised if the lab ideas can be turned into reliable, repeatable systems upon which the buyers can depend. This needs not only engineers but also the expert hands-on skills needed to perform procedures and processes to build the reliability into space missions. This training would be conducted as part of additional tertiary course units and TAFE courses. Do not assume that start-ups will automatically know "how to do". Australia has spent 40 years on the bench while the rest of the world progressed. Money alone will not solve the problem. A highly interventionist approach is required – Engineers Australia submission

Rationale and consultation input

Investment in building an appropriate skills base will underpin the potential to capitalise on growth opportunities. A recent Australian study[13] identified 319 skill sets that are needed to service a fully functioning space ecosystem. In 2018 there were around 10,000 jobs in Australia's space and geospatial industries with estimates that there will be a further 20,000 jobs by 2030. Many of these of these jobs will require geospatial skill sets.

The study found capability existed in 310 of the 319 skill sets, providing a strong foundation on which to build. However, there is a lack of depth in many of these areas. This introduces fragility, impeding workforce mobility and reducing resilience. The study also revealed that a greater volume of skills will be required in each of the 319 skill categories. Even now there are pervasive shortages - a sign that growth risks being curtailed by lack of skills.

Diversity and Inclusion

The skills shortage is compounded by diversity issues facing STEM in general. The 2026 Spatial Industry Action Agenda developed an action plan to address these issues. Several other initiatives have also been developed. For example, the 2021 Space, Spatial and Surveying Diversity Leadership Network (SSS-DLN) has developed important initiatives including establishing a benchmark statement of the current diversity of the two industries, establishing the 'panel pledge' for conducting safe and diverse events, and creating a library of case studies illustrating the benefits of diversity.

Technological changes and the emergence of new applications require a rapidly evolving set of skills to support growth of the industry. Securing a sufficient supply and breadth of skills to support the Australian space and geospatial sector requires strategies and concerted action to meet these skilled workforce needs.

[13] https://smartsatcrc.com/app/uploads/Space-Industry-Skills-Gap-Analysis-Final-Report.pdf

3.2.5 Objective 5: Develop Spatial Digital Twins (SDT)

Build Australia's sovereign capability in SDT as a critical national capability and an economic growth opportunity.

SDTs are an accurate digital representation of the real world in three or four (time) dimensions. They are a powerful tool to improve understanding of the physical environment and inform decisions. SDTs develop predictive capability through artificial intelligence and machine learning and offer real-time analytics, vastly improving the value of data through aggregation from multiple sources and shared access. With their rich information suite, analytics and services, SDTs are rapidly becoming an essential component of critical cyber infrastructure.

SDTs will play an important enabling role as a sovereign capability (ANZLIC Strategic Plan, 2020). Australia is well positioned to become a leading innovator in real-time SDTs, capitalising on its comprehensive geospatial data sets, strong focus on developing practical use cases, well-established geospatial data governance arrangements and long-established and globally competitive geospatial information analytics capabilities. Given the importance of these SDTs, careful thought needs to be given to their security including onshore provision of their data, AI algorithms and systems.

Action 5.1
Develop and publish use cases of SDTs that profile their application in addressing high-priority national challenges. Key candidate areas for consideration include landscape assets at threat from climate-induced catastrophic fires and floods; urban infrastructure planning for excessive heat under energy and water-constrained conditions; and supporting pandemic tracking of rates of spread and contributory factors.

Action Champion for 5.1
GCA and ANZLIC.

Action 5.2
Develop the case for inclusion of SDT research infrastructure in the National Collaborative Research Infrastructure Strategy to enable the research community to develop solutions to the challenge of ingesting, storing, and developing value-added analytics, information products, and systems.

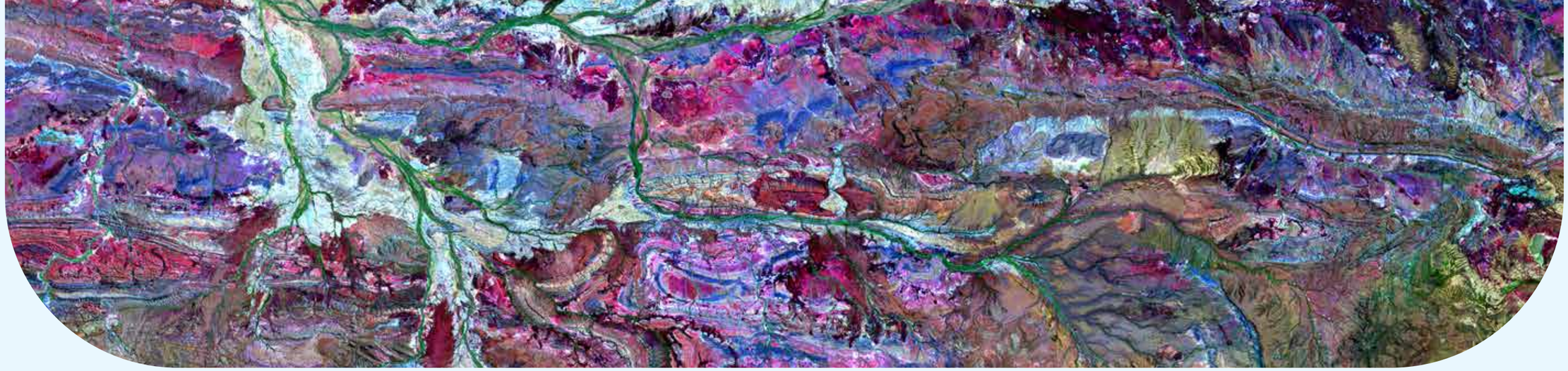
Action Champion for 5.2
AURIN and ANZLIC.

Action 5.3
Improve the usability and application of SDTs through development of national frameworks for SDTs to improve their interoperability, custodianship and access supported by the development and expansion of open and federated data policies to improve access, use, maintenance, and integration.

Action Champion for 5.3
ANZLIC, GCA and ASIERA.

Action 5.4
Establish a collaboration with First Nations on Digital Twin creation and use.

Action Champion for 5.4
SmartSat CRC



"Many of disaster mitigation applications, e.g. bushfires and flooding, require rapid turn-around-time from receiving the satellite data to delivery the information/outputs for assisting quick but informed decision making. This is critical not only to have high volume data downlinks, but also the rapid (or near real-time) accessible analysis ready data (ARD) for further image analyses and interpretations." Anonymous e-mail via website

"I manage an agricultural property, given up-to-date information on soil moisture variability, phenological stage, the weather forecast, product price estimates and a limited water budget, I want to model different scenarios to determine how much water to allocate to crops, to optimise my feasible yield/profit". Anonymous e-mail via website

We need a national approach to Australian datasets (for example, state agencies doing own things vs Geoscience Australia making same datasets; and all firms making own copies of data). Consultation feedback

Rationale and consultation input

There has been a fundamental shift in data science from data to models as the knowledge of the world increases, including SDTs. This leads to an imperative for interoperability and integrated modelling with related technologies including building information models (BIM), underground asset models, and embracing technologies including IoT, machine learning and artificial intelligence to enable new forms of visualisation, learning, and reasoning. Throughout Australia much work is being done to identify the principles, data frameworks and data governance arrangements and standards to enable data sharing and use.

An immediate challenge is to design SDTs with the most efficient pathways for the rapid ingestion and dissemination of next generation satellite-based data, continuous IoT sensor signals, very high resolution and high repeat cycle Earth observations, and centimetre accurate PNT signals, with smart algorithms and high-speed telecommunications. As a form of cyber-infrastructure, they are set to become part of Australia's Foundation Data Framework and perhaps even a recognised element of Australia's critical infrastructure.

The research community is well placed to work with Governments and the private sector to develop essential new capabilities to answer the key questions: How to best embed advanced machine learning and AI capabilities in SDTs; how to improve interoperability and establish consistent frameworks with standards that can operate seamlessly across the public and private interface, and across jurisdictions, and how to efficiently manage the vast flow of new data from the millions of real-time IoT data streams, the hundreds of new Low Earth Orbit (LEO) satellite Earth observation data sources and the huge number of relevant datasets from Government agencies and the private sector?

Case Study: Geospatial data drives massive productivity gains for Brisbane's Queens Wharf Development

Queens Wharf is a $3.6 billion world class development, which covers more than 12 hectares of Brisbane's CBD incorporating an integrated resort development as a destination for tourism, leisure and entertainment. It is likely to play a central role when Brisbane hosts the 2032 Olympics.

Opening in the first half of 2023, Queen's Wharf will transform the CBD and the Brisbane river's edge with an iconic design that embraces Brisbane's inviting subtropical climate and celebrates the precinct's Indigenous and European heritage with interpretive trails and experiences spanning the Brisbane River and ridgeline.

An automated monitoring system was developed to precisely monitor the structural movement of the Riverside Expressway during the construction of Queens Wharf. Riverside Expressway is an elevated roadway carrying around 150,000 vehicle movements per day, making it one of the most heavily congested and busy roads in Brisbane. Using a combination of several remotely controlled robotic surveying total stations comprising electronic theodolites that measure angle and distance to extremely high accuracy to detect structural movement and more than 350 Internet of Things (IoT) vibration sensors, a vast amount of data was captured and processed daily. This solution allowed automatic monitoring, measurement and processing that provided constant data of the vibration and fracture sensors, geotechnical, structural and deformation of the roadway. Over 2,000 precise measurements were taken per day from this solution, over a continuous five-year construction period. This solution was then expanded to monitor the construction over the site during the five-year period.

This monitoring of such a large and elevated roadway using conventional surveying methods would have required three field survey parties of two people on site permanently over the five-year period, totally some 7,200 person days. Instead, this solution allowed one professional to run monitoring mostly remotely from, only visiting the site to move the location of the robotic total stations and sensors to keep up with the construction, and to replace batteries, a saving of about 98 percent in labour. This provided a dramatic productivity improvement and a wealth of high-quality data that removed uncertainty relating to the construction.

Case Study: Space-based Positioning reduces construction costs of Perth to Bunbury Highway

The Perth to Bunbury highway forms the vital link between the two largest cities in Western Australia (WA), reducing the travel time for up to 30,000 vehicles per day by approximately 30 minutes. Although this road was completed in 2009 it was the largest road project ever undertaken in WA, comprising 70.5 km of dual carriageways (32 km to freeway standard), 19 bridges, 6 interchanges, 32 km shared paths, 21 km noise walls, 21 km drainage, landscaping and public art. Approximately nine million cubic meters of soil was moved to raise the road alignment above low-lying areas subject to seasonal inundation.

The consortium building the road utilised machine guidance systems (with space-based positioning systems) to undertake the earthworks without the use of site surveyors. This approach increased accuracy, reduced construction time and eliminated the need for on-site surveying and survey pegs.

In another first, an organisational psychologist was employed to assist in team building, getting the most out of the technology and managers rode in the haulage trucks to provide allow better understanding of and closer communication with the drivers. Utilising machine guidance systems with an organisational psychologist assisted in the adoption of new technology.

The project was completed under budget and three months ahead of schedule – almost unheard of for major road projects. The project was the first-time space-based positioning technology replaced surveyors in the field to set out the new road alignment and pavement. The project was a finalist in the Australian Construction Achievement awards in 2010 and a winner in the infrastructure category of the Asia Pacific Spatial Excellence Awards also in 2010.

The advances in technology and innovation have been substantial over the last decade, enabling far greater productivity gains than was achieved in 2009. Over the next decade technology advances are set to accelerate increasing accuracy, reducing processing times dramatically, increasing productivity and further reducing uncertainty.

3.2.6 Objective 6: Upgrade Position, Navigation and Timing (PNT)

Upgrade Australia's precise and assured PNT capabilities and technologies to meet national needs and position Australian firms to capture a larger share of the global PNT market.

PNT services underpin the precision required for modern navigation services, precision construction services and even the timing signals required for ATM banking, increasingly in near real-time. The use of PNT services will continue to grow globally with the provision of assured PNT for mission-critical and safety-critical applications including automated industrial machines, robotics, driverless vehicles, aircraft and infrastructure. PNT represents a major growth sector for the space and geospatial industries as well as an essential element to enable those industries, especially as demand for centimetre-accurate, near-real-time positioning grows. Australia has significant expertise in PNT technologies, research and innovation. Enhancing the PNT space and geospatial sector can develop the capability to meet Australia's needs for PNT services as well as potentially capturing global market share in areas such as ground-based low-cost mass-market GNSS receivers, space-based GNSS receivers and all aspects of PNT services. Australia has planned many significant developments in PNT and will need to carefully manage and maintain the resilience and future growth of this key capability.

Action 6.1
Facilitate the compilation of an overarching updated 'GNSS Strategic Plan for Promoting Enhanced PNT Capabilities across Australia' building on existing documents (e.g. the PNT Roadmap, due for release from the ASA mid-2023, and the Australian Academy of Science Decadal Plan for Space released in 2022) detailing industry strategy and aligned incentive mechanisms to facilitate development of high-tech Global Navigation Satellite Services (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.

Action Champion for 6.1
ASA, Geoscience Australia and FrontierSI.

Action 6.2
Form a multi-stakeholder 'Strategic Coordination & Engagement Group' responsible for monitoring and advocating for the updated GNSS Strategic Plan (see 6.1) and providing guidance where necessary, to provide consistency, ensure clarity and eliminate duplication through effective collaboration. Ideally, this would comprise federal, academic and industry representatives.

Action Champion for 6.2
The ASA and Department of Industry, together with support from Geoscience Australia and FrontierSI.

Action 6.3
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 and services which complement and augment GNSS, ultimately creating new sectors and jobs. These innovations to 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.

Action Champion for 6.3
The ASA, Department of Industry and SmartSat CRC (with its partners).

Action 6.4
Mechanisms to utilise Defence investments in technology for assured and resilient PNT should be explored as appropriate. This includes the use of quantum PNT and systems to detect and mitigate denial-of-service, interference and spoofing within the consumer marketplace.

Action Champion for 6.4
Department of Defence, with others to be determined through consultation with stakeholders.

Rationale and consultation input

The provision of assured PNT for mission-critical and safety-critical applications including automated industrial machines, robotics, driverless vehicles, aircraft and infrastructure is a key priority for Australia. This extends beyond those provided by current and future generation Global Navigation Satellite Services (GNSS) and will rely upon augmentation capabilities that maintain PNT performance in GNSS-denied or challenged environments. It should be noted that in late 2021, the Australian Space Agency established a Technical Advisory Group to develop the agency's PNT Roadmap, which is expected to be published in mid-2023.

Considerations for improving infrastructure, mitigating vulnerabilities, assuring access as well as provisioning precision positioning for geospatial analytics and information production include:

- The development of assured PNT capabilities for Australia which are suitably protected and secured (with authentication and possibly encryption) will be necessary to cultivate resilience and 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 and manufactured 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.
- Inventing, developing and delivering Australia-specific assured PNT integrity messages especially ones pertaining to high accuracy PNT services (such as RTK and PPP), could become an industry-leading innovation to export regionally and globally further raising Australia's PNT reputation.

[14] A **black swan** is an **event** that is rare, very important, and is both difficult to have predicted but is considered obvious in hindsight.

Case Study: GNSS underpinning critical national infrastructure

The impact of a GPS outage for one day has been costed at USD1b in the US, increasing by almost 50% if the outage is in April-May where precision farming drives agricultural productivity. In the UK, a five-day GNSS disruption would have an economic impact of USD7.2 billion, with road, maritime and emergency service impacts accounting for 88%of the cost. Intentional or unintentional interference of GNSS are real threats to Australia. Mirroring the US and UK, all Australian critical infrastructure is underpinned by GNSS PNT capabilities. GNSS timing drives our financial markets in terms of high frequency trading and even ATM transactions. PNT underpins the efficiency of and reliability of electricity grids and will enable the benefits of 5G wireless connectivity. Without GNSS the environmental and financial benefits of intelligent transportation and smart cities would be lost. Smartphone apps and consumer devices that use location services to deliver services and experiences would be rendered useless, a market estimated to reach USD72 billion by 2026. Australia's overall wellbeing, economic growth and resilience would be severely compromised by a loss of PNT services.

Further investment in GNSS technologies should focus on both improved resilience and performance. Here, Australia has critical advantages. Through decades of investment in fundamental science, Australia now has leadership in the emerging field of quantum PNT – where new quantum devices are used to provide improved services: greater localisation, better timing, and resilience to GNSS outages. The new quantum PNT approaches represent the next generation of precision navigation and timing. By increasing timing precision, we will be able to have more trades per unit time, and with improved resistance to hacking. Timing precision also leads to improved spatial resolution, which means better emergency response. PNT is essential for our defence and disaster relief services and quantum PNT will improve these capabilities. Lastly, the resolution afforded by quantum PNT will improve Australia's ability to monitor the effects of climate change. Australia's emerging sovereign capability in quantum PNT will assure Australia's continued economic development through the 21st and 22nd Centuries.

3.2.7 Objective 7: Reduce Sovereign Risk

Reduce Australia's sovereign risks around critical space and geospatial infrastructure, systems and data.

The Australian economy is critically dependent on services provided by space assets and their supporting geospatial infrastructure including, but not limited to:

- Weather and climate forecasting
- Natural disaster preparation and response
- Telecommunications including broadcasting, telephony and internet access
- Navigation and PNT for all forms of transport and logistics operations
- Timing signals for financial transactions
- Critical infrastructure
- National Defence.

Australia's dependence on space and geospatial capabilities as critical capabilities is rapidly growing but the threats to these capabilities and potential denial of access are growing equally rapidly. It is a strategic imperative for Australia to strengthen its resilience to access space assets and their geospatial capabilities and to create secure data management facilities to ensure timely access to the data and services essential to maintain our economy. Improving resilience to these capabilities will also facilitate opportunities for growing commercial utilisation of space and geospatial services.

Action 7.1
Undertake a thorough risk analysis of the critical dependencies of each of Australia's recognised critical infrastructure areas on space assets and services, geospatial infrastructure, data and services, the threats faced, the consequences and likelihood of damage, the mitigating actions and the residual risk using the ISO 31,000:2018 Risk Management standard and the ISO 27,000-Series on Information Security Standards.

Action Champion for 7.1
The Space Trusted Information Sharing Network of the Australian Critical Infrastructure Advisory Council, supported by the Department of Home Affairs, Department of Defence, ASA and EOA.

Rationale for this objective and consultation input

Almost all areas of Australian society and the Australian economy now rely on space and geospatial technologies and services, ranging from weather forecasting to disaster response, banking and finance, satellite telecommunications for rural and remote areas, transport and logistics and construction. The risks to the continuous provision of these services are mounting rapidly and include cyber threats, spectrum availability, adverse space weather including solar flares, supply chain interruptions and others. The most significant risk is lack of sovereignty as the vast majority of satellite services that Australia uses are foreign owned including those that provide GNSS signals used in PNT services.

This risk profile is compounded by the lack of understanding of the interlinkages across the Australian economy of the many uses of geospatial and services and incomplete knowledge of these interdependencies. The consequences of failure have not been dimensioned. What is known is that the uptake of space and geospatial services is significant and growing very rapidly. Australia is therefore exposed in ways that are not yet fully understood.

Dimensioning these risks across the critical supply and value chains is a task that falls within the remit of Australia's Critical Infrastructure Advisory Council, under the auspices of the Commonwealth Department of Home Affairs, and a project to undertake this work is currently being planned with a focus on Australia's critical infrastructure and its systems of national significance. This work has become even more important with the passing in early 2022 of the Commonwealth's new Security Legislation Amendment (Critical Infrastructure Protection) Act 2022 (SLACIP Act) which implements the final package of amendments to the existing Security of Critical Infrastructure Action 2018 (SOCI Act).

Australia is increasingly dependent on PNT services for many aspects of daily life and many technologies planned for the future, such as driverless cars and advanced positioning services for automation and location which will increasingly rely on PNT services. Australia is also increasingly dependent on services provided by other countries to meet its Earth observation and satellite communications needs. There needs to be awareness of the risks of having all these essential infrastructures outside of Australia's control. Understanding the risk and taking considered steps to reduce and mitigate them, including by building Australian owned and operated satellites for communications, Earth observation and potentially PNT, can reduce sovereign risk while growing the Australian space sector.

Case Study: Space weather and spacecraft resilience

Solar activity is growing as the Sun enters its 25th cycle of increased activity. Based on historical observations, the anticipated "solar maxima" is predicted to occur between 2023 and 2026 and is likely to result in more frequent solar flares and coronal mass ejections. These space weather events have previously and significantly impacted space and ground-based infrastructure so the expectation is that space services will again be affected during this period of heightened solar activity. The best-case scenario is episodic degradation of radio wave propagation, lasting from minutes to days in duration, degrading or denying telecommunications and PNT services, especially at frequencies lower than 2GHz. The worst-case scenario is the confluence of a large solar storm with the near-Earth orbital regions which could cause widespread damage to spacecraft, up to and including complete loss of function, which will have devastating and long-term impacts on space services.

Change detection in orbit, attitude, and communication behaviour is a key capability to predict on-orbit risk to civilian and defence space assets from space weather, debris and/or intentional (cyber) attack. Understanding, monitoring and forecasting space weather is a central component to achieve this goal. The effect of thermosphere density is well known as the biggest contributor to orbit uncertainty in LEO. High energy particles and electrostatic discharge from lower energy particles cand disrupt or destroy spacecraft subsystems. Interactions with the space environment have been proposed as a potential cause for high area to mass ratio debris from GEO graveyard orbit to re-enter the GEO belt.

To counter this increased risk to critical services from space, Australia needs to develop an integrated approach to the use of space weather data. Interpretation of space weather observations and information currently requires large time investments to locate available measurements, understand its accuracies and appropriate uses, and extrapolate to the right location, to the actual hazard, and to place the information into a climatological and statistical context with other similar anomalies. Australian space operators need access to retrospective mission analysis (anomaly analysis) for information sharing, to provide up-to-date and routine assessments of the most recent anomalies, their relationship to space weather, and impact to the Australian space industry as no public centralised reporting system and database exists.

3.2.8 Objective 8: Grow support for Defence

Support Australia's sovereign space and geospatial industry to meet the short, medium and long-term space needs of the Department of Defence, with industry supplying globally competitive space and geospatial products and services.

Defence, national security and civil infrastructure all heavily rely on space and geospatial capabilities. Many space capabilities are dual use and can potentially meet requirements across the Defence and civil domains. Defence will increasingly require space capabilities, recognising the importance of sovereign control of the assets and space-derived information and services. Defence should use its growing need for space assets and products to catalyse and grow the Australian space and geospatial industries by developing procedures and procurement policies to purchase these assets and services from Australian companies to meet its needs and simultaneously stimulate Australian space and geospatial industries.

Case Study: Managing congested and contested space for global prosperity.

By 2030 the world will have recognised the need for, and be on the pathway to, establishing global norms for behaviours in space by state and non-state actors. International efforts to implement treaty level agreements on military operations in space have failed prior to 2020. As Australia becomes more dependent on space the risk of operations below the level of conflict (so called "grey zone operations") impinging in Australian space assets increases. There are reported activities of space systems being deployed that could conduct aggressive or destructive manoeuvres, for example physically interacting with a spacecraft or getting close enough to conduct cyber or electromagnetic attacks.

The high level of dependence by military and national security agencies on commercial systems places them at risk. For example, space acquired meteorological data is critical for the planning of military operations. An adversary may see these space-based systems as a legitimate military target in the event of conflict or in the lead up to conflict.

The ability for Australia to maintain independent Space Domain Awareness and attribute observed events to the originator act to deter such aggressive behaviours. With space-based systems becoming more critical, it may also be desirable to incorporate an appropriate degree of resilience to counter a certain level of adversarial intent. There is scope for Australian industry to play a leading role in developing technical countermeasures to such activities or to develop operational techniques to identify and mitigate this class of hazard.

Action 8.1
Align Defence Priorities and Civil Space National Priority Areas with 10-year and 20-year goals as part of an Integrated National Civil-Defence Space Industry Growth Policy. Industry peak bodies to lead the development of a strategy that gives Defence confidence that it can provision the majority of its allocated $17 billion forward space and geospatial expenditure on Australian sovereign capability, including proactive industry formation of consortia of critical mass, granting programs of scale and procurement that are agile and build to the Blueprint.

Action Champion 8.1
Department of Defence and ASA supported by industry groups.

Action 8.2
Develop a project plan outline that could lead to an integrated National Joint Civil-Defence Disaster Response space and geospatial capability with strong links to Action 7.1. This should include consideration of the Australian Climate Service and key customers in Emergency Management Australia and the National Recovery and Resilience Agency.

Action Champion for 8.2
Department of Home Affairs, ASA and Department of Defence with support from SmartSat CRC.

Rationale for this objective and consultation input

Jointly developed larger and more capable constellations for critical communications and EO, are important elements for Defence and emergency management where a more integrated capability brings spill-over benefits. This model is already operating, for example, in Search and Rescue where the Australian Maritime Safety Authority, the Australian Defence Force and State, Territory and the Australian Federal Police operate under an Inter-Government Agreement with clearly defined roles and responsibilities.

Comprehensive legislation, frameworks, and capabilities at the National and State level for emergency management are in place but lack critical and responsive space-based capabilities such as Synthetic Aperture Radar and day-night all-weather capability which can see through smoke and clouds and is thus ideal for monitoring in near real time the extent of bush fires or flooding under overcast conditions. A national joint Civil-Defence project of this scale would supplement both civil and Defence operational requirements but also be a significant catalyst for accelerating space industry capacity building.

Defence is developing its Sovereign Industrial Capability Priorities (SICP) with space as one of the priority areas. The SICP will define the inputs to capability that demand control by Australian organisations. Exercising of this control may in turn require that key elements of a capability are delivered, operated and sustained by Australian-based or Australian-owned companies. It is vital that Australia retains a technological edge to protect freedom of access to space. This technological edge in, and from, space has historically relied on access to systems developed by Australia's allies. Australia will be increasingly required to contribute to technology development through partnership such as AUKUS and use this nation's proven ability to deliver innovative approaches to the deployment of space technology.

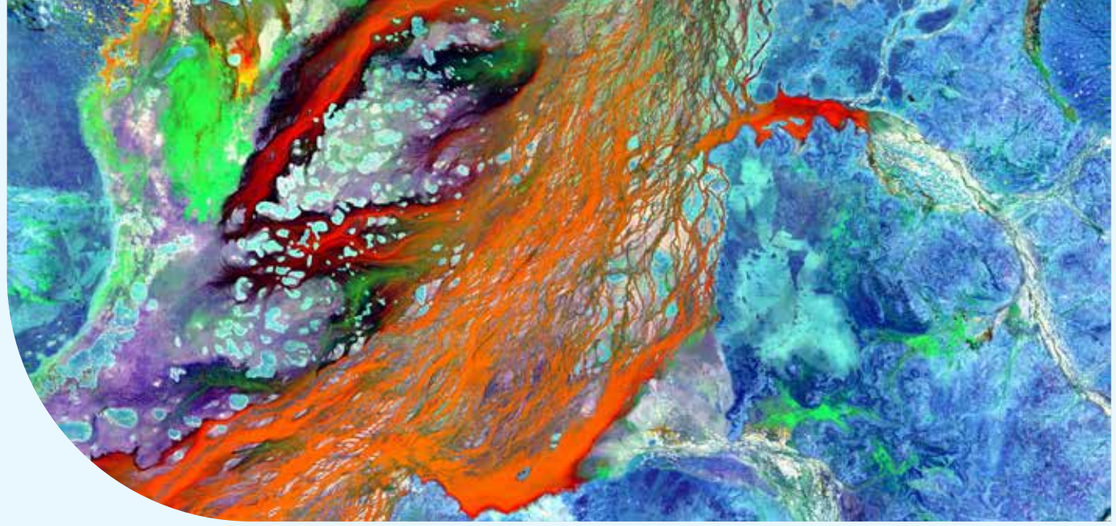
The balance between sovereign capabilities and reliance on allied technology must be decided within the context of escalating risk to space operations as the domain becomes more congested and contested. Defence has stated that it is a matter of when, and not if, Australian space assets are attacked. Designing resilient space systems must factor in hostile actions with cyber or electronic warfare attacks being a far higher risk (likelihood and consequence) than kinetic attacks. There is a need to examine requirements to support rapid restoration of space-based systems in the event of catastrophic failure due to environmental (such as space weather or debris) and human activity (state or non-state-based attacks).

Defence is putting programs in place to build the SICPs including grants and other Australian Industry Content initiatives. A similar approach must be implemented for critical infrastructure, systems, and data. Critical infrastructure must be clearly defined with those sub elements that must be Sovereign Industrial Capabilities. Defence and Civil Space Sovereign Industrial Capability Priorities should be aligned where appropriate and joint initiatives developed to build and strengthen the SICPs. Building Space Industrial Capability from a small and fragmented industry will take decades to achieve with 10-year and 20-year goals and pathways that must be clearly defined for the combined SICPs.

It appears likely that commercial satellite manufacturing and launch capabilities will emerge within Australia by 2030. The Government should commit sufficient resources to ensure continuing capacity to design, build, launch and operate small satellites entirely from Australia. This may entail funding up to five launch missions per year of at least 300kg per launch initially for advanced technology demonstration or service continuity/restoration in extremis. This needs to represent value for money but the value consideration must include a factor that recognises the strategic advantage conferred by freedom of action in space.

On the question of sovereignty, the Defence Industry Capability Plan provides the following definition; 'Defence sovereignty is the ability to independently employ Defence capability or force when and where required to produce the desired military effect. It does not mean that a defence capability must be designed, developed or maintained in Australia, but it does mean Defence has to have access to a functioning defence capability as and when required.' Development of domestic capability is therefore an important element of the development of the space and geospatial industries to ensure assured access.

Defence is a key stakeholder in risks to Australia's geospatial data infrastructure and key data stores, with alignment and assured access to national data from Defence networks to support Defence missions being an existing challenge. Any disruption to the data supply from space to data infrastructure assets would have serious consequences for the defence of Australia, again illustrating the importance of the interconnectedness between space and geospatial capabilities.



The space and geospatial industries are to be developed and structured to meet the requirements of Australia's National Civil and Defence Sovereign Industrial Capability Priorities which includes resilient and responsive space needs. To meet these needs, the space and geospatial industries will require diverse capabilities including advanced manufacturing of space qualified systems, a heritage of designing, building and testing space systems, access to responsive launch and ground stations and operations, and advanced analytics. Regular utilisation of these capabilities will be essential in maintaining this capability which by default means these two industries must be serving a global market. The space and geospatial industry eco-systems must be underpinned by a strong pipeline of appropriately aligned space and geospatial technologists and R&D base.

The ASA has been challenged to grow the Australian Space Industry to some 20,000 permanent jobs and $12B of revenue by 2030. Over the same period, the largest space customer, Defence, has only $7B in its public budget for space acquisitions. Of that figure, little more than 5-10% could be spent in country because there is insufficient capability and capacity in country to satisfy Defence within the timeframes of its acquisition cycle. *Defence industry feedback.*

Defence Industry Capability Plan definition "Defence sovereignty is the ability to independently employ Defence capability or force when and where required to produce the desired military effect. It does not mean that a defence capability has to be designed, developed or maintained in Australia, but it does mean Defence has to have access to a functioning defence capability as and when required." *DoD*

As it is almost certain that some element of the supply chain will rely on international manufacturing achieving 'absolute' national space sovereignty is likely to prove difficult. A more effective approach may be as per the Australian Space Agency pillar of establishing key international relationships to strengthen supply chains for the Australian space industry. *DoD*

3.2.9 Objective 9: Enhance National Mapping Base and its Foundation Geospatial Data

Maintain and enhance the National Mapping Base to ensure the accuracy and integrity of Australia's Geospatial Reference System and the critical national geospatial data that it supports.

Australia maintains large, diverse and growing stores of geospatial datasets that are critical to its national well-being. Anchoring these data in a common reference frame for interoperability, increasingly at cm accuracy, permits geospatial measurements that underpin applications such as disaster response, intelligent transportation, including driverless vehicles, machine guidance for mining and construction, environmental and climate-change modelling. Without this geospatial reference system, productivity gains would not be possible and environmental and emergency management and response would be significantly more difficult. Australia's geospatial reference system requires a highly stable and accurate global coordinate reference system. This is a global challenge that Australia does, and must continue to actively participate in. The importance of this was recognised by the United Nations in 2015 with the adoption of a General Assembly Resolution promoting the importance of an accurate, sustainable, and accessible Global Geodetic Reference Frame.

Australia's current developments and investments to enhance our geospatial reference system recognise that future spaceborne sensors and measuring techniques, enhanced EO capabilities and the unprecedented positioning accuracies achievable from multi-constellation, multi-frequency smartphone-like devices generate data that is inherently aligned to the International Terrestrial Reference Frame (ITRF) or World Geodetic System of 1984 (WGS 84). These are called time-dependent (or dynamic) reference frames – they accommodate tectonic plate motion. For example, without accounting for dynamics, coordinates in Australia will change continuously by between 6 and 7 cm per year to account for movement of the Australian tectonic plate. The significance of the tectonic plate movement, when using space-based positioning, for example the guidance of vehicle, vessels and aircraft is as follows:

Global Navigation Satellite Systems (GNSS) base their coordinates on a framework that is fixed to the centre of the Earth around which satellites are orbiting. These frameworks are called 'time-dependent reference frames / Earth fixed' in which the positions of features change with time due to plate tectonic motion. Historically, location differences of a metre or so have not been an issue, because GNSS has traditionally only provided accuracy of 5-10 metres. In fact, when GDA94 was adopted, GPS positions were 'accurate' to 100 metres. Since then, however, two important things have happened: 1) Australia's tectonic plate – the Earth's fastest moving continental plate – has moved about 1.5 metres northeast (approximately 7 cm / yr), and 2) positioning technology has evolved considerably delivering near real time accuracies of 10 cm or better. By 2020, Australia had moved 1.8 metres northeast of where it was in 1994, and many of us will own devices that pinpoint places as small as a smartphone.

In anticipation of the growing use, generation, and reliance on geospatial data, ANZLIC and ICSM are leading the modernisation of several elements of Australia's Geospatial Reference System including: the current static datum; the introduction of a time-dependent reference frame; improved geodetic infrastructure and standards to improve access and efficiency of geodetic data. Without adequate support and empowerment these agencies are unable to provide the tools, models and standards that will unlock the maximum benefits for critical sectors from precise positioning and emerging space and terrestrial technologies and support the further development of Australia's Foundation Geospatial Data Framework and the many related geospatial data stores nationwide.

Action 9.1
Adequately resource ICSM and ANZLIC to coordinate the upgrade of the Australian Geospatial Reference System.

Action Champion 9.1
ANZLIC and ICSM.

Rationale for this objective and consultation input

People, mobile phones and cars are already capable of being positioned with accuracy of 10 cm (or better) anywhere, anytime in Australia. However, the Australian Geospatial Reference System has elements which do not have the necessary accuracy. It is currently limited in its ability to provide Findable, Accessible, Interoperable and Reusable (FAIR) data. We need to upgrade the Reference System to maximise the benefits from precise positioning.
The recently launched $300m Southern Positioning Augmentation system (SouthPAN) by Geoscience Australia providing 10 cm (or better) accurate positioning is a significant improvement that will deliver substantial productivity gains to the national economy, made possible by maintaining the national geospatial reference system.
While acknowledging that substantial progress has been made to improving our national datums and reference frames, this critical behind-the-scenes work must continue to upgrade a number of elements of Australia's Geospatial Reference System including the static datum, the introduction of a time-dependent reference frame, improved geodetic infrastructure and standards development to improve access and efficiency of geodetic data. Australia must accelerate its transformation from the older existing coordinate systems based on GDA94 and GDA2020, and AHD to the new more accurate horizontal and vertical frameworks (ATRF2014 & AGQG), so that Australia can move past this dual approach, which is potentially confusing and misleading to those unfamiliar with positioning frameworks and technologies.

No mention of the reference frame or datum or any other aspect relating to maintaining the systems underpinning/facilitating the alignment of space and spatial data. While this is work funded by the Commonwealth, it would be good to see this level of maintenance in State and Local governments. The increased supply of space data aligned to a global reference frame over time underscores the need for all agencies to have a capability to align and deliver spatial data according to user need. *ANZLIC*

Case study: Space and spatial supporting UN Sustainable Development Goals

Investing in data to save lives and build back better

Since the start of the COVID-19 pandemic, policymakers and business leaders have routinely had to make time-sensitive decisions, many of which have life-or-death consequences. Yet even basic data to guide decision-making – on health, the society and the economy – are often lacking. The pandemic has brought to the forefront the critical importance of such data. It has also accelerated the transformation of data and statistical systems and how the public perceives and uses that information.

Driving innovation to advance SDG implementation

Innovative methods such as the integration of geospatial information and household survey data are also being used to produce more disaggregated and timely data. Colombia's National Administrative Department of Statistics is using satellite imagery and household surveys to produce municipality-level data on multidimensional poverty. This exercise, supported by the Data for Now initiative, has provided new insights into decision-making to combat poverty.

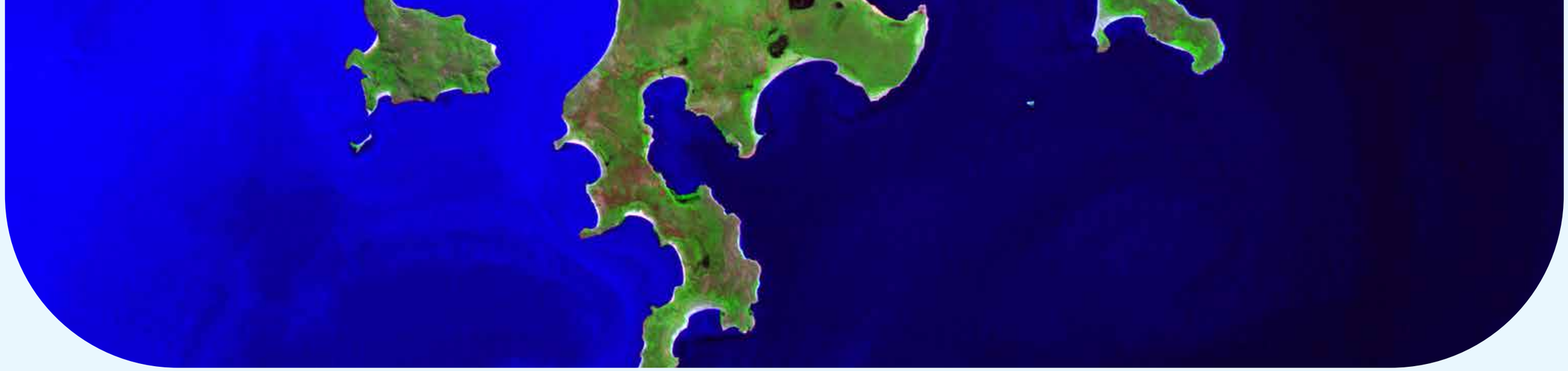
In addition, machine learning algorithms, when coupled with social science, can further understanding of public perceptions on issues such as discrimination. COVID-19 has prompted further innovative data collection methods such as measuring social distancing compliance with mobile phone data and uncovering disease transmission patterns using data from contact-tracing apps.

SDGs and Geospatial

The United Nations SDGs Geospatial Roadmap 2021 has been developed collaboratively as a strategic information and communications mechanism that 'builds the bridge' and understanding between the statistical and geospatial actors working within the Global Indicator Framework. The vision of the SDG Geospatial Roadmap is to see geospatial and location-based information being recognised and accepted as official data for the SDGs and their global indicators. This vision expands on the recommendation of the IAEG-SDGs Working Group on Geospatial Information (WGGI) that, while official statistics are the foundation on which the SDGs are built, the SDGs cannot be fully realised using official statistics alone particularly when they are not produced in sufficient quality, detail and frequency. In fact, the SDGs are highly dependent on the understanding of geographic location, necessitating the inclusion and use of geospatial information, Earth observations and other forms of location-based data.

Big Earth Data for SDGs

International Research Centre of Big Data for Sustainable Development Goals has been set up in China to support the implementation of the United Nations 2030 Agenda for Sustainable Development. The centre aims to be a public science and technology platform for big data for sustainable development, a focus for scientific research on sustainable development, a hub for innovation in data information services and technologies, a high-end think tank on sustainable development, and a centre for developing talent and improving human capacity through education and training. Through these roles, the centre will serve UN agencies and UN member states in implementing the UN's 2030 Agenda.



3.2.10 Summary of the critical role of government

The Government plays a major role across the nine recommendations listed in this section. Most importantly, in order to unlock the massive productivity benefits available across all sectors of the economy, governments at all levels need to become model users and procurers of space and geospatial services. This will require a significant investment in upskilling across government at all levels so that the potential to use geospatial data is understood and the skills are available to utilise it.

Other actions which government needs to address are:

- Work to provide a unified vision for the space and geospatial industries for the civilian and defence sectors, enabling coherent planning and allocation of resources
- Fund a continuing program of National Space Missions to increase Australian sovereign capability and drive innovation
- Fund R&D activities in line with a coherent set of national priorities for space and spatial industries across a mix of firms and research organisations
- Develop procurement practices in both the civil and defence sectors which build sovereign capability and strength Australian companies.

The Government's announcement of the National Reconstruction Fund and the eligibility of space industries is a welcome step toward building the industries of the future. However, it is not clear that NRF eligibility will extend to the geospatial sector although Sensing, Timing and Navigation is a key area in Australia's critical technologies list and is associated with a number of other industries eligible for NRF support.

4 Conclusion and next steps

Space and spatial industry stakeholders are seeking a closer relationship with relevant agencies and the critical role of government is emphasised at every stage of the Roadmap. If we are to generate commitment from these sectors and create sovereignty for our geospatial future, Australia needs stronger industry development policy settings, targeted investment strategies and a more comprehensive collaborative model. Research, industry and government all play a key role in unlocking the massive productivity benefits available across all sectors of the economy.

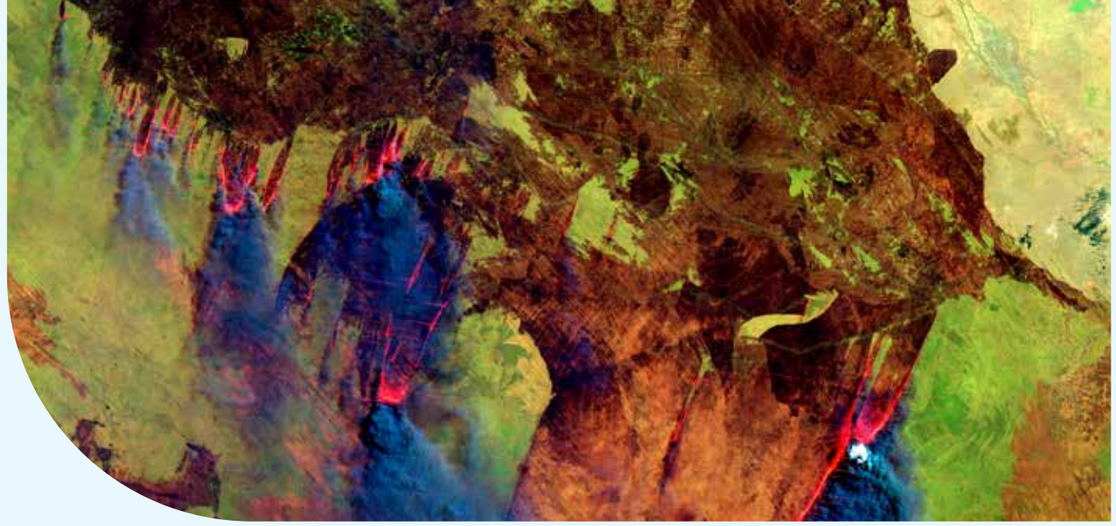
All the market studies referenced in the preparation of the Roadmap show that massive growth in the space and geospatial industries is expected. The cost of launching satellites is falling rapidly. Developments in sensors, communications and artificial intelligence are profoundly altering conventional methods of undertaking business and government functions. As a start, government needs to become model users and procurers of space and geospatial services. This will require new policy settings and a significant investment in upskilling Australia's space and geospatial workforce of the future.

This document has set out the increasingly critical role that space and geospatial industries will play in Australia's economy as essential enablers of productivity, critical infrastructure and national security. A distinctive aspect of the Roadmap is recognition of the synergistic relationship between the space and geospatial industries and the proposal that an integrated approach to their development will be most beneficial.

The Roadmap is predicated on the basis that Australia has many solid foundations on which to build but only nascent capabilities in other areas, in many cases exposing risks to sovereignty. The central challenge is whether Australia will rise to the opportunity to capitalise on existing foundations and develop missing critical links, or simply be a spectator, dependent on others for critical capabilities thereby giving away the chance to build a dynamic and modern industry. These polar positions are reflected in the three growth scenarios presented in the document.

The nine objectives and program of associated actions and action champions are the result of distilling input from an extensive and lengthy consultation process across industry, research and government organisations. If growth ambitions are to be achieved, each recommendation needs to be actioned.

The ambition to implement this Roadmap and deliver significant national benefits involves establishing an ongoing Steering Committee comprising key stakeholders from Industry, Research and Government. Its function is to monitor progress and regularly assess and update the roadmap to reflect current developments.



5 List of Footnotes

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14. https://www.aph.gov.au/Parliamentary_Business/Committees/House/Industry_Innovation_Science_and_Resources/SpaceIndustry/Report
15. Note that these are aspirational scenarios for illustrative purposes only. In developing a blueprint for growth, Australia needs better data to understand the baseline figure for future growth and this should be determined by Gross Value Added, not revenue. Most economic forecasts estimate growth based on revenue and this can be misleading as outlined in the IDA report. (Source: Bryce 2019 Global Space Economy at a Glance)
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18. A black swan is an event that is rare, very important, and is both difficult to have predicted but is considered obvious in hindsight.
19. The 2030 Space and Spatial Industries Consultation Paper (2021) can be found at https://2030spaceandspatial.com/downloads/
20. When this process began the Surveying and Spatial Sciences Institute (SSSI) and the Spatial Industries Business Association both contributed through representation on the working group and steering committee. They merged their operations in March 2023 to become the Geospatial Council of Australia.

6 Acknowledgements

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- Bremer and Co
- Bureau of Meteorology
- CSIRO
- Department of Defence
- Department of Home Affairs
- Earth Observation Australia
- Engineers Australia
- FrontierSI
- Geoscience Australia
- Geospatial Council of Australia
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- SmartSat CRC
- Space Industry Association of Australia (SIAA)
- University of Queensland
- University of New South Wales

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8 Glossary

ABS ..... Australian Bureau of Statistics
AI ..... Artificial Intelligence
ANZLIC ..... the Spatial Information Council
ANZSIC ..... Australian and New Zealand Standard Industrial Classification
ARC ..... Australian Research Council
ASA ..... Australian Space Agency
ASIER ..... Australasian Spatial Information Education and Research Association
ATM ..... Automatic Teller Machine
AUKUS ..... Australia, United Kingdom, United States Security Pact
AURIN ..... Australian Urban Research Infrastructure Network
BIM ..... Building Information Models
BoM ..... Bureau of Meteorology
CAGR ..... Compound Annual Growth Rate
CRC ..... Cooperative Research Centres
CRC-P ..... Cooperative Research Centres Projects
CSIRO ..... Commonwealth Scientific and Industrial Research Organisation
EO ..... Earth Observation
EOA ..... Earth Observation Australia
GA ..... Geoscience Australia
GCA ..... Geospatial Council of Australia
GDP ..... Gross Domestic Product
GEO ..... Group of Earth Observations
GNSS ..... Global Navigation Satellite System
GPS ..... Global Positioning System
IAEG-SDGs ..... Inter-agency and Expert Group on SDG Indicators
IoT ..... Internet of Things
ICSM ..... Intergovernmental Committee on Surveying and Mapping
IP ..... Intellectual Property
ISO ..... International Organisation for Standardisation
ITRP ..... Industrial Transformation Research Program
LEO ..... Low Earth Orbit
MEO ..... Medium Earth Orbit
MMI ..... Modern Manufacturing Initiative
NCRIS ..... National Collaborative Research Infrastructure Strategy
NSTC ..... National Science and Technology Council
OECD ..... Organisation for Economic Co-operation and Development
PNT ..... Position, Navigation and Timing
PPP (PNT) ..... Precise Point Positioning
R&D ..... Research and Development
RTK (PNT) ..... Real-time Kinematic
SATCOM ..... Satellite communications
SBSP ..... Space Based Solar Power
SDGs ..... Sustainable Development Goals
SIAA ..... Space Industry Association of Australia
SIBA-GITA ..... Spatial Industries Business Association – Geospatial Information & Technology Association Australia and New Zealand
SICP ..... Structure and Interpretation of Computer Programs
SICP ..... Sovereign Industry Capability Priorities
SDT ..... Spatial Digital Twin
SMEs ..... Small to Medium Enterprises
SSS-DLN ..... Space, Spatial and Surveying Diversity Leadership Network
SSSI ..... Surveying and Spatial Science Institute
SSR (PNT) ..... State Space Representation
STEM ..... Science, Technology, Engineering, Mathematics
TRL ..... Technology readiness level
WGGI ..... Working Group on Geospatial Information

Appendix A: How consultation shaped this document

The development of an industry growth roadmap for both the space and geospatial sectors required substantial consultation across the space and geospatial industries, civilian and defence sectors, government, publicly funded research sectors and throughout many of their user communities over nearly twelve months during 2021 and 2022.

Specific consultation included:

- The Space Industry Association of Australia representing nearly 200 companies and individuals with a submission from the Board
- The Surveying and Spatial Sciences Institute representing 2100 members with a submission from the CEO
- The Spatial Industries Business Association – Geospatial Information & Technology Association of Australia and New Zealand (SIBA – GITA) representing about 100 companies with a submission from their Board
- Earth Observation Australia representing about 300 members with a submission from their Board
- AURORA, SmartSat CRC's space start-up cluster representing about 70 companies with a submission from their Board
- ANZLIC, representing all eight Commonwealth, State and Territory jurisdictions with a submission from their Council
- Department of Defence, with a submission that represented the views of the whole Department
- Geoscience Australia, with a submission that represented the views of the agency
- CSIRO, with a submission that represented the views of the agency
- Bureau of Meteorology, with a submission that represented the Bureau
- Engineers Australia
- ASIERA, the Australian Spatial Information Education and Research Association
- The Australian National University – InSpace
- Adelaide University
- RMIT University
- University of New South Wales
- University of Queensland

As well as several national workshops involving 200+ attendees and 44 direct submissions from individuals via the interactive website.

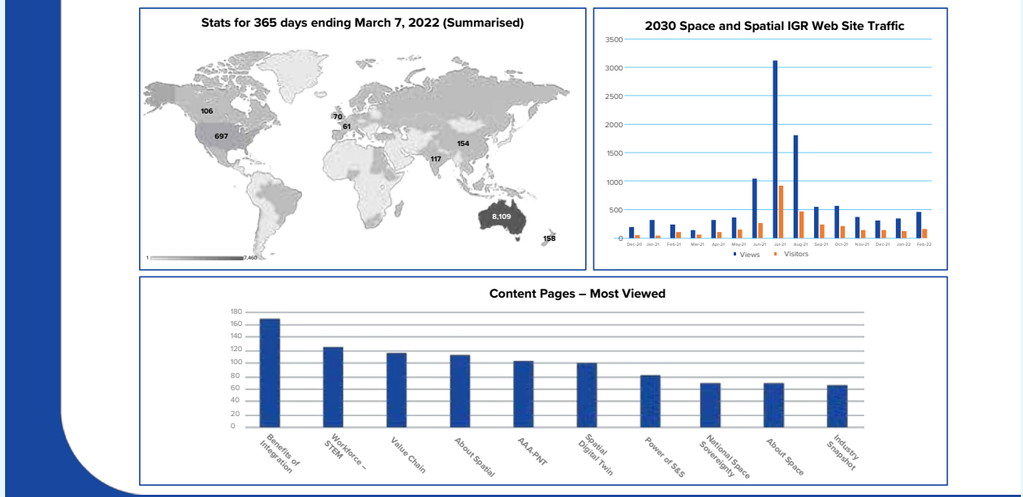


Figure 5: Statistics from website established to support consultation

A Steering Committee (see https://2030spaceandspatial.com) helped guide this work. It contained representatives of peak bodies across both the space and geospatial sector and rotating membership. The Steering Committee was formed and first met in June 2020.

The consultation and preparation of reports and the final roadmap was undertaken by a Working Group, comprised of subject-matter experts and advisors from both the space and geospatial sectors, and in some cases involving members of the Steering Committee directly. All contributed to the provision of detailed content to the objectives of the Growth Plan.

The development of the industry paper took an iterative and highly collaborative approach that led to the creation of (1) the Consultation Paper[15] which was released to the public in June 2021, which formed the basis of the national engagement and feedback gathering, and (2) this document which drew on the consulation to recommend objectives and actions, as highlighted in Figure 6.

[15] The 2030 Space and Spatial Industries Consultation Paper (2021) can be found at https://2030spaceandspatial.com/downloads/

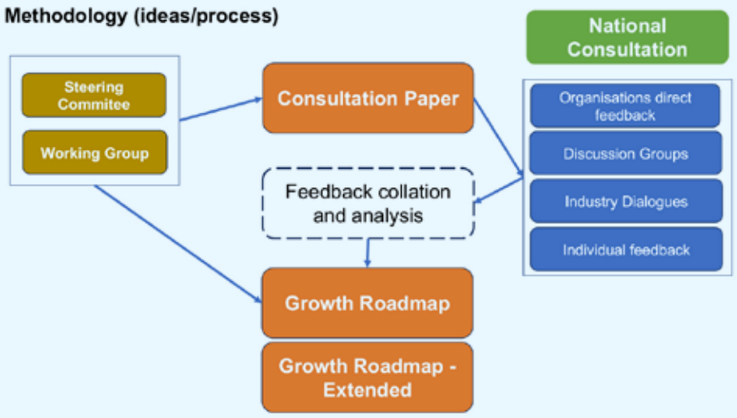


Figure 6: Process for input collection and development of the 2030 Space and Spatial Industry Paper

The consultation paper

The consultation paper was a comprehensive document that presented 24 issues designed to elicit feedback through the process of consultation. Given the broad range of activity in both the space and geospatial sector, the paper focussed on those issues that had not yet been factored into the many existing strategies and plans of the agencies, organisations and companies not yet captured in other national strategies. The priority for the paper was on the growth potential for Earth-oriented applications, recognising that the outward looking space will warrant similar attention in the future.

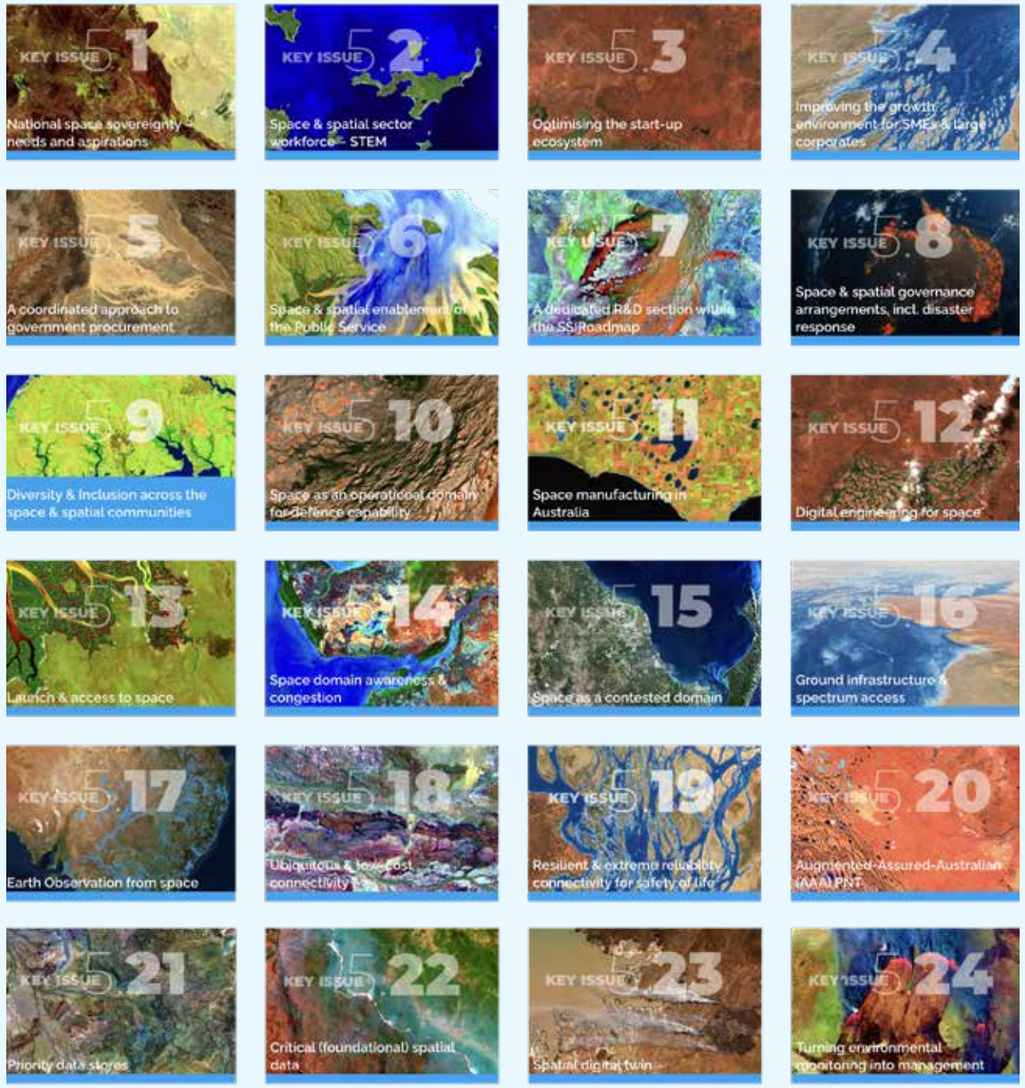


Figure 7: The 24 issues presented for comment in the Consultation Paper

The consultation process

A diverse range of engagement avenues and mechanisms was proposed to ensure the national consultation was broad and reached maximum number of responses across the space and geospatial sectors, therefore removing barriers of access and/or engagement whenever possible. To this end three options were developed:

1. Individual feedback provision through an online survey: a 10-minute survey where respondents provided feedback and input across the 24 key issues online.
2. Self-organised discussion groups: 30min to 1h group discussion, where feedback was then uploaded online by a group representative.
3. Peak organisation-led 'Industry dialogues': Organised by several industry associations that committed to support the national consultation, some undertaken in person and others online via teleconference.

The consultation results

The feedback received on the consultation paper highlighted overall support for the identified issues and gaps, needed to be addressed by the space and geospatial sectors in order to capitalise on the joint growth and opportunities ahead. The consultation was structured around three areas of focus: (A) National Security, (B) Economic Growth and (C) Societal/Environmental Benefit, these were supported by all participants that provided feedback with 68% providing suggestions.

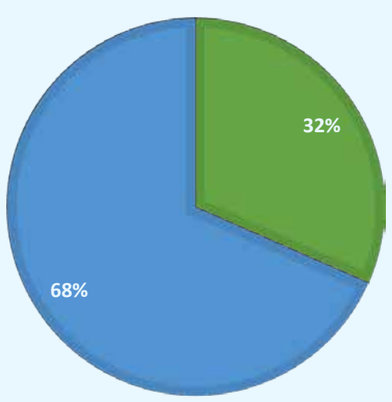


Figure 8: Consultation feedback the focus areas of (A) National Security, (B) Economic Growth and (C) Societal/ Environment Benefit, as being the right lens to view opportunities for Space and Geospatial sectors (combined)

These suggestions mainly related to the balance and perceived importance across the three focus areas. For instance, some participants were strongly willing to prioritise areas such as environmental benefit linked to climate change, over national security, however the range of contrasting views did not present a strong enough argument for prioritising one over the other. Several participants focused on the importance of differentiating between societal and environmental benefits, arguing societal benefit and environmental benefit are quite disparate areas to explore as one focus area, since innovative and environmentally focused initiatives may come at cost to the society that enacts them, arguably putting societal benefit in direct opposition to environmental benefit.

Considering the responses from the online survey only, individual feedback validated the focus on Environment related aspects, with issue *17. Earth Observation from Space* ranking the highest in terms of priority, Figure 9, followed by issue *24. Environmental monitoring to Environmental Management*. The importance of resilient communications in the context of disaster management (issue *19. Resilient Communications for Safety of Life*) and of *20*. Augmented, Assured, Australian Positioning Navigation and Timing (*PNT*) also ranked in the top 5. *Lowest ranking* issues followed the trend of focusing only on either space or geospatial, therefore failing to address the joint added value for both sectors, with the lowest ranking issue being *15. Space as a contested domain*, followed by *9. Space as a military operating domain*. Feedback on Spatial Digital Twins obtained across the industry dialogue sessions as well as direct input from peak body associations considered Spatial Digital Twins as a critical information and decision-making tool. This feedback noted that this capability was a promising avenue to maximise and ease the access to space-derived data and infrastructure, integrating it with geospatially enable datasets that allow creation of near-real time digital representations of our world and can be applied across a range of domains and sectors. The online consultation was not as supportive.

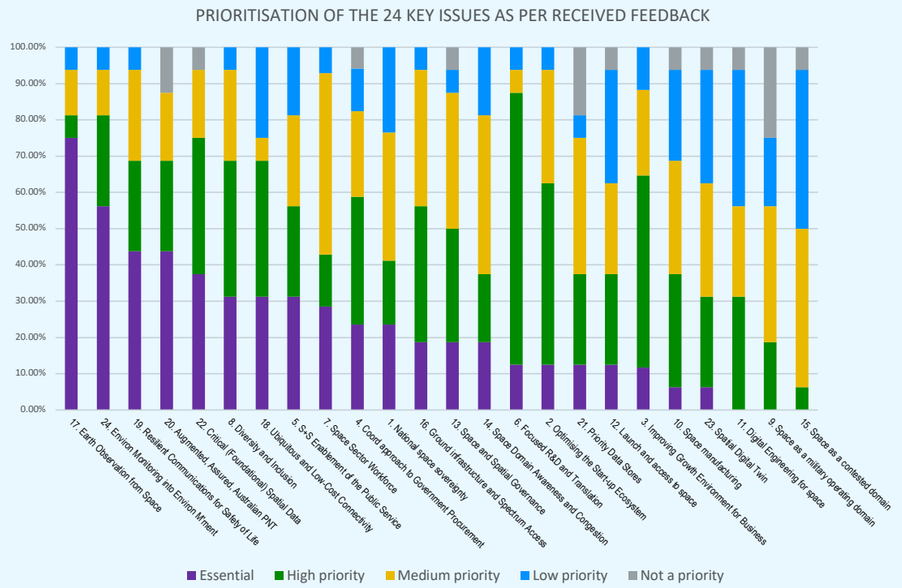


Figure 9: Prioritisation of the 24 Key Issues as per feedback received in the Consultation, going from high priority (left) to low priority (right) and ranged across levels of priority (vertical) from Essential, High priority, Medium priority, to Low priority and No priority

B Appendix B: SWOT Analysis of Australia's Space + Spatial Industry Capabilities

SWOT Analysis for Growth of the Australian Space+Spatial Sectors

Objective: Grow the Space (and Spatial Industry to $12B and add 20,000 jobs by 2030

WEAKNESSES

- Low level of maturity of Australia's space heritage compared with top 20 space nations
- No over-arching national space strategy covering civil and defence applications for space and spatial services
- Skilled capacity shortfalls in nearly every one of the 319 space-related skill areas
- Lack of critical mass and scale for space and spatial companies
- Funding available lacks strategic focus to dive Australian industry growth (too many small and uncoordinated individual grants) (Gap is $50m+ programs of work)
- Sovereign capability and domestic needs not well defined
- Fragmented Australian industry content policy
- Critical role of space services and data to Australia not well understood by Government and the public
- Research translation for commercial products and productivity growth.

THREATS (to growth)

- Inability to quickly solve our skill capacity shortage and competition from adjacent sectors within Australia (eg. mining, financial services)
- Space is contested, congested and competitive
- Defence spend unable to wait for industry development/growth to reach critical mass and sovereign capability levels to procure domestically
- Foreign cyber threats to critical infrastructure and intellectual property
- The absence of visible national Australian space programs undermines credibility for international investors

STRENGTHS

- Australian Space Agency (Technology Roadmaps)
- Commonwealth, State & Territory Government enthusiasm for space
- Increasingly strong industry networks
- Globally respected space applications capabilities
- Longstanding world class experience in key traditional space & spatial areas provides solid platform for growth
- World class expertise in adjacent industries in critical areas for futures space development
- World class space science and research capabilities
- Robust space start-up ecosystem – Australia is generally considered behind the US in worldwide space startups

OPPORTUNITIES

- Greater access to a range of funding lines (commercial and government) is supporting industry growth
- Rapid rate of innovation means technology and capital thresholds for market entry are reducing aligning with Australian capabilities
- Strong growth in domestic and international space and spatial marketplace
- Commercialisation of space reduces dependence on Government funding
- Government commitment to fund development of national infrastructure to support industry growth eg. MMI, Moon-to-Mars, SBAS, NCRIS, DEA
- Large defence space and geospatial funding available ($10B)

C Appendix C: Are we entering a new epoch for human use of space?

The space sector has evolved massively since the launch of the first artificial satellite in 1957.

The notable epochs are:

The pioneering era of space (1957-1964): The launch of Sputnik, the first artificial satellite, on 4 October 1957, by the USSR created a significant strategic shock during the Cold War. This led to a period of space activity that could be characterised as being extremely expensive and extremely high risk and dominated by strategic competition between the USA and USSR. Activities were exclusively funded and controlled by Government and often involved extraordinary degrees of secrecy. During this period approximately 340 satellites were launched. The only nations other than the two super powers to also access space were the UK (1962), Canada (1962) and Italy (1964).

Space 1.0 (1965-2000): This period saw consolidation of the technology base developed during the pioneering era that resulted in over 5000 satellites being launched. This included the first Intelsat satellite launched in 1965, often considered the first commercial telecommunications satellite. This epoch was characterised by the growth of telecommunications satellites in geostationary orbit as well as the development of robust Earth observation satellites and the launching of the GPS positioning and timing satellite constellation. It ended with the first attempt at large constellations of low Earth orbiting communications satellites deployed for purely commercial applications which created a spike in satellite launches and satellites in orbit.

Commercial Growth Era (2001-2011): During the immediate post-dotcom bust period the initial Low Earth Orbit (LEO) communications constellations and their business case failures led to a collapse of the launching of large constellations and a reversion back to the traditional market of geostationary communication satellites. This era saw the development of the initial High Throughput geosynchronous telecommunications satellites increasing the satellite payload throughput capacity from the order of 500 Mbps to 2 – 10 Gbps. The growth in the total number of satellites in orbit then stabilised following a reduction in new satellite purchases by both government and commercial operators due to the completion of the satellite constellations and the longer lifetimes of modern geostationary communications satellites. During this period, just over 1000 satellites were placed in orbit but this era was when commercial investments in space exceeded government expenditure for the first time.

Space 2.0 (2012-2018): This stage was dominated by the development of the cubesat standard and increasing proliferation of small cubesat and nanosatellites which served as a springboard for the emergence of large-scale commercial programs largely based on cubesats or small satellites. It was also characterised by the emergence of lower cost launch capacity including the development of launch activity from commercial operators focused on frequent, reliable and low-cost access to space with specific focus on smaller commercial satellite launch support. Almost 2000 satellites were launched during this period.

The world is now on the cusp of a new and defining epoch which is characterised by an explosion in the number of Earth-orbiting satellites, some 70,000 are now in the planning phase. The immense volume and richness of the information and insights that these services can provide will influence almost every aspect of global society and will be profoundly important for key activities including managing climate resilience, weather forecasting and telecommunications to name just a few.

Space is set to become a critical enabler for digital transformation at a global scale and Australia is positioned to become a leader in exploiting this transformation if we act with pace and purpose. The benefits to the space industry and the opportunities for the geospatial industry are set to expand greatly.

[16] Intelsat was founded as an International Government Organisation within the United Nations until it was privatised in 2001.

Between January 2019 and October 2021, 3200 satellites were orbited, more than were launched between 2010 and 2018. Rapid growth in launches during this period is linked to multiple start-up and scale-up businesses looking to offer new services to developing markets. While the large broadband LEO communications systems such as Starlink and OneWeb are important in driving commercial growth, they are not the only reason for this sustained increase in the orbiting satellite population . Miniaturisation, mass production and massive improvements in big data storage and analysis are all contributing to growth in satellite numbers.

Based on satellite and spectrum filings, it is expected that this growth will continue creating great opportunities in the satellite manufacturing, launch and downstream sectors including businesses utilising and delivering geospatial information and services.

The volume and type of remote sensing data is expected to grow rapidly including the deployment of advanced sensors such as synthetic aperture radar, hyperspectral imaging, radio frequency (RF) sensing and atmospheric monitoring, and the use of machine learning and artificial intelligence.

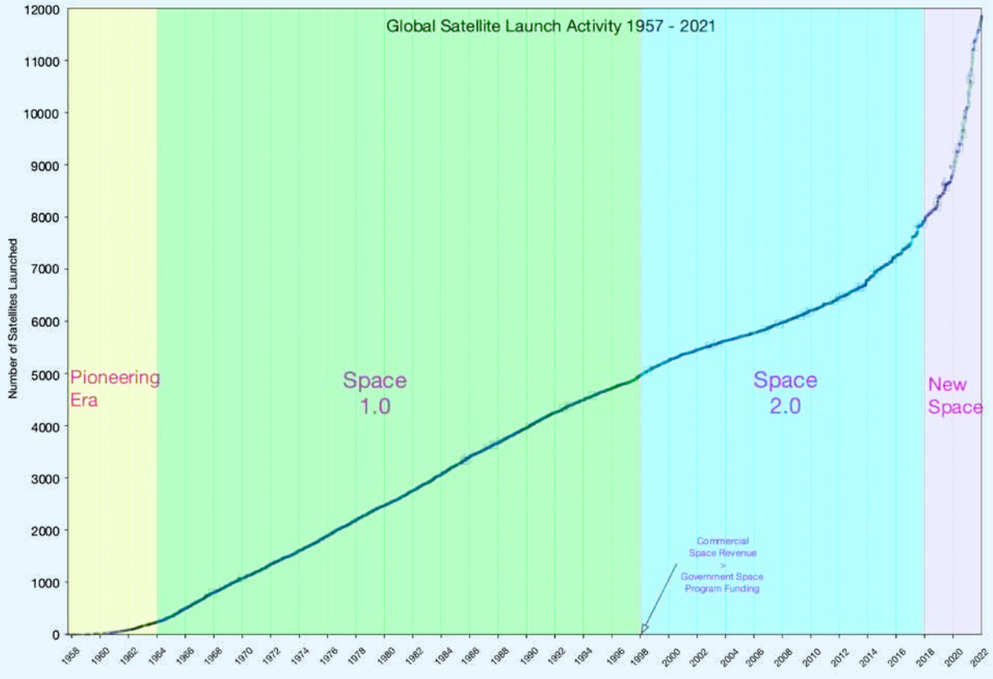


Figure 10: Satellite eras from the early 1950s to the present day

[17] E Kulu, "Satellite Constellations – 2021 Industry Survey and Trends", Small Satellite Conference 2021.

D Appendix D: Summary of feedback through consultation

The consultation process focused on collecting feedback across the 24 identified issues, with the aim of validating their level of priority and to further identity and define the critical areas for the industry.
The consultation process also revealed additional areas of importance to drive joint growth in the space and geospatial sectors. The feedback on the issues and additional areas was synthesised into the nine objectives highlighted in the *"2030 Space + Spatial: A Combined Roadmap for Industry Growth"* and the associated actions. These nine objectives represent the major issues affecting the growth of the industry distilled from the feedback and through the Working Group and Steering Committee meetings and generally contain all the feedback received during the consultation process.
This section summarises feedback collected across the nine objectives as well as feedback on issues/areas where significant feedback was received that is broadly included within the nine objectives but warrant particular mention in their own right.

Objective 1: Establish a Blueprint with ongoing National Space Missions

Feedback focused on the need for consolidating strategy and roadmaps, clear investment priorities, the importance of missions and addressing critical national challenges – such as those posed by climate change. The following are examples of direct feedback gathered through the consultation that illustrate the above points:

- *At the national level consideration should be given to alignment of the many related strategies and roadmaps. Future work must clearly define its relationship to existing work and what value it adds to the national debate/thinking.*
- *The link between data and decisions, and how this can benefit Australia, needs further exploration. The focus has to be on outcomes, not technology. This needs to take a short, medium and long-term view on required investment/support and how this will meet future national needs and address supply chain and operating risks for critical national capabilities.*
- *There is a need to generate greater awareness across government of the critical and entrenched nature of space services and products to the national interest as a critical step in supporting investment in space systems, especially those based on an identified sovereign need.*
- *The ability to adapt to climate change will be an essential element of space-based data in the future*
- *Australia has some catching up to do in prioritising strong and effective environmental regulation and monitoring.*
- *The only way we will grow a solid space sector in Australia is if the Australian Government commits money to develop it.*
- *The areas for growth of Australia's space industry should be prioritised on the basis of the potential for how that investment into each respective area could contribute to addressing major global challenges including climate change, clean water and critical resource security, sustainable development and peace. For example, development of new biotechnologies that address challenges that are faced both in space travel and on Earth (such as managing water security and turning waste into assets) has the potential to provide immediate economic benefit to Australia and position Australia for better sustainability outcomes.*
- *Truly innovative and environmentally focused initiatives may come at cost to the society that enacts them, arguably putting societal benefit in direct opposition to environmental benefit. Tied in with societal license to operate, I feel that an environmental and conservation focus is critically important to connecting this roadmap with the priorities of the upcoming generations of geospatial experts.*
- *The Australian space industry should be encouraged to draw on the experience, expertise, technologies and infrastructure of all sectors of the Australian economy including Australian Government agencies and research organisations. It is important to highlight the potential additional benefit that could be achieved through a closer, more collaborative approach between industry, the public sector and research agencies to improve Australia's position in the global space sector and industry growth.*
- *Smarter, more coordinated government procurement optimised for local and export capability growth will lift SMEs, larger corporate space efforts, and startups, creating a globally competitive Australian space ecosystem sooner*
- *Make Australia's space investments even more explicitly about benefits to Earth, i.e. society and the economy, linking in to critical concerns such as food (agriculture), environment (water, air, weather), and sustainability (economic resilience in the face of climate change).*

- *The paper could expand to include a pathway from consumer priorities to industry partners to overall space missions. (...) the international standard approach to space services is in the form of missions. (...) the success of missions to be built on identifying services to address a consumer priority and collaborating with industry partners to deliver those services.*
- *Needs to address issues from the point of view of states and territories needs and further engagement and discussion with the states to understand the barriers to national coordination of procurement.*

Objective 2: Drive industry growth

From an industry perspective the importance of growth that is sustainable was highlighted, as well as making sure there was a clear understanding of where the Space and Geospatial sector are at. Examples of feedback in this area include:

- *A better definition of what Space + Spatial is would help, as would explaining how better connectivity between two sectors can deliver industry growth – what are the new and emerging markets that are not currently being addressed by Australian or international suppliers?*
- *Sustainability, and data-continuity for the space and geospatial industries should be included.*

Objective 3: Coordinate research

The importance of publicly funded research and of its alignment – across the space and geospatial sectors – was a recurrent topic of importance in the consultation. The consultation highlighted the effectiveness of programs focusing on "prototyping" and the need to have further initiatives in this front for the space and geospatial sectors, some examples of the feedback received that led to the definition of objective 3 included:

1. *Australia needs to focus research funding strategically on agreed priority areas and allocate sustained funding to support research commercialisation and market development. Research activities need to be linked to industry and government needs and aligned with other national programs (e.g., manufacturing). The need for curiosity driven research as a component of an overall research program must be recognised.*

2. *Another challenge, probably a fundamental one, is for SMEs to have a chance to participate in Proof-Of-Concept demonstrations of new systems and technologies. By pro-actively engaging SMEs that operate in the downstream markets, the PoCs can help them meet their business development goals while also ensuring that the research has the best possible commercialization pathway.*

3. *Knowledge, research, innovation... these words are bandied about as if "space + spatial" is just another tech area, like biotech. It is not. We do not just work in "labs" or "start-up hubs". We need "sand pits" or "testbeds". An example is the evaluation of augmented (DFMC) GNSS of the Positioning Infrastructure GA has been working on. There were many real-world tests, at an application/sector level, e.g. transportation, construction, agriculture, marine, etc. I would suggest we need permanent testbeds, appropriately equipped with check, calibration, alternative tech so that researchers (from industry and academia) could evaluate new tech.*

4. *Need to develop improved pathways/mechanisms for universities and research groups to work with public sector and private sectors. Not all innovation comes from SME's and start-ups.*

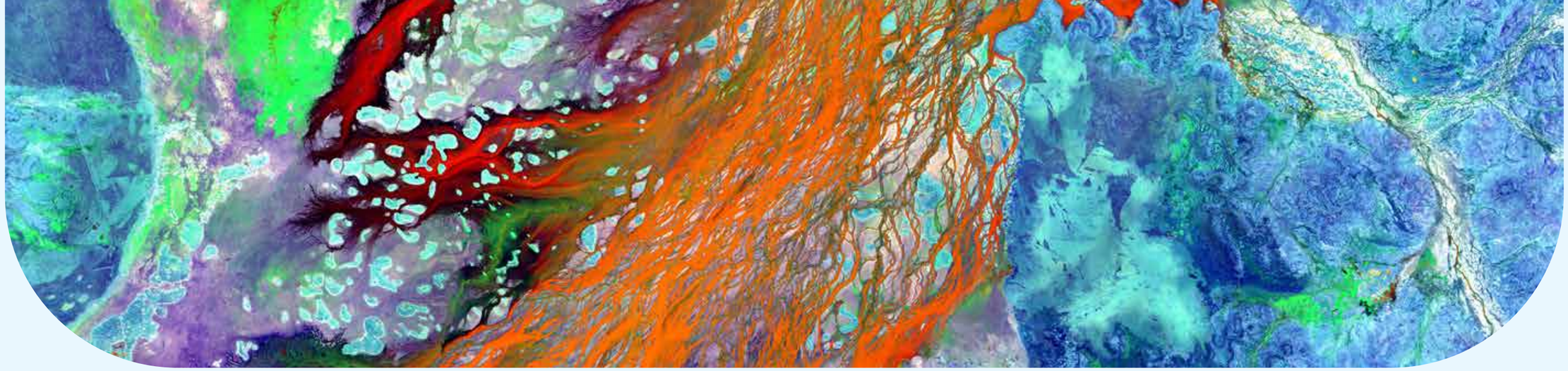
5. *The Australian space industry should be encouraged to draw on the experience, expertise, technologies and infrastructure of all sectors of the Australian economy including Australian Government agencies and research organisations. Most of the existing infrastructure and analytical tools described in the Space and Spatial Roadmap Consultation Paper have been produced through collaborations amongst Australian Government agencies (including CSIRO, Geoscience Australia and the Bureau of Meteorology). We suggest highlighting the potential additional benefit that could be achieved through a closer, more collaborative approach between industry, the public sector and research agencies to improve Australia's position in the global space sector and industry growth.*

6. *The view that only start-ups drive innovation is incorrect. Currently the vast majority of existing space and geospatial data infrastructure is used and operated by Government research agencies (federal and state), and innovation is provided by the academic and research sector in addition to the geospatial 'value-add' industry sector. While ensuring that start-ups can build on these data sets and sources, developing a properly collaborative model for industry to engage with Government and public sector research and academic agencies will ensure the best outcomes for Australia.*

Objective 4: Increase capability

Understanding and developing the skills and knowledge required to deliver on the growth ambitions of the space and geospatial sectors in Australia proved to be an area where there are still challenges, according to the consultation feedback. The current limited data and understanding of the status of both sectors – in terms of needed skills and how to effectively build these in the workforce – still remains an area of concern and a gap that led to Objective 4 and its actions definition. Some examples of feedback received included:

1. *Industry in its current form is not "fit-for-purpose" in supporting long term national needs, especially for national security. Intervention is required to address gaps and create scale but this needs to be supported by a national plan to ensure that capabilities are strengthen or created in the right areas.*
2. *What industrial capabilities best contribute to achieving desirable levels of sovereign access and control for space and geospatial capabilities?*
3. *STEM is crucial: Talent is going to be a key constraint on growth if we don't support it*
4. *("Start-Up") relies on students and recent grads to help it meet the needs of partners and its development path*
5. *It would be good for the document to call out the issue of low-level (computational infrastructure) skills, capability, and capacity in state and local governments to deliver the data, services, and analytics that the roadmap is calling support for. For example, jurisdictions have been greatly challenged with resourcing the delivery of geospatial data in GDA2020; a significantly higher resource requirement is anticipated to address the needs set out in the roadmap for a digital future. Whole of Government (Federal, State and Local) must be funded and resourced in this aspect.*
6. *Missing is the need to train industry, not just government, to understand the international standards and associated international expectations. The innovation can only be realised if the lab ideas can be turned into reliable, repeatable systems upon which the buyers can depend. This needs not only engineers but also the expert hands-on skills needed to perform procedures and processes to build the reliability into space missions. This training would be conducted as part of additional tertiary course units and TAFE courses. Do not assume that start-ups will automatically know 'how to do'. Australia has spent 40 years on the bench while the rest of the world progressed. Money alone will not solve the problem. A highly interventionist approach is required.*



Objective 5: Advance Spatial Digital Twins (SDT)

The need for accessible, timely, reliable, (spatially) accurate digital data, ready for decision making emerged as a critical area were Space and Geospatial can play a key role. Several of the current challenges and unmet needs in this area are prime to be addressed through further capitalising on the development of Spatial Digital Twins.
As captured in the consultation:

1. *Data access is the key, at this stage, to new business development".*
2. *Many of disaster mitigation applications, e.g., bushfires and flooding, require rapid turn-around-time from receiving the satellite data to deliver the information/outputs for assisting quick but informed decision making. This is critical not only to have high volume data downlinks, but also the rapid (or near real-time) accessible analysis ready data (ARD) for further image analyses and interpretations.*
3. *I manage an agricultural property, given dating information on soil moisture variability, phenological stage, the weather forecast, product price estimates and a limited water budget, I want to model different scenarios to determine how much water to allocate to crops, to optimize my feasible yield/profit.*
4. *Build new climate products, and to use them better and to consolidate existing products -this is lacking.*
5. *We need a National approach to Australian datasets (for example, state agencies doing own things vs GA making same datasets; and all firms making own copies of data)*
6. *Sustainability, and data-continuity for the space and geospatial industries should be included.*

Objective 6: Upgrade Position, Navigation and Timing (PNT)

The opportunity for Australia to leverage its leadership in PNT as an avenue for national industry growth with strong global export opportunities was identified in the consultation and validated by the Steering Committee, examples of feedback included:

1. *GNSS denial is a significant risk to Defence, with more traditional geospatial datasets essential to mitigate this risk.*
2. *Issues (...) relating to sovereignty. Some aspects of this are important - e.g., to improve access to data (ground infra & spectrum access) or because Australia is in a unique position to export capability (e.g., PNT).*

Objective 7: Enhance sovereign capability

The issue of Australia's risks around critical space and geospatial infrastructure, systems and data and its sovereignty received support in the consultation. In particular, the need to better understand Australia's dependence on space and geospatial capabilities and the dependencies and relationship with other areas such as considering *"The impact of international law, behavioural norms and standardisation may place constraints or barriers on growth opportunities and need to be better understood".*

Objective 8: Grow Australian capabilities to support Defence

Space sovereignty as an issue was thought to be overstated in a number of responses – as expressed by several consultation participants – however, the importance of supporting Australia's space and geospatial industry to develop capability to increasingly be in a position to support Defence was a recurring need, as well as the critical role Defence can play in supporting disaster response in the civilian space. Some of the feedback received in this area included:

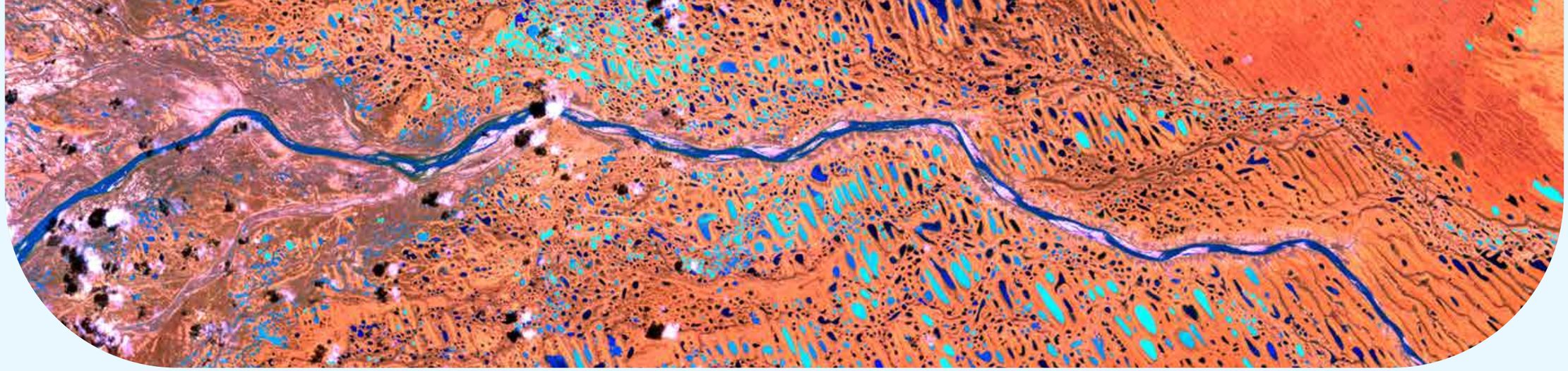
1. *The ASA has been challenged to grow the Australian Space Industry to some 20000 permanent jobs and $12B of revenue by 2030. Over the same period of time, the largest space customer, Defence, has only $7B in its public budget for space acquisitions. Of that figure, little more than 5-10% could actually be spent in country because there is insufficient capability and capacity in country to satisfy Defence within the time frames of its acquisition cycle.*
2. *Discussion on sovereignty requirements should be targeted at how it can support prioritisation of industrial development. That is, it should be separated from the concept of achieving '100% sovereignty' or '100% made in Australia'. What industrial capabilities best contribute to achieving desirable levels of sovereign access and control for space and geospatial capabilities?*
3. *Defence Industry Capability Plan definition "Defence sovereignty is the ability to independently employ Defence capability or force when and where required to produce the desired military effect. It does not mean that a defence capability has to be designed, developed or maintained in Australia, but it does mean Defence has to have access to a functioning defence capability as and when required." As it is almost certain that some element of the supply chain will rely on international manufacturing achieving 'absolute' national space sovereignty is likely to prove difficult. A more effective approach may be as per the Australian Space Agency pillar of establishing key international relationships to strengthen supply chains for the Australian space industry.*
4. *Effectiveness of Space and Geospatial Governance Arrangements, Particularly for Disaster Response should be a higher priority. The provision of space effects to support Disaster Response is likely to be the most visible benefit from space assets to the Australian public.*

Objective 9: Enhance National Mapping Base and its Foundation Geospatial Data

The argument and importance of maintaining and enhancing Australia's national mapping base was presented to the consultation by several of the geospatial peak bodies, therefore identifying a very critical gap that other roadmaps and strategies have missed. The importance of this objective for both the space and geospatial sector became evident to the Steering Committee, which deemed it a priority area. Feedback received highlighted *"no mention of the reference frame or datum or any other aspect relating to maintaining the systems underpinning/facilitating the alignment of space and geospatial data. Whilst this is work funded by the commonwealth, it would be good to see this level of maintenance in State and Local governments. The increased supply of space data aligned to a global reference frame over time underscores the need for all agencies to have a capability to align and deliver geospatial data according to user need".*

Other areas of feedback

A number of additional themes emerged through the consultation and are captured in this section. These have not warranted a dedicated objective or action as they are either 1) strongly captured and addressed by other national roadmaps and strategies of the peak space and geospatial organisations or 2) are indirectly captured across objectives and actions included in this Industry Paper.



International Collaboration and Partnerships

The importance of international collaboration and partnerships was a recurrent argument, with feedback including:

1. *It will take time to increase sovereign space capabilities, but that time can be significantly reduced if we can bolster our industry through targeted collaboration with like-minded space-faring nations.*
2. *Using space and geospatial data to drive deeper engagement with global environmental initiatives. There is intensive global activity dedicated to providing geospatial information to support achieving the UN Sustainable Development Goals (SDGs) and a range of other aligned initiatives supported by entities such as GEO and CEOS, that are directly applicable to Australia. However, Australia engages very little with these initiatives, which may hamper our international trade relations in future as environmental and social benefits are becoming increasingly important amongst our trading partners.*
3. *Asia-Pacific engagement - for example the opportunity to take global forest watch data down to the next level to improve environmental and economic outcomes across south-east Asia.*
4. *The opportunity for Australia to grow our support for vital international partnerships and data access agreements, via sustained high-capacity ground station services plus the calibration/validation of their EO satellite data, should be highlighted.*
5. *Using space and geospatial data to drive deeper engagement with global environmental initiatives. There is intensive global activity dedicated to providing geospatial information to support achieving the UN Sustainable Development Goals (SDGs) and a range of other aligned initiatives supported by entities such as GEO and CEOS, that are directly applicable to Australia. However, Australia engages very little with these initiatives, which may hamper our international trade relations in future as environmental and social benefits are becoming increasingly important amongst our trading partners.*
6. *One issue is missing completely (international co-operation), and another is understated (environment). The space industry (peaceful applications) has always stood as not only a good example of international co-operation but as an enabler and promoter of it. Programmes to develop Australian operated space systems should be economically tested against options for collaboration on international projects. Other countries may be better placed to act as specialist providers and strength comes from collaborative efforts. The space and geospatial industries are awash with examples of international projects ranging from international space stations and satellites to the development of the Open Geospatial Consortium (OGC) standards now widely recognised across OECDE countries.*
7. *I would add an area related to international cooperation - many space data acquisition systems of value to Australia are developed and operated by other countries. There is a need to increase international cooperation to ensure data from these systems are relevant and accessible to Australia. I would see this as a significantly higher priority than 'national space sovereignty'.*
8. *(Start-up) is focused on partnerships... if they've got capability X and we've got Y, then we need to get together as a force multiplier - and hopefully we can come to a commercial agreement*
9. *(Organisation) is interested in building stronger partnerships with industrial partners and sees industry-led roadmaps as an opportunity to strengthen these relationships.*

Awareness and communication of the value of space and geospatial

The need to increase the awareness of the impact of space and geospatial for the public, and to better equip those involved in the sector with skills to do so:

1. *There needs to be a focus on development of communication skills within the sector to better explain how space solves critical national challenges.*
2. *Not to detract from Moon-to-Mars which is a high-aspiration project... rather to add in the much deeper, bigger impact on day-to-day lives that space has. there's now a perfect opportunity to talk about how space can support the environment, but the public is not hearing that. more work is needed to make space relevant to people's everyday lives, rather than be perceived as 'toys for billionaires to play with'.*
3. *A better definition of what Space + Spatial is would help, as would explaining how better connectivity between two sectors can deliver industry growth – what are the new and emerging markets that are not currently being addressed by Australian or international suppliers?*

Cybersecurity

The importance of acknowledging the impacts and risks of cybersecurity to the space and geospatial sectors assets, infrastructure and data:

1. *Cyber defence of space assets. Although cyber is discussed throughout the paper, it is not identified as high-risk threat vector to space assets and operations.*
2. *Australia would benefit from the capability to geolocate and attribute irresponsible behaviours to specific entities. This is necessary when faced with jamming or interference of SATCOM, dazzling of imagery satellites, spoofing or negation of PNT signals, or even identifying aggressive on-orbit manoeuvres. This could take the form of a "Space ACMA" in terms of identifying sources of interference.*

Standards

The inclusion of and focus on standards to ensure usability of space and geospatial data and systems is maximised nationally and internationally:

1. *The greatest value from EO and geospatial data is realised at the point where the information is used to plan actions or define policies. However, integrating EO data into high level decision-making processes remains a key challenge, and having an agreed set of standards for data processing and analytics could underpin greater trust in the valuable information that EO can provide.*
2. *More emphasis on standards is required. Whilst mentioned under section 'Spatial Digital Twin' - the issue of standards is far broader than just Digital Twin - it's an area affecting all space and geospatial domains. Suggest this be made its own section (rather than assumed to be a Digital Twin issue alone).*

Focus on Climate Change and the Environment

The importance for the actions resulting from the consultation to have a focus on the environment and climate change was a recurrent piece of feedback. This has been recognised and captured as an overarching theme in the industry paper. Examples include:

1. *Geospatial data generated from space based EO have principally been used by the civilian and defence sectors to provide information on the structure and dynamics of the landscape, and we anticipate this is likely to remain amongst the most widely accessed application area for geospatial data for the foreseeable future. A healthy, functional environment is the foundation of national prosperity, and improving the availability, quality and relevance of EO and geospatial data for environmental applications should be a stronger focus of this Roadmap.*
2. *Environmental, climate and sustainability. The application domains are huge, and hugely important, with fantastic local capabilities. (...) Things to focus on include future as a renewables superpower, Net Zero, land-use and land-management, biodiversity and conservation, public health to name a few.*
3. *While climate has been mentioned, the ability to adapt to climate change will be an essential element of space-based data in future. Some predictions have been expressed that Australia could be an importer of food in the second half of the century. In any case food production will decrease because of less rainfall and hotter conditions. Therefore, the ability to adapt to changes in climate leading to changes in farming practices that will guarantee food supply in the future is critical.*
4. *The consequences of the increase in severity and frequency of extreme weather events due to climate change may include disruption of food and water security. Loss of food and water security is expected to result in conflict and societal collapse. This would destroy the potential for space industry growth. It is in the interest of the space industry sector to ensure appropriate response to climate change and deliver technologies that enable a circular economy (including water and waste recycling). The top priority should be "turning environmental monitoring into management".*
5. *Societal benefit and Environmental benefit are quite disparate areas to explore as one focus area. Truly innovative and environmentally focused initiatives may come at cost to the society that enacts them, arguably putting societal benefit in direct opposition to environmental benefit. Tied in with societal license to operate, I feel that an environmental and conservation focus is critically important to connecting this roadmap with the priorities of the upcoming generations of geospatial experts.*

Legal aspects of increasing high resolution from satellite data

The issue of considering the legal aspects of increasing high resolution from satellite data was posed as an important area for consideration:

1. *There appears to be a gap with regards to the legal and policy questions that may arise given the greater detail, and improved accuracy of depicted real-world geospatial features that comes along with the increasingly enhanced resolution that EO technology is achieving. Internationally, there is a growing community of lawmakers and professionals examining the policy and legal issues that could have an impact on the collection, licensing and use, privacy, provenance, and accessibility of geospatial information.*

Contact Details