

Advancing Space

Communications Technologies and Services

ROADMAP 2021-2030



Head of Agency - Introduction



Communications Technologies and Services is the first technical roadmap in the series, a National Civil Space Priority Area that significantly impacts the lives of all Australians.

Growing Australia's space sector

Space technologies and services touch virtually every sector of the Australian economy. Space capabilities are drawn on by Australian farmers to monitor the health of their crops, by marine pilots to guide cruise liners, by emergency workers to plan and respond to bushfires, and by scientists to study the effects and impact of droughts. When positioned alongside other core industries like manufacturing, resources and agriculture, space is also an enabler of industry growth and will help Australia's economy emerge out of the COVID-19 pandemic.

The Australian Government launched *Advancing Space: Australian Civil Space Strategy 2019 - 2028*¹ (the Strategy) in 2019 to provide a long-term framework to grow and transform the national civil space sector. The Strategy has four strategic space pillars: international, national, responsible, and inspire, which are central to achieving this vision. Activities under the space pillars are guided by seven National Civil Space Priority Areas: position, navigation and timing; Earth observation; communications technologies and services; space situational awareness and debris monitoring; leapfrog R&D; robotics and automation on Earth and in space; and access to space. The priority areas capture the unique strengths of the space industry which can be further developed to advance Australia's competitiveness and role as a responsible actor in civil space activities.

The ultimate goal of the Strategy is to triple the size of the sector to \$12 billion and create up to another 20,000 jobs by 2030, with further jobs and industry growth from spill over effects.

Roadmaps overview

The Strategy outlines the importance of technical roadmaps for each of the Civil Space Priority Areas as a mechanism to build on activities to date, recognise areas of opportunity for industry, and identify where Australia could have a significant role in the future. The roadmap for each Civil Space Priority Area provides a vision, ambition and aspirational capability targets to support the growth of a globally-respected and thriving industry in Australia consistent with the Australian Space Agency's strategic goals.

Communications technologies and services

Australia is connected, respected and globally competitive in communications technologies and services. Australia's heritage in space includes substantial contributions in satellite communications, signal processing and astronomy. Our pedigree in long range communications has for many decades connected our geographically dispersed communities, and is the foundation of our support of pioneering space programs. When Apollo 11 made the first successful landing on the Moon in July 1969, Australia was instrumental in broadcasting that "one giant leap" to the world. Today, the Canberra Deep Space Communication Complex is an integral part of NASA's Deep Space Network. The complex tracks more than 40 robotic spacecraft from dozens of nations exploring the solar system and beyond.

This rich history has laid solid foundations for the Communications Technologies and Services Roadmap which will provide a vision for the next phase of space communications capability to drive economic growth and industry transformation. Importantly, the increasing demand for connectivity and the importance of staying connected following the COVID-19 pandemic presents an opportunity for the Australian civil space sector to strengthen national capability and capacity in communications technologies and services.

A collaborative future

Collaboration across industry, government, the research sector and with our international space agency counterparts is vital to achieving a globally responsible and respected space sector that lifts the broader economy and inspires and improves the lives of Australians. We look forward to working with the sector to seize the enormous opportunities ahead of us and continue building our national capability in space-enabled communications technologies and services. The technical roadmaps are a significant milestone for the civil space sector on its exciting journey of growth and transformation into the next decade.

Dr Megan Clark AC
Head, Australian Space Agency
December 2020



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The Communications Technologies and Services Roadmap 2021-2030 is an Australian Government publication which will provide a vision for the next phase of space communications capability to drive economic growth and industry transformation.

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¹ Australian Space Agency (2019), Canberra: Commonwealth of Australia, 2019, accessed 26 Nov 20.
<https://publications.industry.gov.au/publications/advancing-space-australian-civil-space-strategy-2019-2028.pdf>

National Civil Space Priority Areas Roadmap development approach

An aligned, connected, and informed Australian space sector that is united behind a shared vision for each Civil Space Priority Area and clear pathways to meeting our ambitions.

Roadmaps guiding principles

Development of technical roadmaps for each of the Civil Space Priority Areas is an action identified in the national space pillar of the Strategy. The roadmaps serve to provide strategic direction for the sector, and to inform and guide opportunities to support the growth of the industry. Each roadmap identifies necessary activities and supporting conditions for achieving the vision in each Civil Space Priority Area on a 10 year horizon. Their development and implementation are guided by the following principles:

- Describe a pathway to uplift capability in a manner that enables the tripling of the size of the Australian space sector to \$12 billion and the creation of up to an extra 20,000 jobs by 2030
- Identify and engage with opportunity - aligning activities by consulting widely and deeply with industry, researchers and government agencies
- Encourage organisations to invest resources and efforts where they want to pursue the opportunities identified in the roadmaps
- Re-inforce the role of government as a partner, facilitator and regulator for, and customer of, the sector (in line with the Strategy, including its investment principles).

Roadmap priorities and inclusions

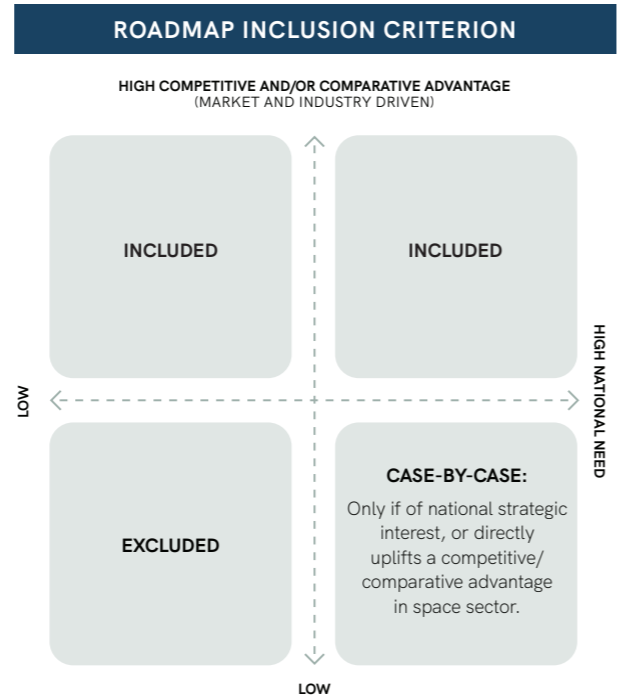
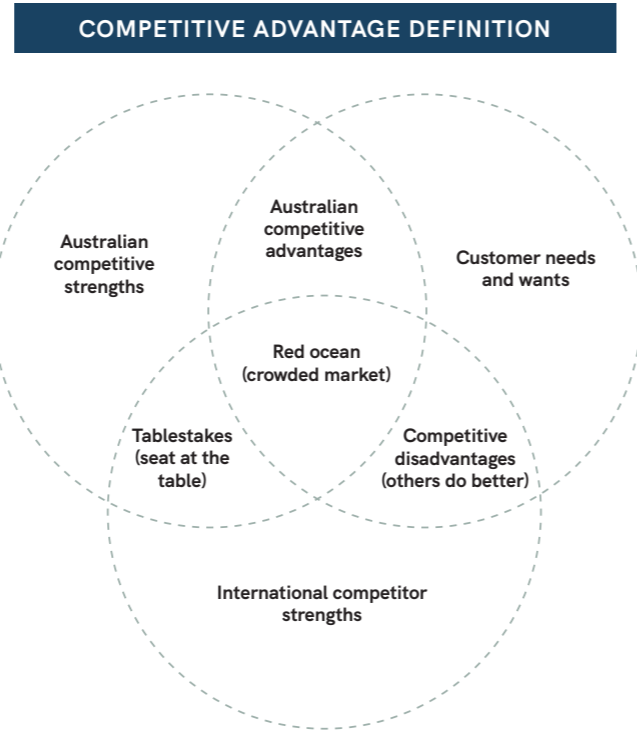
The roadmaps chart capability developments, rather than detailed technology developments, so industry and government researchers can drive innovation and have flexibility in their delivery.

To be included, a capability must:

- Strive towards bold visions and ambitions that align with the Strategy, and
- Have the potential to synergise with other selected capabilities to uplift the sector in an enduring manner, and
- Be based on a comparative or competitive advantage (a domestic government or commercial market opportunity for which Australia has a competitive strength), and/or
- Be an area of national strategic interest, or
- Be a necessary input to realise another included capability.

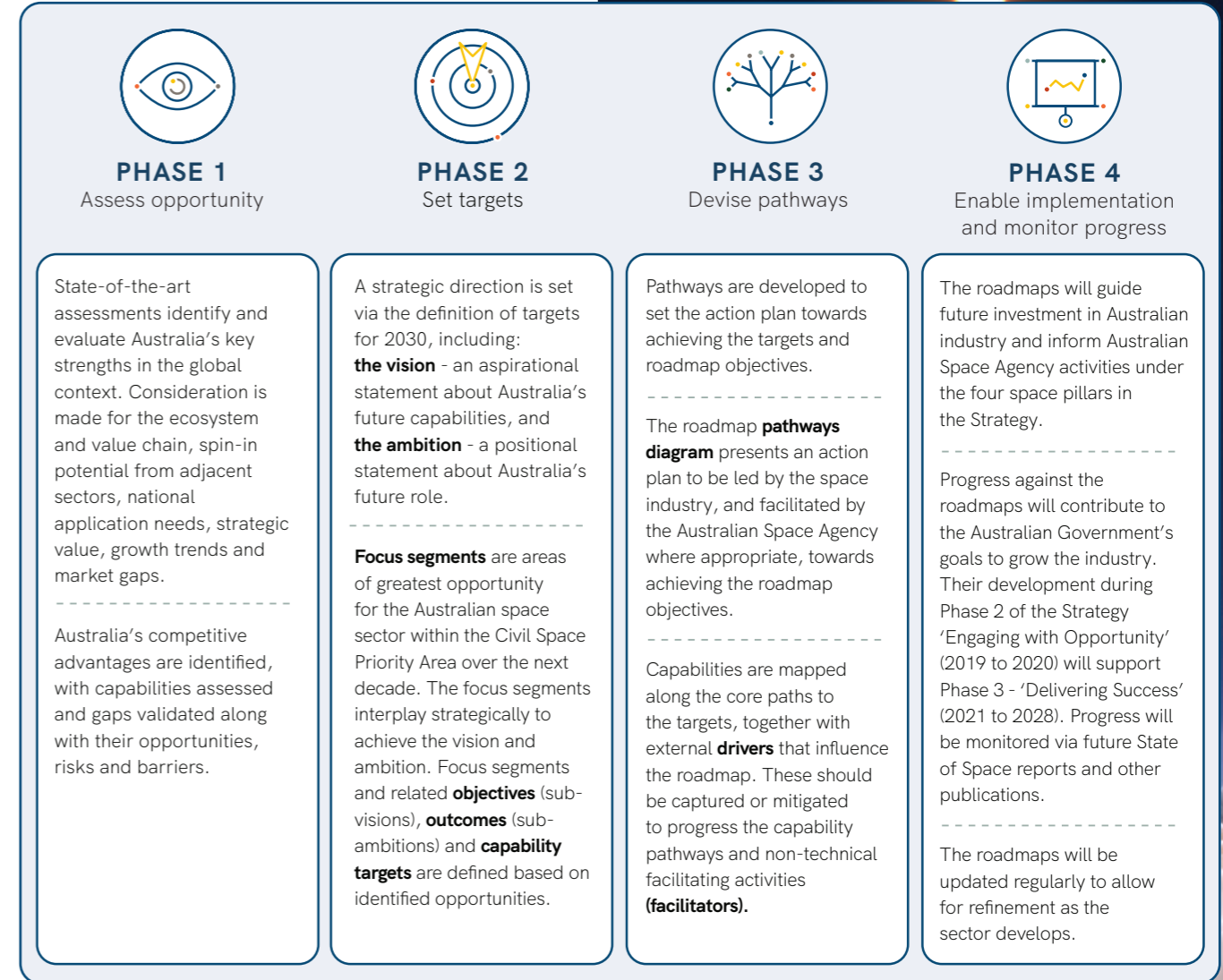
The roadmaps prioritise capabilities that are essential to the stated vision and ambition for each pathway. Opportunities exist outside the pathways that may still be pursued by the Australian space sector.

The roadmaps also include supporting conditions that would harmonise, support and facilitate the growth of these capabilities. These are prioritised according to their capacity to address challenges and foster opportunity.



Approach to developing the roadmaps

The Australian Space Agency worked together with industry, researchers and Australian Government agencies to develop each roadmap. Feedback and support to the validation of the assessments of Australia's state-of-the-art capabilities, technologies and opportunities were provided by peer space agencies and stakeholder organisations.

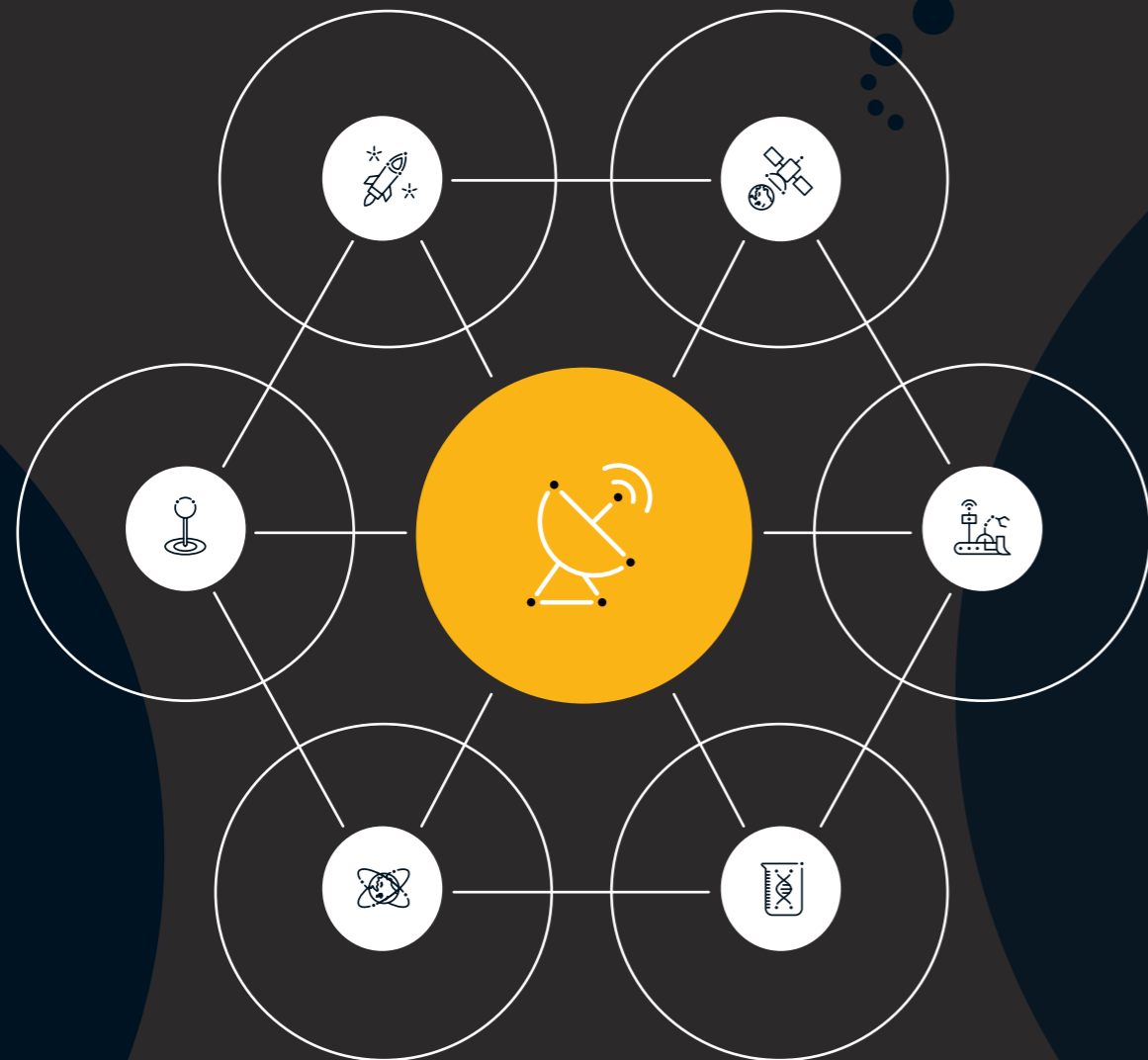


Roadmaps audience

The roadmaps are for all Australian space sector stakeholders, including industry, governments, researchers, the future workforce, investors and international partners. The roadmaps can also inform stakeholders in adjacent sectors, including mining and energy, defence and national security, agriculture and natural resources, remote medicine, and environmental and disaster management. These stakeholders could extend their existing capabilities into the space sector, leverage expertise in the space sector or become customers of the sector.



Photo: Arianespace



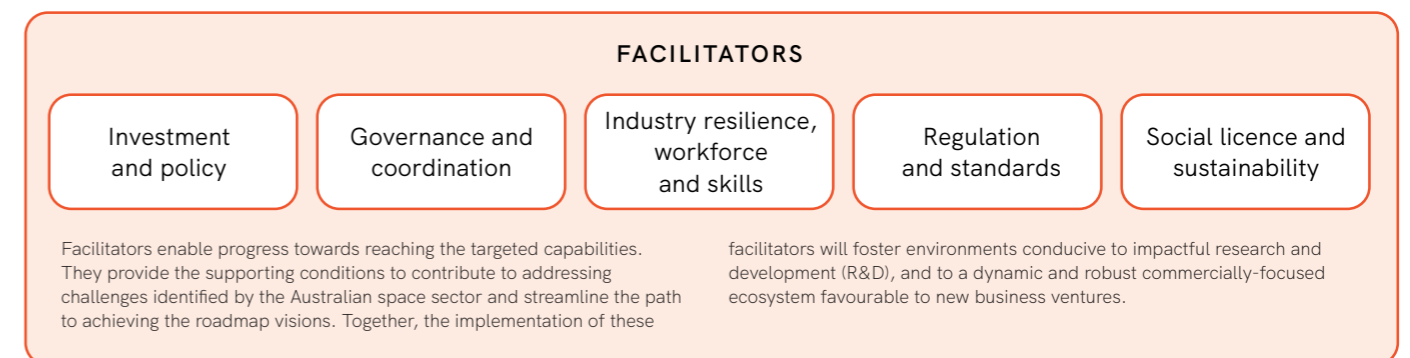
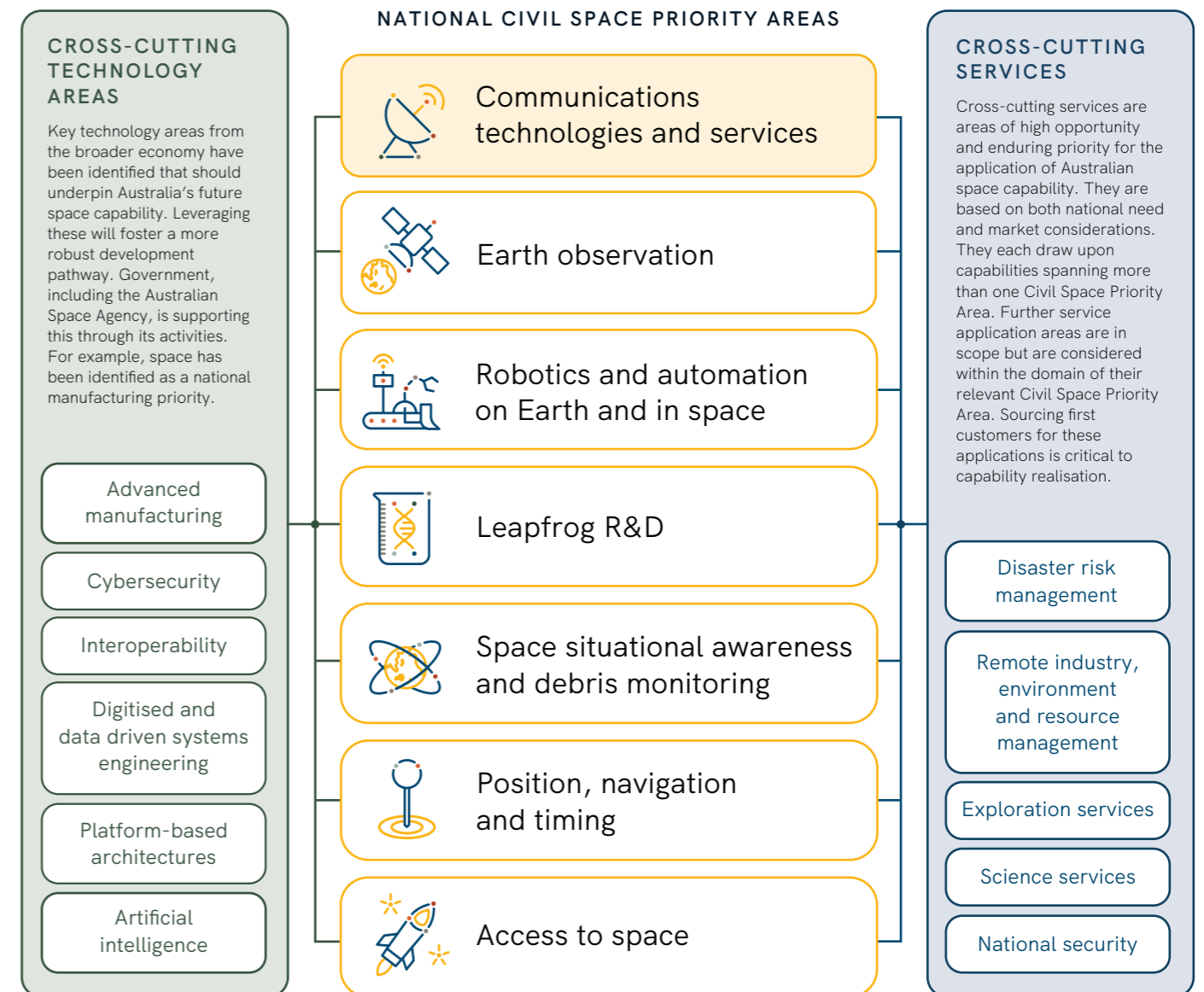
Seven interconnected roadmaps

The Civil Space Priority Areas are interconnected, reliant on cross-cutting technology areas, facilitated by non-technical enabling activities, and may be applied to many cross-cutting services. The roadmap for each Civil Space Priority Area details the significance of these factors to its implementation. The roadmaps nexus illustrates the strategic interplay of these important categories.

While the Australian Space Agency has an important role as a partner, facilitator and regulator, it is the initiative of the space sector that will drive the pursuit and capture of the identified opportunities.

Roadmaps nexus

Identifying growth activities





Opportunities in communications are growing

Modern society's insatiable thirst for information is an opportunity the space industry can capitalise on, but Australia needs to significantly advance our commercial competitiveness if we are to succeed in growing our space industry.²

An information-enabled world

Access to the right information at the right time can have transformative outcomes, creating economic opportunity and bringing communities closer together. Demand for data grew at approximately 50 per cent per year from 2009 to 2016 for Australian households using fixed-line connections.³

The world is turning to satellite communications and the Internet of Things (IoT) to provide connectivity across a global footprint. Satellite communications enables a range of sectors exemplified by: autonomous mining operations; remote working and education; connecting our communities socially and for entertainment; and, in the event of national disaster, coordinating planning and responses. Defence also uses satellite communications for the command and control of deployed sea, air and land forces regionally and abroad. A trend towards autonomous and uninhabited vehicles that increasingly use satellite communications is a further application with a broad market. Whether we are extending networks to connect families in regional Australia, connecting to our oil platforms or communicating with deep space missions, opportunities in resilient satellite communications abound. The development of optical communications technology, which can provide high data rates and low latency, provides an opportunity for Australia to leverage our R&D to meet the ever increasing demand for data.

² The satellite communications market in Australia is \$1.6 billion AUD annually (KPMG, Investment in the Australian Space Sector, 2020, pg 5, citing IBIS World 2018).

³ Bureau of Communications and Arts Research, Demand for fixed-line broadband in Australia, 2018, pg 1, citing Australian Bureau of Statistics (ABS), Internet Activity, Australia, June 2016, 8153.0.

Communications technologies enable:

- **Socio-economic game changers.** Increased societal and industrial connectivity across Australia, particularly for Australians living in rural areas. Improving connections across communities lifts social well-being and provides economic benefits for all Australians.
- **Future workforce.** A high-tech STEM-educated workforce pipeline by creating new jobs in high growth areas.
- **Increased security.** Increased information assurance for a safer Australia in times of crisis by developing technologies that contribute to secure, resilient communications.
- **Economic growth.** Contribution of communication technologies and services to global supply chains where Australian industry has the technological competitive advantage.
- **Increased connectivity.** Increased global and local connectivity ranging from monitoring and control of Australia's remote infrastructure in smarter ways using IoT technologies, to secure international communication to overseas users.
- **Downstream development.** Innovation at the downstream end of the space value chain has led to an expansion of the applications for space derived data and services, leading to new businesses and ways to solve challenges.

How do satellites communicate?

Satellites extend the range of our networks to users beyond the next hill, the next continent, between orbits or even into deep space. They play the role of a relay, similar to how mobile phone towers connect mobile phone users.

Satellite communication technologies are all around us, they are used to access information we cannot touch, via the electromagnetic spectrum that we cannot see, via satellites that are hundreds to tens of thousands of kilometres away.

There are two key segments to a satellite communications system, which connect to users via satellite communication devices:

- the space segment, where satellites receive and transmit signals from various orbits (including between satellites)
- the ground segment, comprised of antennas such as large dishes, back on Earth sending and capturing the communications, the control systems operating the satellites, and the workforce system that critically underpins all activities.



CONTROL SUBSYSTEM

GROUND SEGMENT

LAND USERS

SEA USERS

AIR USERS

SPACE USERS

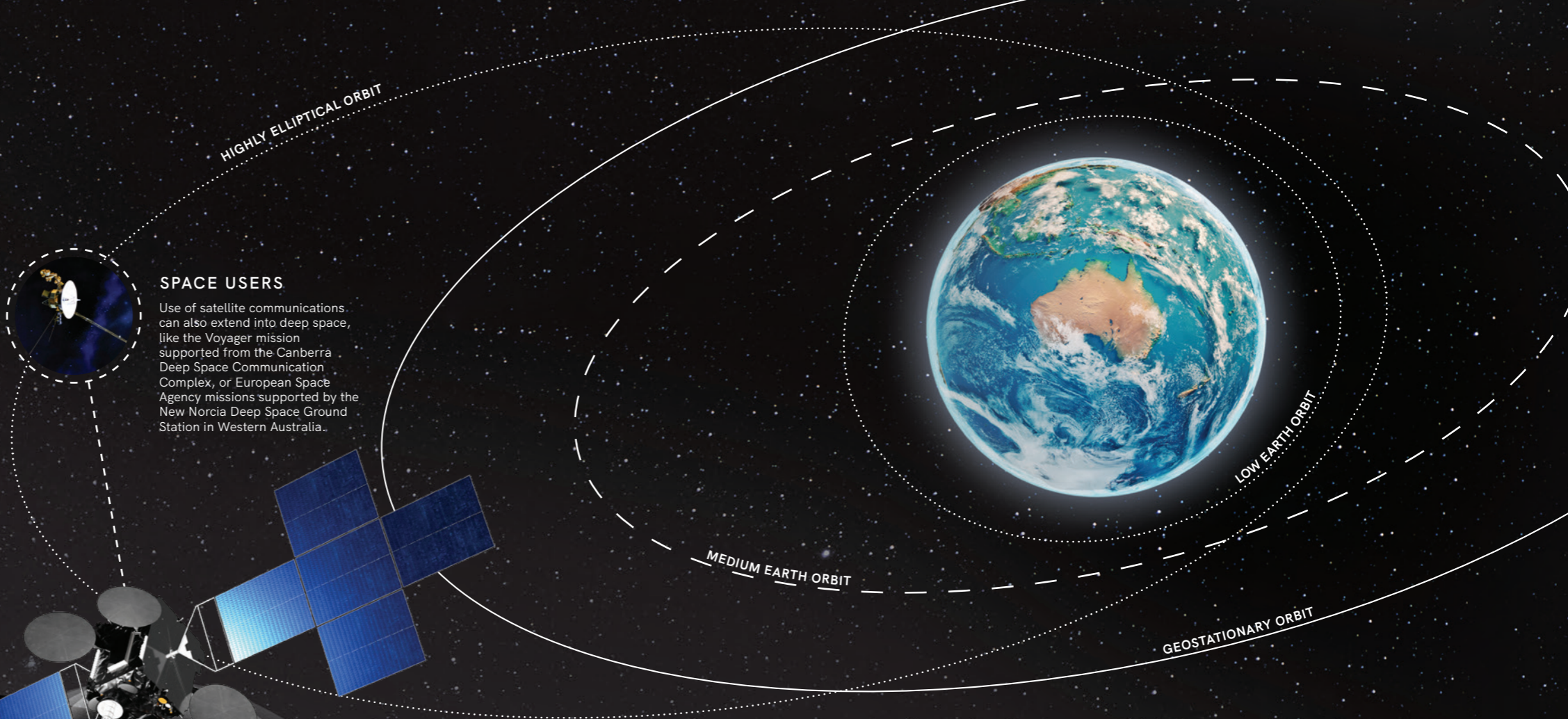
Use of satellite communications can also extend into deep space, like the Voyager mission supported from the Canberra Deep Space Communication Complex, or European Space Agency missions supported by the New Norcia Deep Space Ground Station in Western Australia.

SPACE SEGMENT

SKILLED WORKFORCE

A highly skilled workforce is required to design, manufacture, integrate, acquire, sustain and operate a satellite communications system, providing satellite communication services for both deep space use or to support land, sea or air users.

Photos: NASA, CSIRO, Optus



TYPICAL SATELLITE COMMUNICATION ORBITS⁴

There are four orbits that we typically use to extend our networks:

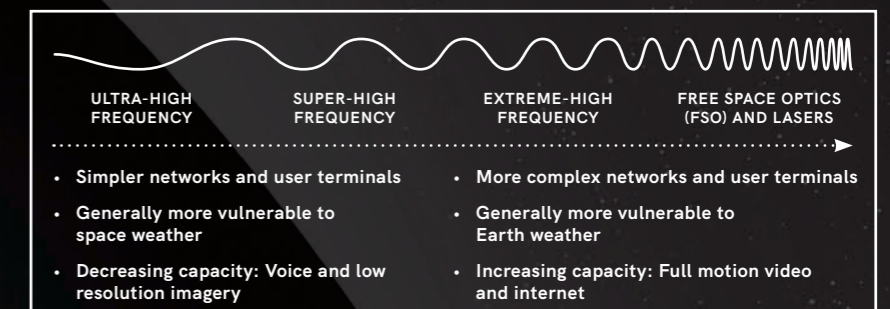
- **Low Earth orbit (LEO)** is an orbit with a maximum altitude of 2,000 km. The International Space Station sits within this orbit. Although stronger signals and lower latency is achievable, LEO networks are complex and persistence is very difficult as the satellites pass by relatively quickly.
- **Medium Earth orbit (MEO)** is more than 2,000 km from the Earth's surface. MEO is where the GPS constellation orbits. It is increasingly used for communication satellites, providing more persistence than lower orbits as they can spend more time viewing any given point on Earth.
- **The geostationary orbit (GEO)** is approximately 36,000 km from the Earth's surface and is the mainstay orbit for communication satellites. Satellites in GEO appear stationary when viewed from our vantage point on Earth, since they complete one orbit in one Earth day.
- **A highly elliptical orbit (HEO)** can be used to achieve communications over the poles since its elliptical shape provides higher persistence across the outer range of the orbit.

Satellites in these four orbits typically support communications back on Earth or other orbits, but can also be used to support communications deeper into space.

Extending our networks through space, enabled by spectrum

Communication satellites connect us by using the electromagnetic spectrum to transfer information. Just like terrestrial communications, the available spectrum is finite and needs to be coordinated responsibly. Communication use of the electromagnetic spectrum ranges from lower frequencies capable of supporting voice communications and low resolution imagery, right up to super high frequencies that can support large file transfers and high definition video. Our demand for more information is seeing increasing demand for higher frequencies up into the visible part of the spectrum. These frequencies enable optical

communications that can support data rates commensurate with optical fibre networks on Earth. No one part of the spectrum can meet all of our needs. Lower frequencies are simpler to access for the users. These are more resilient to the effects of weather such as atmospheric absorption, but cannot support the capacity of higher frequencies. The visible or optical spectrum is like optical fibre in space, however it is the most vulnerable to the effects of weather. A smarter use of the spectrum, balancing different orbits and a mix of frequencies, is how our world is benefitting from information extended by satellite communications.



⁴ This explanation intentionally excludes the orbital dynamics associated with deep space operations or other near Earth orbits such as Molniya and Tundra orbits in order to remain illustrative.

The demand for higher capacity and higher assurance communications requires developments in non-traditional spectrum bands (including optical), non-traditional communication orbits, Non-Geostationary Orbits (NGSO), lunar orbit and deep space, and more agile user terminals (across spectrum bands and orbits). This will be made possible by advanced dynamic spectrum access and satellite communications network management tools.

WHERE ARE WE NOW?

Australia has leveraged its clear skies relatively free from atmospheric interference, robust spectrum regulation and unique geographic position, to aid research and industry development of communications technologies. The Canberra Deep Space Communication Complex supports international space missions and exemplifies Australia's strong expertise in radio frequency communications and operations – developed from capabilities such as the Jindalee Operational Radar Network. Australia has a growing pedigree in optical communications and world-leading quantum capabilities. Its respected global commercial LEO IoT satellite services capability is catalysed by increasing demand for connectivity between devices in remote areas not serviced by terrestrial networks. Australia provides communication services to space missions and is entrenched as a trusted international partner.

Australia's competitive strengths and existing capabilities will support the transition to next generation communications technologies. These have both civil and military use applications, in line with where the future market is expected to demand technological growth such as optical communications and quantum technologies. Australia's LEO satellite services set the foundations for Australian industry to explore other orbits such as MEO.

The roadmap illustrates a range of relatively independent pathways to target for each focus segment. There are significant opportunities between technologies further enabling each other, although each target may be achieved independently. The national need for higher capacity and higher assurance communications can be met through targeted investments in these technologies of competitive advantage. This could include the support of identified gaps such as laboratory demonstration to first space mission utilisation.

VISION

Australia will mature from hosting communications infrastructure to also providing solutions for increasing demands on radio frequency (RF), by incorporating optical communications and moving towards quantum technologies enabled by our own network management tools. LEO will initially assist to access global markets while contributing to a more connected Australia. This will be followed by other orbits and satellite services.

AMBITION

Australia refines the foundations of our satellite communications industry remaining a trusted provider of communications services for space operations, while emerging as a trusted international partner for the provision of secure RF and optical communications, quantum technologies, LEO satellite services and satellite network management tools.

Facilitators

The Australian Government will continue to work across the sector to grow the economy and create jobs, by ensuring the facilitating conditions are right.

INVESTMENT AND POLICY:

- The Australian Government investment to implement the Strategy includes \$235 million through the Australian Space Agency. This consists of \$150 million to support Australian participation in NASA's Moon to Mars ambitions, the \$19.5 million Space Infrastructure Fund, \$6 million for the Australian Space Discovery Centre, the \$15 million International Space Investment initiative and funding for the ongoing operations of the Australian Space Agency. Over the next 15 years, the Department of Defence, in cooperation with the Australian Space Agency, will invest \$50 million in the Australian space industry for innovation in satellite communication technologies.
- The Australian Space Agency will continue to focus on the four space pillars under the Australian Civil Space Strategy: international, national, responsible and inspire. This will include a focus on being a partner and facilitator and providing advice to government on opportunities to grow Australia's space industry.

GOVERNANCE AND COORDINATION:

- Co-design clear visions and pathways, together with the sector and state and territory governments, and communicate strategic directions, capability and potential - domestically and internationally.
- Support Australia's obligations under its International Treaties and strengthen domestic and international statements of strategic intent (SSI), agreements with researchers, industry and peer space agencies. This will promote capability, create new opportunities and support collaborative partnerships that grow the domestic space industry and enhance our global space position.

INDUSTRY RESILIENCE, WORKFORCE AND SKILLS:

- Continue to support the development of a diverse and inclusive future workforce, with the capacity and proficiency to deliver high quality solutions, and an ecosystem of supply chain capabilities.
- Foster the transfer of knowledge from overseas and other industries into the space industry to build a robust ecosystem.

REGULATION AND STANDARDS:

- Allow for education, R&D and commercial progression via provision of a supportive spectrum management framework that achieves timely and cost effective access to the requisite spectrum and ensures the responsible use of information derived from the use of satellite communications.
- Ensure ongoing review and implementation of industry standards and practices to keep pace with changing technologies, such as the maturation of satellite communications during a decade that will see the advent of quantum technologies.

SOCIAL LICENCE AND SUSTAINABILITY:

- Promote behavioural norms through fostering collaborative behaviours and STEM education.
- Leverage communications technology developments to ensure cybersecurity across entire networks and the appropriate application of artificial intelligence.

Focus segments

Australia can play a lead role in emerging technologies such as lasers for data communication, quantum technologies for secure communication, and hybrid radio and optical communications.⁵

Six focus segments have been identified as the priorities for communications technologies and services capability development. These are considered to be the areas of greatest opportunity for the Australian space sector, where there is high potential to deliver to the market with competitive and comparative advantage over the next decade.



LOW EARTH ORBIT (LEO) SATELLITE SERVICES



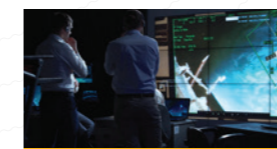
OPTICAL GROUND STATIONS



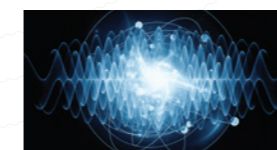
HYBRID RF-OPTICAL COMMUNICATIONS



RECONFIGURABLE NETWORKS, RADIOS, MODEMS AND WAVEFORMS



SATELLITE COMMUNICATION NETWORK MANAGEMENT TOOLS



QUANTUM ENABLED COMMUNICATIONS

While these six focus segments provide the greatest opportunities for Australia, there are a range of other opportunities that will contribute to Australia's space sector, particularly the delivery of space communication services. There are also a range of manufacturing opportunities interwoven into each of the focus segments, such as the manufacturing of communications payloads and systems.

⁵ Australian Space Agency, [State of Space Report](#). A report by the Australian Government Space Coordination Committee, 1 Jan 2018 - 30 June 2019, pg 22.

Communications technologies and services roadmap



2021 2022 2023 2024 2025 2026 2027 2028 2029 2030 TARGETS

Drivers

Continually increasing demand for higher capacity and higher assurance communications

Proliferation of autonomous and uninhabited systems in all domains

Advent of quantum technologies requiring optical satellite communications



LEO satellite services

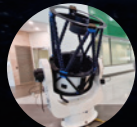
Demonstrations of Australian designed and operated single mission non-persistent LEO satellites and service-enabling technologies

Demonstrations of Australian designed and sustainable manufacturing of single mission non-persistent LEO satellites and service-enabling technologies

Demonstrations of RF and/or optical ISLs between orbits

Demonstrations of Australian operated single mission persistent MEO communication satellites and lunar missions

Australian LEO and other NGSO satellite communications networks including ISLs



Optical ground stations

First Australian optical ground station

Australian optical network link demos

Australian optical network handover demos

Remote terrestrial optical data relay

Demonstration of low or medium Earth orbit optical data relay integration

Demonstration of deep space optical data relay integration

Federated global and deep space optical networks



Hybrid RF-optical communications

Demonstration of single aperture system combining RF and optical in one portable terminal

Operationalise a single aperture system combining RF and optical for maritime and terrestrial users

Operationalise a single aperture system combining RF and optical for airborne use

Demonstrate use of RF and optical for use in space



Reconfigurable networks, radios, modems and waveforms

Network ground stations for deep space missions

Automation of national ground station networks demonstrations

Integration demonstrations with RF-optical hybrid

Networked Multi-In Multi-Out ground stations

Improved access to optical fibre network

Support to lunar and or deep space missions

Federated ground stations integrated into a global network

Radios, modems and waveforms

Library of Australian certification standards to inform software development and modem/waveform development

Demonstration of software definable cognitive radio with low size, weight, and power (SWaP) for LEO satellites

Demonstration of software definable cognitive radio with low SWaP for users

Demonstration of software definable cognitive networks with dynamic spectrum access technologies

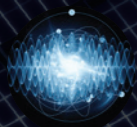


Satellite communication network management tools

Consideration of agile certification standards to promote evolutionary software development

Demonstrations of integrated multi-band and multi-network satellite communication planning and operation tools

Iterative operationalisation of integrated multi-band and multi-network satellite communication planning and operation tools for commercial and/or military use, with increasing integration of cyber defence capabilities



Quantum enabled communications

Quantum enhanced receiver (QR) demonstrations

Hosted quantum payload demonstrations

Dedicated quantum missions utilising terrestrial QM

Networked quantum enhanced communications

QM satellite utilising entanglement swapping

Demonstrate participation in QM enabled networks

Global quantum network

Facilitators

Investment and policy: Early activities include \$150 million to support Moon to Mars, Defence investment of \$50 million in satellite communications innovation in cooperation with the Australian Space Agency; foster a policy environment conducive to a commercial space communications ecosystem.

Governance and coordination: Communicate strategic directions and co-design clear pathways, support existing Treaties, and strengthen collaboration domestically and internationally to grow the domestic space industry and enhance our global space position.

Workforce, skills and resilience: Foster the transfer of knowledge from overseas and other industries into the Australian space industry to build a robust ecosystem. Continue to support the development of a diverse and inclusive future workforce.

Regulation and standards: Ensure ongoing review and implementation of industry standards and practices to keep pace with changing technologies; pursue timely and cost effective access to, and responsible use of, the electromagnetic spectrum.

Social licence and sustainability: Promote behavioural norms through fostering collaborative behaviours and STEM education; responsible use of the information derived from the use of satellite communications; leverage communications technology developments to ensure cybersecurity across entire networks.

Multi-mission LEO and MEO networks augmenting traditional satellite communication networks on Earth and deeper in space.

Increased Australian access to high capacity global, space data relay and deep space communications networks (quantum optical enabled) from portable/mobile users.

Australia emerges as a trusted partner for the provision of RF and optical communications, quantum technologies, LEO satellite services and satellite operations tools, refining the foundations of our satellite communications industry.

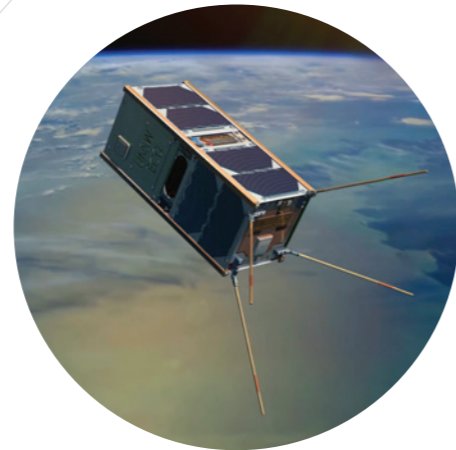
Smarter use of limited spectrum infrastructure, accessible via software definable cognitive radios on satellites and by portable/mobile users for use on Earth and in space networks.

Cyber-resilient multi-band and multi-network planning and operations tools.

High assurance for high capacity global communications networks.

LEO satellite services

Maintaining Australia's trajectory in LEO satellite services will enable Australia to capitalise on the digital transformation of regional and remote industries. This allows cost-effective monitoring and control of devices and sensors in areas such as autonomous systems in mining, environmental, logistics, and utilities industries.⁶



SEGMENT TARGET CAPABILITY

Multi-mission LEO and MEO networks augmenting traditional satellite communication networks on Earth and deeper in space.

OPPORTUNITY

Australian industry excels in the use of integrated networks of ruggedised, small, low power/long battery life units for sensing assets, specialising in remote detection and surveillance. Sensors can have a long life-cycle and are linked with small communications satellites with advanced, smart payloads to enable more efficient spectrum utilisation driving down costs for users. LEO also affords potential opportunities in increased integration with airborne and terrestrial networks, where the user may become agnostic of whether their services are being provided from Earth, an aircraft or from space. Once proven in providing services on Earth, IoT technologies could be extended for Low Lunar Orbit operations around the Moon.

LEO satellite IoT spans a range of peer Civil Space Priority Areas, and is critically enabled by communications. Direct to orbit IoT communications is a key differentiating capability that Australian industry provides. By maintaining our trajectory in satellite IoT, Australia can implement solutions to cost effectively monitor and control dispersed devices. This will deliver efficiencies in Australian industry, defence, civil emergency management and environmental monitoring.

Australia is mature in the provision of LEO satellite services, but opportunity also exists in the niche manufacturing of nano and small satellites applicable for use in LEO.

OBJECTIVE

Enable monitoring and control of Australia's terrestrial and orbital infrastructure in smarter ways and become a global leader in the application and sustainable manufacturing of space and Earth-based satellite IoT technologies.

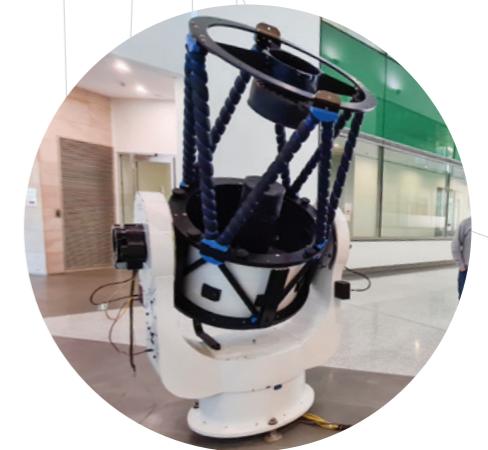
OUTCOME

The increasing demand for connectivity between devices globally and in near-Earth industries such as agriculture, resources and water management has been met; connecting both areas not cost-effectively serviced by terrestrial networks, and space missions not adequately serviced by traditional satellite and ground segments.

Photo: UNSW Sydney

Optical ground stations

Australia's geographical size and minimal cloud cover, together with strong optical communications research have set the foundations for competitive advantage in the provision of optical ground segment services.



SEGMENT TARGET CAPABILITY

Increased Australian access to high capacity global, space data relay and deep space communications networks that may be optical and quantum enabled.

OPPORTUNITY

Australia's unique geographic diversity, weather, national stability, and technological pedigree enables a contribution to satellite missions requiring high bandwidth and high volume data transfer. There is opportunity to provide infrastructure via an Optical Ground Station Network extensible to international use and regional growth. This will set a leadership position in providing secure high capacity optical links enabling other technologies. There is potential to integrate with inter-satellite links (ISL), for example from LEO to GEO, building increased resilience across these orbits.

OBJECTIVE

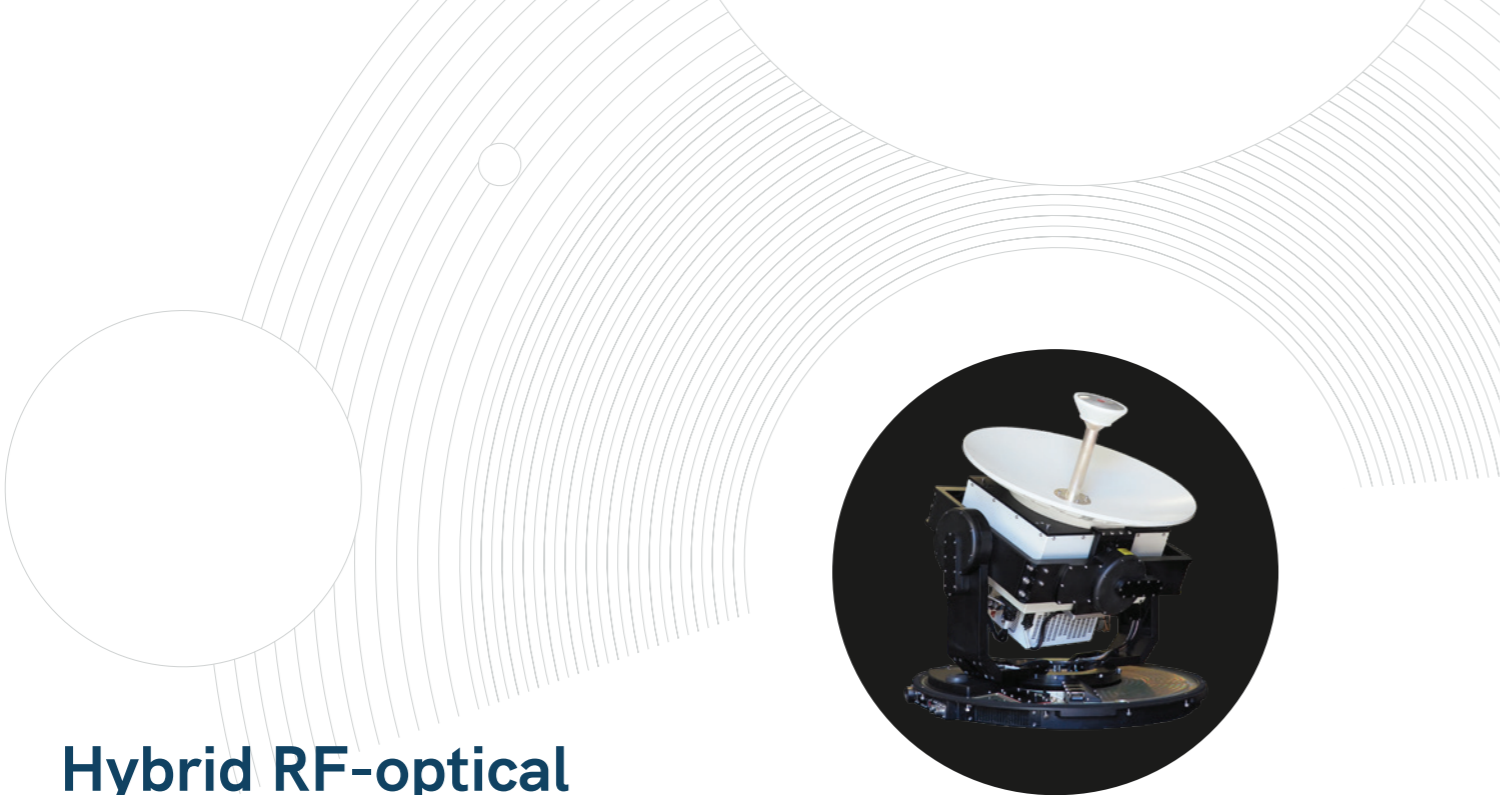
Establish Australia as an internationally trusted partner and the destination of choice for secure and high-bandwidth optical satellite communications, and optical global services and products. Capability to network with mobile optical or hybrid RF-optical terminals, as part of hybrid networks matching the data rates afforded by optical ISLs.

OUTCOME

Australia provides high data rate and secure optical communications offering global connectivity and robust networks for international collaborations and operations.

Photo: UWA

⁶ The 2020 Northern Sky Research M2M and IoT via satellite report (2020) forecasts \$12.4 billion in revenues to be generated over the next 10 years, with growth of between 3% and 26% in the above sectors, [nsr.com/nsr-satellite-m2m-iot-continues-on-growth-trajectory-despite-covid-19](https://www.nsr.com/nsr-satellite-m2m-iot-continues-on-growth-trajectory-despite-covid-19), and [nsr.com/research/m2m-and-iot-via-satellite-11th-edition](https://www.nsr.com/research/m2m-and-iot-via-satellite-11th-edition).



Hybrid RF-optical communications

Limited RF spectrum availability requires higher capacity satellite communication terminals where a single hybrid antenna can support both RF communications and higher speed optical communications.



SEGMENT TARGET CAPABILITY

Increased Australian access to high capacity global, space data relay and deep space communications networks (quantum/optical enabled) from portable/mobile users.

OPPORTUNITY

Hybrid RF-optical communications terminals have the potential to provide high capacity RF and optical connectivity to mobile users with increased levels of communications security. Developing this capability could create a new market for high data rate user terminals, enabled by new optical Earth stations and complemented by significant developments that are being made in artificial intelligence defined waveforms, optical technologies and on-the-move RF terminals.

OBJECTIVE

Establish Australia as a trusted partner in the provision of RF-optical global services and products, bridging the gap between RF limitations and future optical capability.

OUTCOME

High capacity and resilient communications for dual civil and military use applications, particularly for responsive disaster planning and relief.

Photo: EM Solutions



Reconfigurable networks, radios, modems and waveforms

Australia's experience in RF ground segment mission support⁷ and software development forms the foundation for the development of agile RF network management systems, and dynamic spectrum access.



SEGMENT TARGET CAPABILITY

Smarter use of limited spectrum infrastructure, accessible via software definable cognitive radios on satellites and by portable/mobile users for use on Earth and in space networks.

OPPORTUNITY

Australia's solid foundation in optical, RF and satellite communication software development critically enables networks both on the ground and in-orbit. The maturation of Hybrid RF-optical terminals, and optical ground station networks that underpin the implementation of quantum communication technologies also rely on these developments.

Australia seeks to leverage opportunities in optical and RF applications over the next 10 years to build capabilities that:

- take advantage of advances in dynamic spectrum management and planning and operations tools

- expand and improve ground station infrastructure to be a recognised global partner in the next generation deep space network, including antenna manufacturing and construction, and related operational support.

OBJECTIVE

Establish Australia as a trusted partner in contributing to cognitive radio global supply chains and hosting ground segment support to international space missions, forming an integral part of evolving next generation communications spanning the integration of optical and RF technologies.

OUTCOME

Leverage our experience in optical, RF communication and radar technologies, and operational support to further develop a highly capable workforce, enabling Australia to use spectrum resources efficiently, and paving the way forward to foster world-leading cognitive radios and antenna manufacturing.

⁷ Via the New Norcia Deep Space Ground Station and Canberra Deep Space Communication Complex.

Satellite communications network management tools

Australia's momentum in communications technologies can be further enhanced by commensurate advancements in our spectrum situational awareness systems and advanced waveforms.



SEGMENT TARGET CAPABILITY

Cyber-resilient multi-band and multi-network planning and operations tools.

OPPORTUNITY

There is an increasing momentum in emerging satellite communications capabilities, including large constellations in non-geostationary orbits. Opportunities are created for global supply chain participation from Australia across the space enterprise resulting from:

- increasing digitisation and processing on satellites
- increasing integration between satellite, airborne and terrestrial networks
- advances in cloud computing, machine learning and data management.

Beyond the space industry, regional Australians may also benefit from a technology that increases capacity and reduces the cost to enable applications that support remote sensing.

OBJECTIVE

Australia's competitiveness in satellite communications is amplified by advances in satellite operations tools. Software enabled network planning tools, underpinned by high fidelity modelling and simulation and artificial intelligence, support operators' planning and operations to cope with the increasing demand and complexities of communication sub-systems.

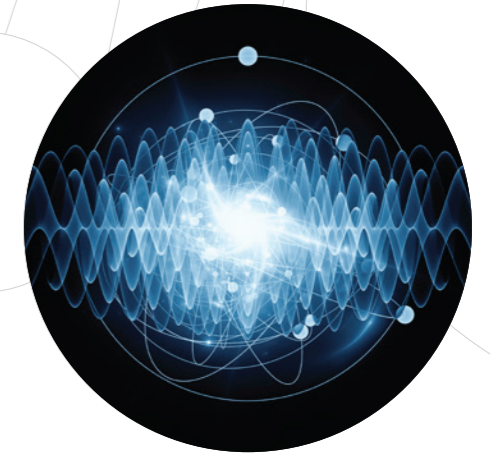
OUTCOME

Enabled peer communication segments, with conditions set for Australia to compete efficiently in higher capacity and information assured satellite communications for both civil and military applications, particularly in disaster planning and relief.

Photo: NASA

Quantum enabled communications

Australia's research pedigree in quantum technologies is a global competitive strength. The next generation communication technologies will help meet increasing demands for capacity and information assurance.



SEGMENT TARGET CAPABILITY

High assurance for high capacity global communications networks.

OPPORTUNITY

Australia's world-leading research in Quantum Memory (QM) together with research strengths in other quantum technologies has the potential to catalyse a new global industry of particular relevance to Australia. Despite a lower technology readiness compared to those of other focus segments, investing in areas where Australia has a niche advantage provides the potential to leap-frog other planned quantum technology enabled space missions. These drawback Australian quantum technologies also include Quantum Receivers (QR) and Quantum Key Distribution (QKD).

The security advances from quantum enabled communications are expected to transform data security in sectors such as finance and defence.⁸

⁸ CSIRO, Growing Australia's Quantum Technology Industry, May 2020, pg 24.

Quantum enhanced receivers promise to significantly extend RF and microwave communication bandwidths and distances. There is a potential to utilise quantum research towards quantum sensing - with broad-reaching applications.

Quantum technologies have the potential to:

- pave the way to a global ultra-secure, robust and resilient quantum encryption network
- create a new market for satellite quantum services and hardware
- position Australia at the forefront of the international supply chain for satellite quantum communication
- grow an Australian workforce of trained scientists and engineers in quantum-space technologies with extensibility to support other quantum technology demands.

OBJECTIVE

Establish Australia as a respected contributor to the global quantum communication community and service supply chains, leading the provision of QM, QR and QKD.

OUTCOME

Australia's quantum communication meets the increasing demands for capacity and information assurance, leveraging its competitive advantage in quantum memory, keying and receiver technologies.

Photo: QI Labs

Setting the conditions for the 2030s

At the end of this decade, the Australian Government's goal would see an Australian space sector around \$12 billion in size that will sustain around 30,000 jobs. Looking into the 2030s and beyond, the investment into the four space pillars of inspire, national, international and responsible sets the conditions for Australia to realise significant social and economic benefits.

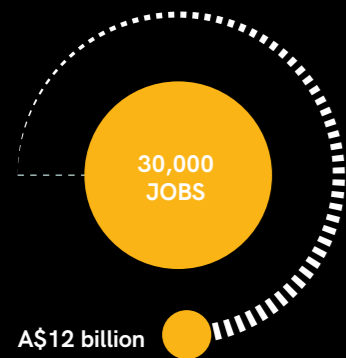
This roadmap is communications technology centric and it is only achievable through a highly-skilled STEM workforce. STEM professionals not only enable the space sector, but those skills are also transferable to other sectors. As a more connected Australia, and as part of a more connected world, we can leverage the Civil Space Priority Areas to advance our economy and society back here on Earth. Our dependence on information is likely to increase into the next decade. This is shaped by:

- securing that information with quantum technologies
- exchanging that information using optical communications
- managing that information
- using artificial intelligence to help interpret that information for autonomous system use and human use.

Communications technologies and services support the creation of high tech jobs in Australia and assist in other areas of the economy, including agriculture, remote medicine and resources. This is testament to space technologies being an enabler of industry growth across the value chain.

This roadmap presents a common vision for the space communications sector and dynamic pathways towards seizing opportunities and achieving the sector's potential. As the roadmap progresses towards the targeted capabilities, new competitive advantages may emerge that call for the development of further capabilities and facilitators to grow the sector.

The roadmaps can be read alongside the CSIRO Space Roadmap 2018 and the developing Australian Academy of Science's Australia's Future in Space: a strategic plan for space science. The Australian Space Agency will periodically review the roadmap in collaboration with industry.



"Satellites make you look up and imagine. They give you a different perspective over a fragile and interconnected world in which we live. Working in the satellite communications field shrinks distances, increases one's horizons, allows new connections all over the world, opens new possibilities..."

Associate Professor Sorin Adrian Barbulescu

Associate Research Professor in Satellite Communications, University of South Australia.⁹

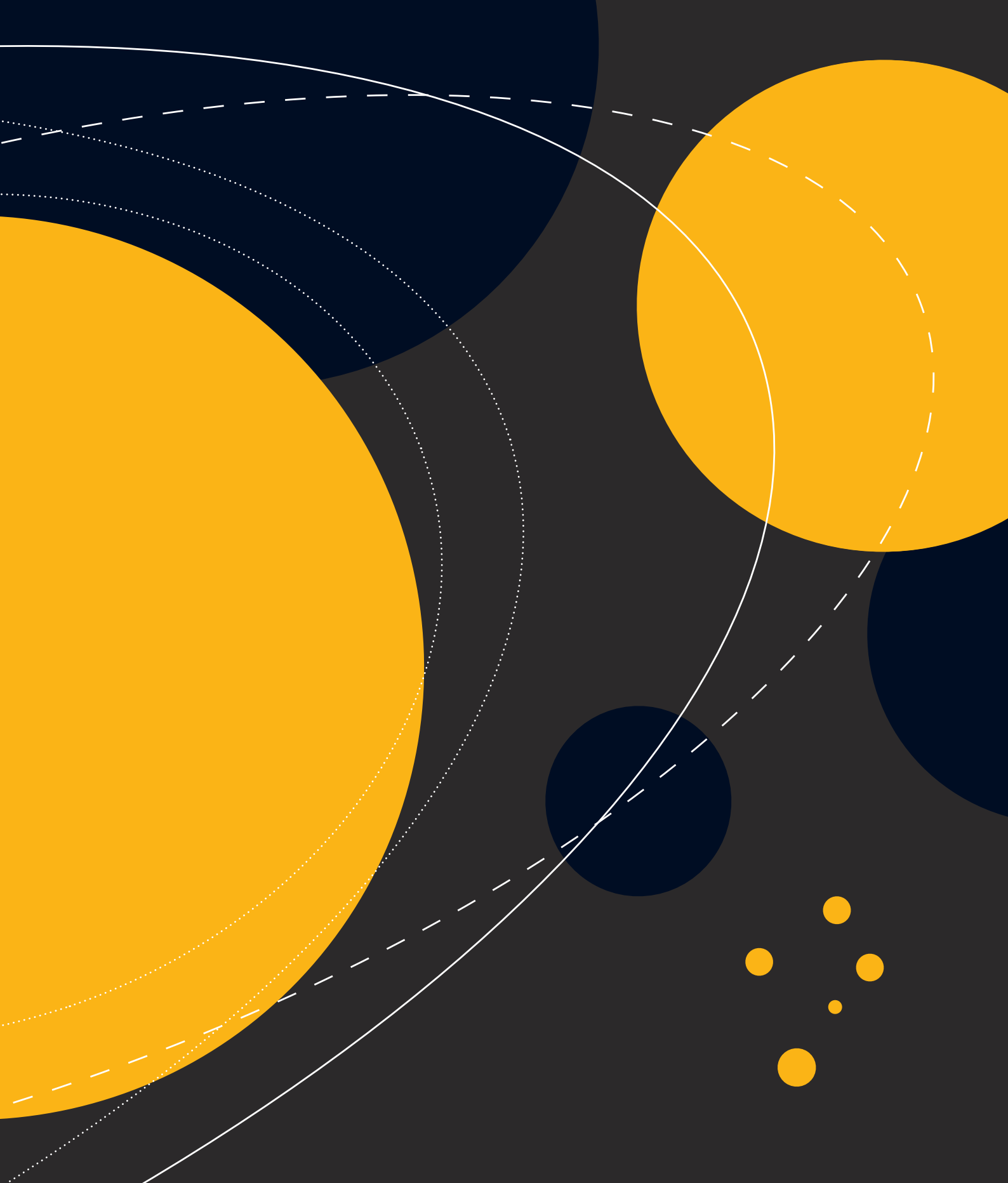
Acknowledgements

The Australian Space Agency is grateful to all those who participated in the roadmap's development to refine the analysis of Australia's capabilities and hone in on the best opportunities for our industry's future.



Photo: University of Western Australia

⁹ Quoted in: Institute for Telecommunications Research, 25 year anniversary, 2010, pg 29.



Australian Government



Australian
Space Agency