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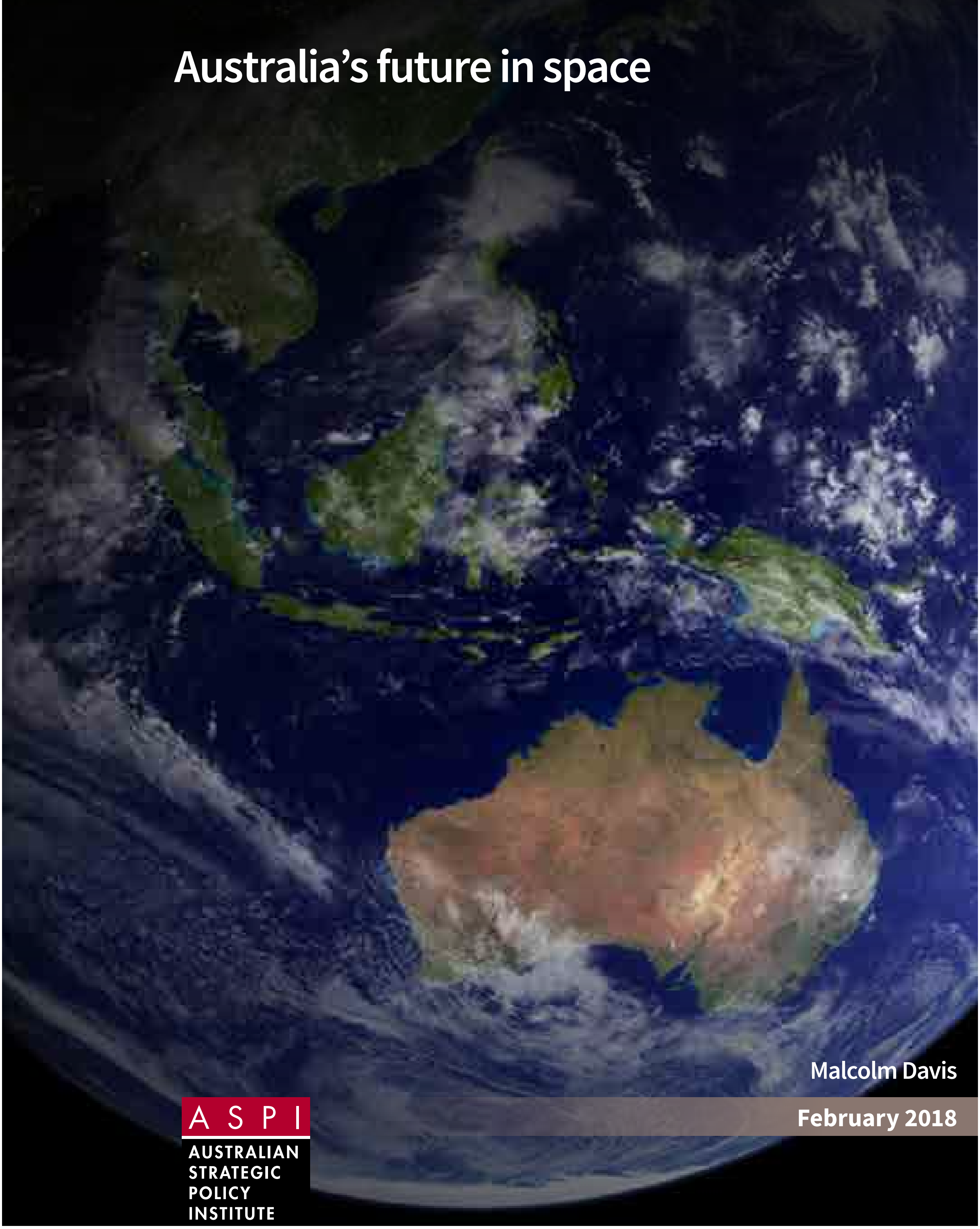
Australia's future in space



Malcolm Davis

February 2018

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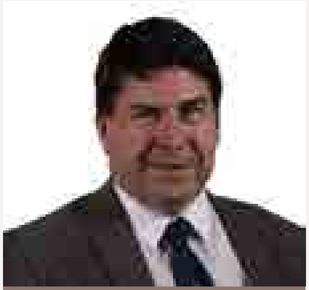

Malcolm Davis

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About ASPI

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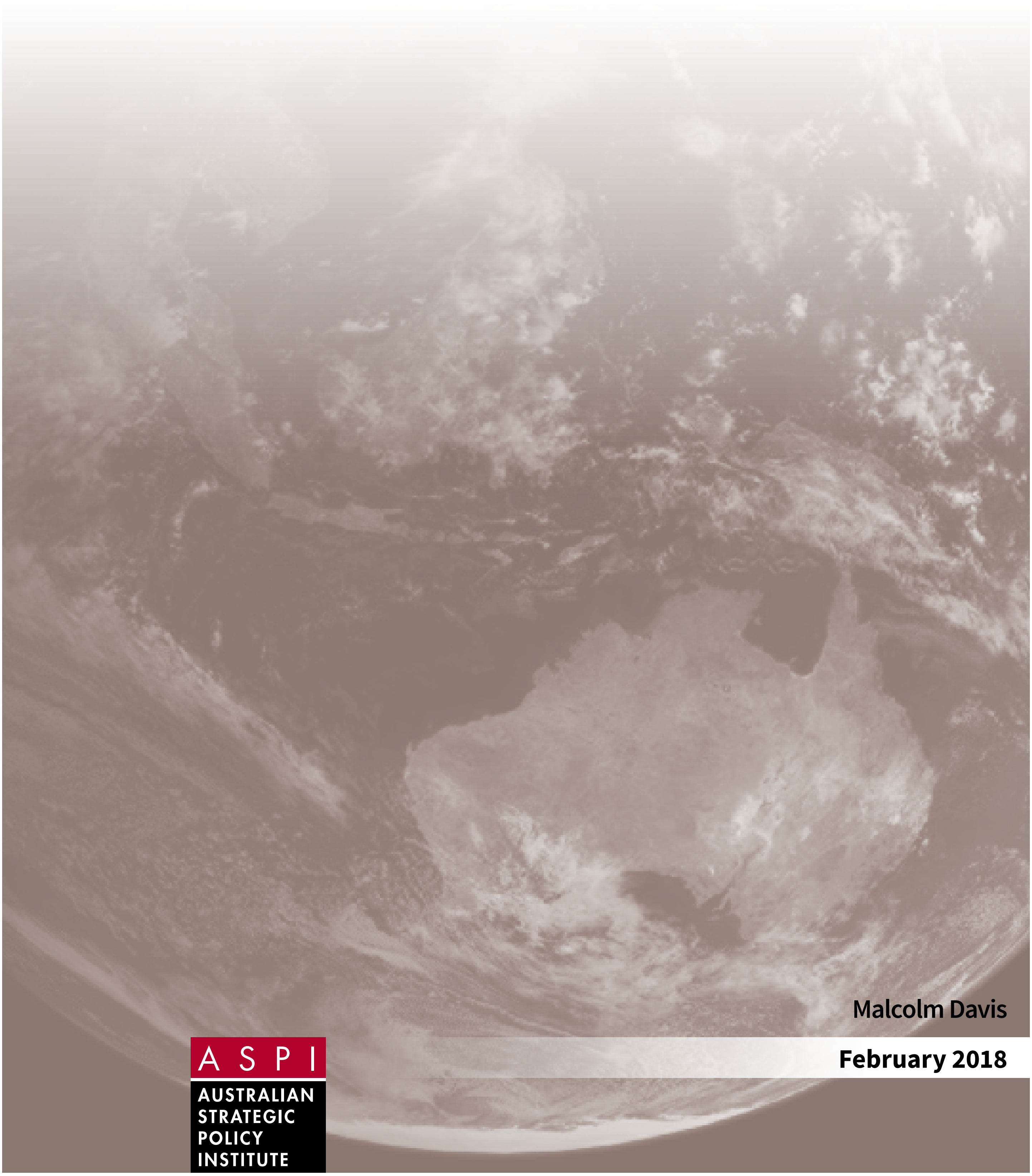

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EXECUTIVE SUMMARY

Australia is approaching an important window of opportunity to change our approach to the use of space for defence and national security purposes and, more broadly, to the establishment of a sovereign space industry. We now have the opportunity to move from a traditional policy of dependency on others to become an active space power—one with sovereign space capabilities in orbit and an active and growing space industry sector coordinated by an Australian space agency.

Traditionally, Australia has had a very risk-averse approach to space. There have been inconsistent and erratic efforts to develop the nation's role in space beyond one as a passive recipient of capabilities provided by other states. We've contributed expertise and skilled personnel and a regulatory framework for accessing data from satellites owned by other states or commercial entities and, to paraphrase the late Des Ball, we've provided a 'suitable piece of real estate' for ground facilities. There have been little government support and no real government funding for developing our own satellites since our first one, WRESAT, in the 1960s, and no government support for establishing an Australian space agency.

In defence terms, the ADF is largely dependent on the US for vital satellite communications; intelligence, surveillance and reconnaissance; and precision navigation and timing functions from space. Australia has played an important role in supporting space situational awareness, but *the ADF is a space power only through US support*. Without access to US space capabilities, the ADF couldn't undertake military operations in the modern joint and integrated battlespace. Furthermore, this dependency places an unnecessary burden on the US. By contrast, were we to develop our own space capabilities, we'd strengthen our own defence self-reliance and add new capabilities that 'burden share in orbit', making the US–Australia alliance stronger.

Our dependency on others for both defence and national security purposes, and more broadly for national economic activity, creates an unacceptable risk that in a crisis Australia could lose access to vital space systems, resulting in the rapid and catastrophic loss of military effectiveness and broader risks to national economic wellbeing. The absence of government support for a more independent and sovereign space capability has constrained the Australian commercial space industry, which is underperforming in comparison with other sectors of the Australian economy. That underperformance is curious, given our significant contribution in other defence-technology sectors, such as unmanned aerial vehicles and advanced radar technology. It's not an absence of technological base that limits our role in space—it's the absence of political support.

However, this disappointing state of affairs may be about to change. The Australian Government announced the establishment of a space agency in October 2017 and is completing a wide-ranging review of the Australian space industry, the findings of which will be released in March 2018. As these important developments are occurring, there's rapid innovation globally, including the establishment of 'Space 2.0'—a new paradigm based on low-cost systems and innovation, which embraces risk and emphasises commercial sector leadership, rather than government-run space programs. Space 2.0 is leading to the 'democratisation of space', as low-cost technologies allow more states (and non-state actors) to access and use space. Australia is well positioned to use Space 2.0 as the basis for our future approach to space development.

This ASPI Strategy argues that the next Defence White Paper should support a shift from the current nearly total reliance on external providers for critical space support to the ADF. It should explicitly embrace an increasing degree of *space self-reliance* in the form of locally developed sovereign space capabilities based on the Space 2.0 model. This would include the sovereign development of small Australian satellites and a space launch capability. This could occur simultaneously as Australia moves to develop a sovereign space industry in which commercial space enterprises contribute to Defence's needs in space capabilities wherever possible.

CHAPTER 1

Introduction

Australia has a long history of depending on space capabilities provided by other states. Efforts to develop our own independent capabilities have consistently failed to deliver them. The cause has been a lack of strong support from successive governments on both sides of the political fence, which has translated into a lack of funding, haphazard and chaotic administration, and ultimately an absence of sound policy on space. However, this disappointing state of affairs may be about to give way to a much more ambitious and successful future for Australia in space.

There's now a clear appreciation of the risk for Australia of continuing dependency on foreign or external providers as the sole sources of our space capability. At the same time, there's recognition on the part of government, the commercial sector and promoters of an Australian space capability of the growing opportunities emerging from potential 'Space 2.0' innovations. Engagement with industry has demonstrated that an energetic commercial space industry sector is beginning to stir here.

In the past, the lack of economies of scale available and the high costs of space activity were disincentives to the development of Australian space capability. For much of the past few decades, our contribution was to provide personnel and ground facilities to support our allies' activities in space, while establishing a regulatory framework to manage our access to data from space for use on Earth.

Over time, we've accepted a degree of strategic vulnerability that's now increasing as space becomes more contested, congested and competitive. But recent technological developments have reduced the costs of accessing and exploiting space and made the local development of sovereign space operations much more viable. Those developments have opened some niche areas in the commercial sector where Australia can participate profitably. The old approach of taxpayer-funded, government-run space programs (such as NASA in the US) is Space 1.0. The new approach, Space 2.0, emphasises commercial space enterprises as leaders and exploits new technologies that deliver low costs and high returns in good time.

Some important steps are being taken to break Australia's space dependency. The Turnbull government announced the establishment of an Australian space agency at the International Astronautical Congress in Adelaide on 25 September 2017 (Sinodinos 2017). The announcement was a good move, but the devil is in the details. The success of the agency will depend on what it's required to achieve and its level of funding. In parallel with the establishment of a space agency, the government is running a review into revitalising the Australian space industry. A report is to be delivered in March 2018, at about the same time as details of the charter and funding of the space agency are to be revealed (DIIS 2017).

It's hoped that those two steps will lead Australia to embrace a more proactive and ambitious approach to space. The outcomes of the review and the establishment of the agency are likely to help the Australian space industry grow.

At the state and territory level, there's cooperation between South Australia, the Australian Capital Territory and the Northern Territory to build the industry. The industry sector includes 'downstream' (ground) and 'upstream' (space) components, and the upstream component includes the development of small satellites and microsatellites. Much activity is occurring in South Australia, which is a 'Defence industry' state. Defence SA has published the *Space Innovation and Growth Strategy: Action Plan 2016–2020* and the *South Australian space capability directory* (SA Government & Defence SA 2016a, 2016b). The University of New South Wales (UNSW) Canberra and the Australian Centre for Space Engineering Research (ACSER) in Sydney are emerging as leading centres for space research in Australia. UNSW Canberra has also generated commercial spin-offs that are manufacturing satellites for the RAAF. The Northern Territory is promoting its advantageous geographical characteristics for a future Australian space launch industry based on a proposed Arnhem Space Centre being developed through the Canberra-based company Equatorial Launch Australia (Zillman 2017).

The Defence organisation is now recognising that space is an operational domain in its own right, and that it's vital to joint and integrated ADF operations. Defence is still heavily dependent on US support, but has begun to consider establishing sovereign Australian capabilities based on microsatellites known as 'CubeSats'.

Our ability to develop and manufacture our own satellites and launch them on Australian vehicles from an Australian launch site would energise and sustain the domestic space industry, which can become an important new economic sector. The sector's growth could start in the Defence portfolio through investment designed to exploit operationally responsive space capabilities for maritime domain awareness and communications support to the ADF. More specialised roles, such as space-based space situational awareness and cueing for integrated air and missile defence, could follow.

The private space sector in Australia is young, energetic and full of smart people with big ideas who feel that the right time is coming for Australia to become a fully-fledged space power. The Space Industry Association of Australia (SIAA) noted in its recently released White Paper (SIAA 2017):

> The Australian space sector currently produces annual revenues of $3–4 billion and employs between 9,500 and 11,500 people from its 0.8 percent share of the global space economy. The SIAA believes there is an opportunity to double this within five years, if the Australian Government is prepared to commit to the establishment of an Australian Space Agency to lead a cohesive national space strategy. Further, the agency should have an aim of capturing four per cent of the world market for Australian industry within 20 years, a five-fold increase in the industry's global market share.

By becoming an active provider of space capabilities, rather than just a passive recipient, Australia could participate in a global sector that's growing at 9.52% per year (SIAA 2017).

This ASPI Strategy argues that the next Defence White Paper should support a shift from our current total reliance on others for critical space support to the ADF. We should develop our *space self-reliance* in the form of locally developed CubeSats and other small satellites and a sovereign space launch capability. We could develop the satellites and launch vehicles simultaneously, based on contributions from the commercial space industry.

There are both costs and benefits in defence self-reliance. There are obviously costs in stimulating a sovereign space industry, as governments would need to provide some funding. An argument could be made to stick with our current dependence on the US, but that ignores important changes in the space sector, such as Space 2.0 technology. We would be relying on the risky assumption that we'll always have access to US-provided space capability, which is under increasing threat from Chinese and Russian counter-space capabilities. And it would do nothing to stimulate growth in a potentially lucrative sector of the economy. It's important to see Australia's future in space from a Space 2.0 perspective, in which government lets the private sector lead. Defence can plug into the rapid growth of an emerging industry to acquire new capabilities, including satellites and launchers.

Furthermore, building a sovereign space capability for Australia would allow us to 'burden share in orbit' with the US to a far greater degree than before. Australia currently supports the US mainly by providing ground facilities for space situational awareness—that is, for monitoring to gather intelligence, dissuade hostile counter-space threats and manage the challenge of space debris. This is an important role that takes advantage of our strategic and geographical position as a key ally of the US in the Southern Hemisphere. However we could do much more than merely providing a suitable piece of real estate or paying for one (out of 10) Wideband Global SATCOM satellites. We should play to our natural advantages, particularly our location, as northern Australia is an ideal location for space launches. In developing a sovereign space capability, we should offer specialised satellite capabilities that both Australia and the US could use. In particular, we could contribute to deterrence in space by supporting the rapid replacement of lost satellites with networked constellations of microsatellite and small satellite systems. This would mitigate risk to the US in a contested and congested domain and dissuade adversaries from mounting anti-satellite attacks.

Finally, Australia could also cooperate multilaterally with partners in the Asia–Pacific region to build constellations of networked satellites that could contribute to regional security and create public goods, such as maritime domain awareness. This would also counterbalance China's attempts to establish a 'Space Silk Road' and reduce regional states' dependence on Beijing for space support.

In the remainder of this ASPI Strategy, I first consider the development of space policy, including the perceived role of space in defence policy, in Chapter 2. In Chapter 3, I examine the role of space capabilities as they relate to the ADF today and introduce the Space 2.0 concept. Chapter 4 considers the commercial and business case for Space 2.0 in Australia. Chapter 5 explores how Space 2.0 could help the ADF acquire an operationally responsive space capability, including a sovereign space launch capability, and Chapter 6 analyses broader strategic dimensions, including burden sharing in orbit and advocacy for multilateral space collaboration. Chapter 7 draws some pertinent conclusions.

CHAPTER 2

Australian space policy

Since the days of Australian involvement in the European Launcher Development Organisation at Woomera in the 1950s, our attempts to develop our own space capabilities have consistently failed to meet the hopes of Australian space proponents (Morton 1989:447–495). The story is one of consistently missed opportunities, lack of vision, incoherent organisation and government indifference to space-related matters. Kerrie Dougherty (2017:163–177) notes that:

> … successive Australian governments … saw no need to develop a national space policy or to support an active national space effort, preferring instead to allow various government departments to exercise control over different programs and budgets for space activities.

She also notes that:

> … the status quo of fragmented management and budget for national space activities has prevailed to the present day.

By the beginning of the 21st century, there were no overall coordinating body and no overall policy for space. This led to a lack of clarity for overseas agencies seeking Australian participation in space activities about who to contact, and a continued 'brain drain' of expertise in the absence of any real opportunities for Australian space jobs (Dougherty 2017:173). Even pleas from former Australian astronauts Andy Thomas and Paul Scully-Power failed to convince the government of the need for a more ambitious approach.

The satellite utilisation policy

The 2013 'satellite utilisation policy' (SUP) is the most recent formal 'space policy' to be promulgated by government. Prepared by the then Department of Industry, Innovation, Science, Research and Tertiary Education (DIISRTE 2013:11), the SUP states clearly:

> Australia recognises the opportunities presented by the increasing capabilities and diminishing cost of small satellites, particularly for education and research. However, the Australian Government does not see an Australian satellite manufacturing or launch capability as an essential element of its approach to assured access to critical space-enabled services.

The SUP argues that:

> the most effective contributions Australia can make are nationally coordinated efforts in the areas of niche Australian strength, particularly in ground infrastructure and in the application of space information to achieve cost-effective outcomes.

Rather than focusing on establishing an Australian presence in orbit, under the SUP *our gaze is firmly directed Earthwards*, towards formulating regulatory structures, managing the ground segment and then disseminating information from ground facilities to users in government, science and business. In short, we continue to provide 'a suitable piece of real estate' and a regulatory framework.

The SUP goes on to acknowledge the importance of maintaining assured access to space capabilities, but notes that future access is uncertain, with 'the satellites on which Australia relies … reaching the end of their life spans, and new satellites not always replacing them'. It notes that 'nearly forty percent of the civilian earth-observing satellite information Australia relies on has a high risk of not being provided within the next five years' and states that:

> while a passive approach has served Australia in the past, Australia must now develop its nascent and growing capabilities and use them to strengthen international relationships if it is to continue to access space information.

Even with these cautionary warnings, the SUP doesn't budge from advising continued dependence on other states and commercial partners for our space capabilities:

> Australia will continue to rely to a substantial degree on international support for critical functions enabled by space systems and the information which comes from them. And Australia will continue to accept a substantial degree of dependence on global supply chains for space system capability. (DIISRTE 2013:10)

The SUP's willingness to accept dependency is outdated and ignores the many opportunities offered by Space 2.0 that were evident even the policy was being written. This apparent gap between policy and reality was part of the rationale for reviewing the *Space Activities Act 1998* in 2015 (DIIS, n.d.). In announcing the review, the then Minister for Industry, Innovation and Science, Christopher Pyne commented that

> Space technologies have advanced significantly since the Act was introduced in 1998. We must ensure Australia's civil space regulation effectively stimulates innovation and investment in this growing industry sector. At the same time we need to be able to effectively meet our international obligations in managing the space environment, for example, the proliferation of space debris. (DIIS, n.d.:3–4)

Pyne was noting that good policy must be flexible and responsive to change. The 2013 SUP ignored the dramatic changes occurring in the global space sector and took a least-cost, least-risk approach that sacrificed any potential for future innovation. As a result, the Australian Government must now deal with an emerging gap between a changing space sector and a policy that has acted to limit progress in building local space capabilities.

In future, the government should aim not to replicate existing US defence or commercial space capabilities, but to develop complementary sovereign space capabilities that reduce the defence risks posed by our dependency and to stimulate the growth of a local space industry. It's time to move on from the 2013 SUP.

Space policy and defence

The Defence organisation's space policy, as stated in the *2016 Defence White Paper* (DWP16; DoD 2016a), continues to emphasise dependence rather than local capability development. The White Paper recognises the importance of space-based capabilities for intelligence collection, communications, navigation, targeting and surveillance (paragraph 4.14). It states that 'Defence's imagery and targeting capacity will be enhanced through greater access to allied and commercial space-based capabilities', and it stresses the importance of developing space surveillance and space situational awareness capabilities. DWP16 notes that 'additional investment is planned in ADF space capability, including space-based and ground-based intelligence, reconnaissance and surveillance systems' (4.16) and states that:

> Enhancements to our imagery capability will provide the basis to further develop our intelligence, surveillance and reconnaissance capabilities in the longer term, including through potential investment in space-based sensors. (4.14)

DWP16 thus suggests that an Australian satellite capability may be on the horizon. Subsequent to the publication of the White Paper, this has emerged as Defence Project DEF-799 Phase 2, which is currently undertaking conceptual studies on the eventual acquisition of space-based sensors to provide geospatial intelligence to the Australian Geospatial-Intelligence Organisation (AGO) by the late 2020s (DoD 2017). The 2016 Integrated Investment Program (IIP; DoD 2016b:1.21–1.24) reinforces this long-term vision for space and notes that a number of projects are either approved or being considered. The IIP also emphasises ‘space situational awareness systems and radars’, with a program time frame of 2018 to 2033 and an approximate investment value of $1–2 billion.

There’s a paucity of detail in the IIP on those projects. However, it implies that improvements in Australia’s ability to collect and use imagery data will be substantially enhanced through investment in the workforce and ground facilities, rather than through developing locally produced satellites, and through expanding access to data via existing and new commercial and partner arrangements under Defence Project DEF-799 Phase 1 (1.22–1.23). The White Paper and IIP also emphasise the role and importance of ground-based space situational awareness by ‘re-announcing’ the relocation of a C-band radar and optical space surveillance telescope to Australia, along with other sensors to potentially expand Australia’s space situational awareness coverage in the future (1.24).

The Defence Industry Policy Statement that accompanied DWP16 and the IIP notes that space capabilities are of particular interest as a transformational technology area to be considered under the $730 million Next Generation Technologies Fund, which will enable Defence to better position itself to respond to strategic challenges, retain a technology edge against adversaries and provide game-changing defence capabilities for the future (DoD 2016c:72). The policy statement says that the Defence Science and Technology Group will take the lead in conducting and integrating research into next-generation technologies, including integrating the operation of sensors and assets and fusing processing, exploitation and dissemination systems to support current and future tactical and operational needs (DSTG, n.d.).

Drilling down from DWP16, the Department of Defence’s Strategic Policy and Intelligence Group ‘space policy’ statement was approved in June 2016. The unclassified version reinforces the importance of space in Australian life and provides four policy objectives that form a basis for future capability development:

- Defence should organise, train, sustain and equip so that it can leverage the advantages provided by space systems.
- Defence must work in cooperation with other government departments, Australian entities and key international partners to maximise the advantages that we derive from space and develop and promote international norms.
- Defence must be able to continue operations and win in a contested, degraded and operationally limited space environment.
- Defence must protect Australia’s access to space.

The four policy objectives all imply growing concern about ensuring access to space and about the risks of an adversary denying that access. This is not just a concern for Defence, but also a national concern:

> Space is vital for Australia’s day-to-day functions and affects all industries and sectors … Defence relies on access to space for global positioning, navigation and timing, satellite communications, targeting, intelligence, surveillance and reconnaissance (including missile warning), mapping, hydrography, geodesy and terrestrial and space weather forecasting. (SPIG 2016:1)

The document highlights that ‘Australia has very limited sovereign capabilities in space’ and ‘relies upon the US for access to high end space capabilities’ and ‘on other international partnerships and commercial arrangements for access to space systems’ (SPIG 2016:1). It acknowledges that this degree of dependency on space capabilities to enable modern information-based warfare indicates ‘significant vulnerability for the ADF’. Although Australia ‘assumes access to space’, it’s clear that ‘as some nations increase their use of space and develop and test counter-space technology, it will become important for Defence to have the ability to monitor and protect our interests in space through a spectrum of responses’ (SPIG 2016:2). The policy document makes clear that this is a growing challenge:

> The risk of malicious activity through space against our strategic interests will increase out to 2035, [and] … some countries are now developing capabilities which can target and destroy space-based capabilities, or degrade their capabilities, which could threaten our networks. (SPIG 2016:1)

The space policy statement also notes the importance of Australia's geographical location in the Southern Hemisphere and our status as a key US ally and member of the Five Eyes partnership as advantages in supporting allied space operations, including through the Five Eyes Combined Space Operations memorandum (CSpO) (May 2016). Our location and nearness to the equator mean that we're well placed to support US space situational awareness tasks. The policy argues that Australia plays a valuable role by hosting space situational awareness sensors, which are now a key focus for US–Australian space cooperation.

The emphasis on space situational awareness is consistent with government policy that seeks to 'strengthen international frameworks and norms that promote the rule of law and international security', reinforcing the idea that space is a global commons. The policy 'supports the development of international norms and governance regarding the responsible use of outer space' (SPIG 2016:1). It clearly aligned with the Obama administration's 2010 National Space Policy, which emphasised space situational awareness for dissuasion, resilience through ensuring a means to operate in a contested and degraded environment, and the potential for the reconstitution of systems after an attack (White House 2010: 13–14).

Looking ahead, any US shift towards a policy of offensive and defensive space control to meet challenges posed by Chinese and Russian counter-space capability would certainly create new opportunities for current Australian defence space policy (Davis 2016a). Under those circumstances, Australia could contribute directly to US space resilience and thus deterrence in a more contested space domain by providing a useful reconstitution capability through small satellites and CubeSats that could plug gaps after an adversary's anti-satellite attack, potentially dissuading such attacks (Davis 2017a).

At the level of doctrine, the 2013 RAAF *Air power manual* definition of space power is important because it highlights a gap between current capability and policy aspirations. It defines space power as 'the total strength of a nation's capability to conduct and influence activities to, in, through and from space to achieve its objectives', and notes that 'although Australia has not sought to develop indigenous space-based capabilities, it has capitalised on space-derived services through its strategic alliance with the US and by accessing commercial space systems' (APDC 2013:124–125).

Our current approach of dependency allows us to use US and allied or foreign commercial space technology to acquire an essential force multiplier at much lower cost than would be the case if we sought to replicate, for ourselves, all the space systems that we now use. Our satellite communications and space-based intelligence, surveillance and reconnaissance (ISR) capabilities are those of the US and remain its property, they're a secondary payload on a commercial satellite, or they're the property of a commercial company of which we're simply one client among many, including potential adversaries.

In effect, Australia has a space-enabled military force—it's a space power—*only so long as the US and our allies, or commercial providers, are willing and able to provide such a capability for our use*. Australia *can't* guarantee constant access to space to conduct and influence activities in, through and from space.

CHAPTER 3

ADF space capabilities and Space 2.0

The ADF depends heavily on space support to function, and over 90% of the IIP is in some way dependent on space support (May 2016). The ADF depends on:

- satellite communications to provide beyond-line-of-sight support to command and control and to disseminate ISR products
- precision navigation and timing, primarily using GPS, which supports navigation, communications and timing, as well as guidance for GPS-guided weapons
- space-based ISR capabilities to support decision superiority, operations planning and execution, and targeting
- space-based meteorology and other specialised services to support the planning and execution of ADF operations.

The 2007 edition of *The air power manual* states that:

> Australian military participation in recent operations has reinforced the vital role played by space systems in 21st Century conflict. Satellite communications, space-derived intelligence products, and satellite-referenced position, navigation, and timing data have all proved crucial in the provision of improved situational awareness, global command and control and the creation of precise effects, (APDC 2013:101)

That dependency on space increasingly generates risk. The 2013 edition of the manual states:

> Air Force and the ADF have a significant reliance on space operations. Employing space power is critical to the effectiveness of airpower, and therefore, potential risks associated with this reliance will have to be carefully managed by mitigating vulnerabilities of space systems and countering emergent threats. (APDC 2013:125)

Satellites are vulnerable to interference, so 'military operations need to consider the possibilities of disruption of activities in the space domain in the planning and execution of terrestrial campaigns' (APDC 2013:127). The loss of space support in the event of an adversary's counter-space offensive would rapidly erode the ADF's vital information edge. A war without space support would be a costly and more indiscriminate process, and greater risk and loss of life would be likely. William Shelton, former Commander USAF Space Command, stated in 2015 that:

> We are so dependent on Space these days. We plug into it like a utility. It is always there. Nobody worries about it … You do not even know sometimes that you are touching Space. So, to lose [US] space capabilities it would be almost a reversion back to industrial-based warfare. (USCESRC 2015:328)

Those risks extend to threats to national economic activity and support for infrastructure, including navigation, banking and finance, communications, weather forecasting, search and rescue and land management (May 2016). In effect, without access to space support for military activities and other national purposes, Australia's ability to ensure our national security and defence would be imperilled and our economy and society would be at risk.

The reality is that space, while being a global commons, is *already* a contested operational domain. It's not a sanctuary from warfare. The militarisation of space that began in the early 1960s with the deployment of satellites to support terrestrial forces is now being increasingly characterised by *weaponisation*. States such as China, Russia and others, test and deploy ground- and space-based anti-satellite weapons or maintain the ability to do so at short notice (Pollpeter et al. 2015).

Modern information-based warfare is also leading to surging demand for bandwidth for satellite support during operations. Cebrowski and Raymond (2005) noted that:

> In Desert Storm [in 1991], coalition military forces numbered 542,000 [personnel] and they had 99 megabits per second of bandwidth available. In [Afghanistan in 2001 and Iraq in 2003] bandwidth rose to 3,200 megabits per second, while forces were reduced to 350,000. Satellite communications provided the backbone for Blue Force Tracking, shared situational awareness down to the individual level, and allowed operational and tactical level commanders to exploit an unprecedented speed of command. The nation's space capabilities directly increased speed of maneuver, the tempo of the fight, and the boldness and lethality of coalition forces.

The growth in demand for bandwidth that was apparent between Operation Desert Storm in 1991 and Operation Iraqi Freedom in 2003 has continued throughout the past decade and a half. This is particularly the case where there's more prolific use of advanced unmanned aerial vehicles (UAVs) for tactical ISR (all of which depend on high bandwidth to relay high-resolution video from the UAV to operators on the ground) and for videoconferencing within complex command and control systems.

The ADF's bandwidth challenge will grow when it brings into service systems such as the F-35 Joint Strike Fighter, UAVs such as the MQ-4C Triton and the eventual winner of AIR 7003, and as it employs a range of unmanned systems in the air, on or below the waves, and on land. There will be increasing requirements to use satellite communications for voice, video and data via our access to high-end 'mil-spec' satellites such as the Wideband Global SATCOM system and a greater requirement to use commercial satellites to provide additional bandwidth. The bandwidth challenge is already apparent, as more and more units depend on space support at the tactical level to function effectively. The extensive use of unmanned systems and the emerging era of robotics and the 'internet of things' in the battlespace tightens the linkage between the Earth and space in war.

Our access to space may also be at risk because that domain is becoming not only contested (challenged by opponents) but also congested. There's a growing risk that space capabilities will be damaged or lost in collisions with space debris (Aerospace Corporation 2018). Part of the risk is from second-generation debris, or fragments of objects shattered by collisions or explosions, and the creation of debris outpaces the removal rate in low Earth orbit (LEO) by around 5% per year.

Another key challenge will be the emergence of 'mega constellations' of satellites to provide broadband communications globally. In 2016, there were 803 satellites in LEO. The sheer number of satellites being planned (SpaceX is proposing as many as 4,000 satellites in LEO, while Boeing is proposing up to 3,000) not only dramatically complicates traffic management, but also increases the risk of collisional cascading (Foust 2016). Ironically, the driver for a growing space market that would justify investment in low-cost access also raises the risk of space debris that would threaten that access.

Australia's defence space policy argues that it's important to continue operations and achieve operational success even if the space environment is 'contested, degraded and operationally limited'. In any case, Defence 'must ensure and protect Australia's access to space' and do so in a manner that continues to allow the ADF to fight and win. Access alone is judged to be insufficient (DoD 2016d:2–3). The Defence Department argues that Australia should 'develop capabilities that are able to withstand adversary efforts to degrade them and identify and mitigate the current level of reliance on space support, by developing longer-term space-independent solutions (DoD 2016d:3). This suggests a need for greater resilience through rapid and effective reconstitution, allowing lost space capabilities to be replaced quickly in a crisis.

Moving our focus away from developing space capabilities to embrace terrestrial alternatives is not an answer. Certainly, high-altitude UAVs such as the MQ-4C Triton (of which Australia will acquire seven) will offer complementary capabilities for ISR within a specific geographical region of interest. However, UAVs can be more easily intercepted and destroyed without the political consequences that would be associated with a counter-space attack, while emerging electronic warfare capabilities are going to make terrestrially based C4ISR networks less effective.

Nor do high-altitude UAVs have global sensor coverage comparable to the view from LEO. For example, a single synthetic aperture radar satellite tasked with reconnaissance over the Indian Ocean would be able to 'image a thousand square kilometres in scan mode (and identify objects 30 m in resolution), and 100 square kilometres in high resolution mode (objects at 1 m resolution), in minutes, and in all weather conditions' (Scott 2014). In comparison, a maritime patrol aircraft or UAV can cover a greater area, but only over much longer time frames. There's benefit from investments into high-altitude UAVs, which may offer similar capabilities in terms of sensors mounted, command and control and the management of data, and which can dwell over an area of interest, unlike a satellite, which must follow laws of orbital dynamics. But they're a complementary capability to space, not an alternative.

The suggested framework in Table 1 shows where an Australian Space 2.0 capability would sit against current ADF space support. In this framework, Tier I is epitomised by high-end, US-provided 'strategic' space capabilities that deliver strategic communications, precision navigation and timing and strategic ISR. Satellites in Tier I tend to be large, complex and expensive; their cost and complexity are driven by risk reduction and extended operational lives stretching out over a decade. They have high capability in terms of sensors and systems and a requirement for propulsion.

Table 1: A framework for ADF space capability

	Satcomm	**Intelligence, surveillance and reconnaissance**	**Precision navigation and timing**	**Space situational awareness (SSA)**	**Other**
Tier I: US-provided 'strategic space'	Wideband Global SATCOMM	'National technical means' (NSA, NRO, NGA)	GPS	Ground-based SSA, space-based space surveillance (SBSS)	Missile early warning and tracking (SBIRS, STSS)
Tier II: Commercial space	Intelsat, Indium, Optus, etc.	Spot, Planet, Skybox imaging, DigitalGlobe 'Hawkeye 360', etc.		ComSpOC – AGI-STK Schafer Commercial SSA Lockheed Martin	
Tier III: Australian indigenous space capability	Operations			Experimentation	
	V-band ubiquitous satellite communications for ADF and commercial application	ISR satellites for maritime domain awareness of AIS targets Space 'leg' to support P-8 Orion and MQ-4C Triton		SSA support SBSS development, participation and experimentation 'Space fence' support	Joint ballistic missile defence cueing experimentation

A good example of a Tier I system is the US Wideband Global SATCOM (WGS) satellite constellation. WGS is a high-bandwidth satellite communications system that supports US and allied military forces, including the ADF (Davies 2015). The WGS system augments satellite communications provided by the US Defense Satellite Communications System and is the basis for a transformational communications architecture that, together with GPS, enables such innovative functions as 'blue force tracking', which has transformed the command and control of joint forces engaged in combat operations (Northrop Grumman 2003). While later versions of the WGS will resist jamming, they could still be vulnerable to direct attack with anti-satellite weapons (Boeing 2016). There are only nine WGS satellites deployed into geostationary orbit (an additional one is yet to be launched), so they're a brittle capability. If they were attacked, US and allied warfighting capability would collapse catastrophically.

The WGS system also boosts connectivity and interoperability between the US and its key allies, including Australia (Deagel.com 2007). Australia has funded the sixth satellite out of the eventual 10 as part of WGS Block 2, although delays in establishing ground infrastructure have meant that the returns on our $927 million investment have been limited (Davies 2015).

In addition to the WGS system, the ADF's satellite communications needs are also supported by transponders on commercial satellites (within Tier II in Table 1). The most significant is the Optus C1 satellite, which was launched in 2003 as a joint project by Optus and the ADF and has 24 commercial Ku-band transponders (Singtel Optus 2013). The Optus C1 will deliver satellite communications support to the ADF until 2020, when it will be approaching the end of its useful operational life (Optus 2015).

The Intelsat 22 satellite, launched in 2012, has a 'hosted payload' that supports ADF UHF satellite communications alongside the WGS system and Optus C1, with a geographical focus on the Indian Ocean region, including Afghanistan. Costing the ADF $500 million, the UHF payload 'saved money and accelerated its availability' compared to purchasing a separate satellite (Clark 2012). Yet its high cost and minimal capability (UHF only) contrast sharply with the potential offered by lower cost small satellite technologies that are now available.

For ISR, Australia also accesses a range of highly classified US ISR satellites via the Australian Geospatial-Intelligence Organisation (AGO) (DoD, n.d.). Under Defence Project DEF-799 Phase 1, Australia will develop a ground segment to access and control Tier II commercial satellite systems for defence purposes (DoD 2017). Imagery from high-end commercial satellites 'will be integrated directly into the Australian Geospatial Intelligence Organisation's imagery dissemination systems, reducing the time it will take for satellite imagery to get to a member of the ADF or the officers of Australia's national security agencies' (Pyne 2017b). This has been approved and has an approximate investment value of $507 million. In addition, a satellite imagery capability (Defence Project DEF-799 Phase 2), with a program time frame stretching from 2023 to 2039 and an approximate investment value of $3–4 billion, is to be considered.

Like most US allies, the ADF makes full use of satellite-based precision navigation and timing services through the US Global Positioning System (GPS) for communications, navigation, data relay, weapons guidance and other purposes (US Government 2018).

The high cost of Tier I capabilities puts them beyond Australia's capacity to develop them locally, and there would be little sense in replicating existing Tier II commercial space infrastructure when the ADF can easily access it as a customer. Where Australia's best positioned to contribute sovereign space capabilities is with much smaller, lower cost satellites in Tier III, ranging from 'small' satellites (weighing up to 500 kilograms) down to CubeSats that range from less than 100 grams to 10 kilograms (Table 2).

Table 2: Classification of satellites according to mass

Classification	Mass
Large satellites	>1,000 kilograms
Medium satellites	500 to 1,000 kilograms
Small satellites	100 to 500 kilograms
Microsatellites	10 to 100 kilograms
Nanosatellites	1 to 10 kilograms
Picosatellites	100 grams to 1 kilogram
Femtosatellites	<100 grams

Source: Spaceworks, 2017 nano/microsatellite market forecast.

Tier II focuses on commercial space capabilities using satellites across the full range of sizes. Commercial space companies, such as Intelsat, that provide satellite communications have been an established feature of the space industry for decades. However, the larger companies are now increasingly being challenged by small, agile new Space 2.0 start-ups that are exploiting new technologies in the form of low-cost Tier III type small satellite and CubeSat capabilities, rather than traditional large satellites. Technological progress in sensors, computing and engineering is giving smaller, cheaper satellites capabilities comparable to those of large and expensive systems.

For space imaging, large numbers of low-cost satellites are capable of rapid revisit rates to allow daily imaging and analysis of changing activity patterns on Earth. Companies such as Planet and DigitalGlobe offer such services, while Hawkeye 360 is offering commercial signals intelligence products to paying customers. The growth in commercial satellite providers will necessitate a better understanding the complexity of space traffic management, so US company AGI now promotes commercial space situational awareness through its ComSpOC product, which can help space companies to plan orbital operations and understand the growing risk from space debris (AGI 2018).

Australia should exploit the development of Space 2.0 and the commercial space sector in a manner that complements 'strategic space' in Tier I and supplements Tier II commercial systems. There are real benefits in developing our own sovereign space capabilities that aren't based on high-end, ultra-expensive and complex Tier I type systems, but instead take their inspiration from Space 2.0 and Tier II. It's in Tier III where the development of a sovereign Australian space capability would allow us direct control over our own assets and the information we gather to ensure timely and secure space support for the ADF. The potential opportunities offered by these new technologies, including CubeSats (encompassing nano-, pico- and femtosatellites) as well as larger and more capable microsatellites and even, potentially, small satellites, is clear. These types of satellites could be locally designed and built. They could then be launched at very low cost using commercial launch systems overseas, or eventually using sovereign launch capabilities once that sector of Australia's commercial space industry is established (Defence SA 2016).

Towards Space 2.0

ADF Tier III sovereign space capabilities would be based on CubeSats and, potentially, small satellites, that would be developed to provide support for two key operational tasks:

- Complement the air (P-8 Poseidon, G-550, E/A-18G Growler, and MQ-4C Triton UAV) segment of Australia's ISR in support of maritime domain awareness tasks.
- Provide the ADF with a ubiquitous communications capability to support joint taskforce operations both domestically and in expeditionary operations.

Noting the model suggested by framework in Table 1, in considering niche applications of Australian space capabilities, Australia could also undertake joint experimentation with key allies through building and flying CubeSat and small satellite missions for roles such as space-based space situational awareness, and developing space-based missile tracking and cueing for future ballistic missile defence capabilities that the ADF might acquire under an integrated air and missile defence project. More exotic missions might include Australian support for on-orbit resupply, servicing and repair, and support for US counter-space capability.

The CubeSat concept dates back to 1999, when it was conceived as a joint venture between California Polytechnic State University and Stanford University to facilitate greater access to space for university researchers (Mehrparvar 2014). CubeSats are classed as 'picosatellites', which the Aerospace Corporation developed in 1995 based on a 1-kilogram spacecraft (Welle & Hinkley 2014). CubeSats are, as implied, designed in a cube shape of 10 × 10 × 11.35 centimetres (known as 1u) and have an average mass of around 1.33 kilograms (Murphey 2012). The CubeSat design is modular: it can be scaled up by adding additional cube components (3U+ designs comprise three 1u cubes stacked together) and adding solar panels and sensors. Larger 6U and 12U designs are also possible. CubeSats use commercial off-the-shelf components and are usually launched as secondary payloads on launch vehicles that are carrying larger satellites. The first CubeSats were launched in June 2003 (Swartout 2016). At the time of writing, 811 CubeSat missions have been launched.

The diminutive size of CubeSats and their use of off-the-shelf technology results in their construction and operating costs being much lower than those of larger traditional satellites. While the larger satellites are certainly much more capable of delivering a broader range of capabilities at a higher level, and they have longer operational lives than cheaper CubeSats, their higher capability comes at a price: they cost more to deploy and offer less flexibility for upgrading their capabilities. The key significance of the CubeSat approach is that it opens space to a much wider range of participants, ranging from nation-states down to commercial companies, private organisations, universities and schools, while at the same time allowing more rapid innovation in satellite design and greater operational flexibility.

Constellations of networked CubeSats would enable the ADF to undertake specific tasks and missions that directly serve the needs of the ADF joint commander in a given theatre of operations. They could also provide valuable opportunities for defence experimentation in pursuit of future capability development using more sophisticated (although more costly) space capabilities, including small satellites.

Biarri and Buccaneer lead the way to new Australian space opportunities

The Department of Defence, in collaboration with UNSW Canberra, has led two key projects based on locally built CubeSats.

The first is Biarri, which is a four-nation project involving Australia, the US, the UK and Canada. The focus of the project is on precision flying experiments for which Australia provides Namuru GPS receivers for each of four spacecraft, which will fly in two phases. A single CubeSat (Biarri Point) was launched on 19 April 2017 on a risk mitigation mission (Aishwarya 2017). It was deployed from the International Space Station. A constellation (Biarri Squad) will be launched together in 2018 (ACSER, n.d.). The goal of Biarri is to test space-qualified GPS receiver cards in a manner that allows improved formation flying of CubeSats using the Namuru GPS systems to get very accurate measurements of the distance between the CubeSats. This will be done in concert with a laser tracking system ('ladar') based at Mt Stromlo, near Canberra, as a backup to the GPS systems on board. The Biarri Squad CubeSats will be tracked by Australia's space situational awareness ground-based sensors to determine the extent to which Earth-based sensors can track CubeSats flying in formation. The Biarri Squad mission will perform differential drag analysis to examine and learn more about the forces of drag and lift on CubeSats in very low orbits (Benson 2016). Biarri is the Department of Defence's first foray into CubeSat technologies. Even though Australia is not producing the complete satellites, which are being built in the US, the mission is important for what it teaches us and our partners about formation-flying CubeSats in swarms.

The knowledge gained may one day enable swarms of many CubeSats to operate as collective wholes, sharing data to produce useful ISR, communications or other applications for terrestrial forces at a fraction of the cost of a single satellite. The potential for CubeSats to share information across multiple and different types of sensors (optical, infra-red, synthetic aperture radar and so on) suggests much lower costs for sovereign space-based ISR capabilities, and could potentially lead to multilateral space constellations that provide greater dissuasion and deterrence against counter-space threats. A swarm of CubeSats operating in a networked formation is also much more difficult for an adversary to attack than a single large, expensive satellite.

On 27 November 2017, Australia launched the Buccaneer CubeSat, which was developed at the UNSW – Australian Defence Force Academy campus in cooperation with the Defence Science and Technology Group (Figure 1). Buccaneer will perform calibration experiments for Australia's world-leading over-the-horizon Jindalee Operational Radar Network from LOE, several hundred kilometres above the surface of the Earth, and will also support research that contributes towards developing ways to more accurately predict the orbits of space objects, and thus avoid collisions with space debris.

Both Buccaneer and Biarri point to the future of a sovereign Australian space capability built around CubeSats and small satellites.

Figure 1: The Buccaneer CubeSat at University of New South Wales, January 2017

Photo: Malcolm Davis, 2017.

During the 2017 International Astronautical Congress, the space research faculty of UNSW Canberra signed a $9.96 million contract with the RAAF to develop three CubeSats for two maritime surveillance missions in early 2018 and 2019. The director of the research faculty, Professor Russell Boyce, stated:

> These spacecraft are able to gather remote sensing information with radios and cameras, and are the sort of innovative space capability that can help meet many ground-based needs in ways that make sense for Australia. Because they have re-programmable software defined radios on board, we can change their purpose on the fly during the mission, which greatly improves the spacecraft's functional capabilities for multiple use by Defence. (UNSW Canberra 2017a)

Together with Biarri and Buccaneer, the three RAAF CubeSats may be the first of a new wave of space projects for the ADF. Future efforts in this area should be fully supported by the new Australian space agency. This would increase the ADF's ability to act independently and ensure defence self-reliance by strengthening our resilience in space and enhancing our national ability to reconstitute lost capability quickly. We would no longer be dependent on US- or other foreign-provided space capabilities, but instead would emerge as a true space power that has the capability to conduct and influence activities in, through and from space to achieve our objectives.

CHAPTER 4

Commercial space and Australia

The recent Space Industry Association of Australia (SIAA) White Paper, *Advancing Australia in space*, notes that Australia is underperforming in the rapidly growing global space sector. Australian space activities make up only 0.8% of the global space economy, which was worth US$328.8 billion in 2014 and US$329.3 billion in 2016, despite Australia having a 1.8% share of the world's total economy (SIAA 2017). This poor performance is driven by a:

> widely held perception, both within Australia and internationally, that Australia's general approach to space activities is that of a passive consumer purchasing … satellites and satellite data from other nations while generating few resources ourselves … Australia is generally not perceived as being active in space hence Australian space companies suffer from a credibility gap when competing in international markets. (SIAA 2017:5)

The SIAA argues that the 2013 satellite utilisation policy fails in a number of key areas, and that it has 'no clear, ambitious and measurable strategy for growing [the space] industry' that could generate jobs and economic activity, an absence of 'national oversight and program management', an absence of a 'unified approach to a national strategy for capability development', and 'no strategy for follow through to promote the commercialisation of [space] technology' (SIAA 2017).

This sorry state of affairs may change with the recent decision to create an Australian space agency, but that announcement needs to be backed up by strong government commitment in the agency's charter and funding, details of which are to be released in March 2018, along with the outcome of the Space Industry Review (Davis 2017b). If the substance is not there to back the government's rhetoric, there's a strong risk that this latest attempt to kickstart Australia's greater participation in space will fall flat, like previous efforts. Another key factor is the outcome of the review of the *Space Activities Act 1998*, which seeks to examine regulatory environments shaping Australia's space activities (DIIS, n.d.). The *Legislative proposals paper* produced by the review in March 2017 aims to bring about new legislation by 2018. The establishment of a space agency and the deregulation of Australia's space industry sector should stimulate rapid growth in that sector:

> If Australia is able to replicate the performance of the UK space economy over the first eight years, following the establishment of the UK Space Agency, it is possible to extrapolate that over a similar time frame, there would be an absolute improvement of about A$5.3 billion (132% increase on current figures) and an increase in direct employment in the sector of about 11,700 jobs (102% increase on current figures). These calculations are based on conservative assumptions. (Piva & Sasanelli 2017)

Professor Andrew Dempster, the director of UNSW's Australian Centre for Space Engineering Research (ACSER), refers to the 'Rocket Lab' effect. The New Zealand-based company Rocket Lab, which established its own space launch capability based on the Electron rocket, launched from Hawke's Bay on New Zealand's east coast in May 2017 (Coady 2017). The innovative lead from Rocket Lab forced the New Zealand Government to respond by establishing its own space agency.

In Australia's case, Dempster argues that 'several startup companies are effectively putting the same type of pressure on the Australian government.' He refers to Fleet, a South Australian company that's building CubeSats to enable the 'internet of things', and Gilmour Space Technology, a Queensland and Singapore based company developing space launch capability. It's clear that private-sector 'pull' may ultimately drive governmental 'push', leading to an opening up of the Australian space industry that could see an explosion of activity. Groups of space start-ups are already active in Australia, forming new space alliances. One such group is Delta-V, which comprises a number of Australian space companies, including Saber Astronautics, which are involved in space mission planning, operations and predictive analytics; UNSW's ACSER; the University of Sydney; and Hypercubes, a US company exploring advances in satellite imaging.

UNSW Canberra Space Research, led by Professor Russell Boyce, is heavily involved in CubeSat development. Its activities have spawned a commercial offshoot in the form of SkyKraft, which is dedicated to providing Space 2.0 technologies, such as CubeSats. There's a rapid growth in space start-ups across Australia, particularly in South Australia, where the state government and Defence SA are strongly promoting South Australia as one of Australia's key 'space states' (Defence SA, n.d.; SA Government & Defence SA 2016b).

Previous government examinations of Australian commercial space activities and their suggestions for developing the sector have tended to emphasise the ground segment rather than looking at developing sovereign space capabilities, including locally built satellites (DIIS 2016). Yet, as Dempster notes, that traditional Earthwards gaze ignores the dramatic changes brought about by Space 2.0 capabilities such as CubeSats:

> The old paradigm of big, expensive satellites and big, clunky agencies has been disrupted by easier access to space and the increasingly commercial use of space. Australia can leapfrog the old way of doing things, because most local start-ups are working on Space 2.0 applications. The small satellite market causing this disruption is growing at more than 20% per year and will be worth about US$7 billion by 2020. Nanosats or 'CubeSats' are fundamental to this growth. (Dempster 2017)

Government has to be forward thinking and embrace innovation in the space sector. It must understand the reality that the Australian space industry is already changing. Market forces are driving start-ups to invest in new technology and embrace innovation, rather than remain stuck in traditional Space 1.0 thinking that forces us to remain dependent on others to provide the space segment while remaining firmly Earth-bound. An analysis of Canada's experience is illuminating, given its comparably sized economy and technological base:

> The longer experience of the Canadian Space Agency delivers Australia a second-mover advantage in the space-market, suggesting a cluster of useful practices and facts to learn from, both in terms of what is best practice and what should be avoided. Canada currently captures 2% of the global space economy [compared to Australia's 0.8%], and experienced over the 15-year period between 2000 and 2015 an improvement of C$3.867 billion of space turnover (corresponding to an additional 0.177% of GDP); and 3,977 total space-related jobs. (Piva & Sasanelli 2017)

A failure to deregulate adequately or to properly support the new space agency will starve the space industry of oxygen needed to grow, and history will repeat itself. Local companies will shut down if profits can't be made, and jobs and expertise will once again go overseas. Australia will lose the chance to end its dependency on foreign providers for space support, and we'll slip back into traditional approaches that bring increasing risk of a loss of access to space. That would be another missed opportunity for Australia to be competitive in a global space sector that's rapidly expanding, but it would also be a missed chance for the ADF's own sovereign space capability.

While there's a clear link between commercial space technology, including locally developed CubeSat and small satellite capabilities, and the needs of defence and national security, another key market is for Earth observation, which contributes to a broad range of Australian economic and commercial activities as well as to improved situational awareness and support for the ADF. The potential economic benefits and returns generated by the commercial sector can support greater investment in defence space capabilities by boosting economic growth, jobs and productivity. In effect, Australia can bootstrap defence space capability from the commercial sector. Conversely, defence requirements can drive commercial development; SkyKraft is an example in which a defence requirement has generated commercial activity.

One key area that would play to both the requirements of the ADF and the potential for Australian space industry to support Defence's needs would be the development of an Australian operationally responsive space capability. This would be based on locally developed satellites and could be launched using an Australian space launch capability provided by commercial firms. Those capabilities would be developed to provide direct space support for the ADF, undertaking a range of tasks on the basis of operational need.

CHAPTER 5

Operationally responsive space and the ADF

In 2005, the late Arthur Cebrowski and John Raymond came up with a bright idea. They recognised the importance of small satellites weighing less than 1,000 kilograms and what were then called micro- and nanosatellites to redefine the business model for space. They saw the benefit of new technology, lower cost, and a new pace of development that they said suggested ‘an age of the small, the fast, and the many’. If applied in space, those factors would fundamentally reshape how space activities occurred, not just in national security and defence-related activities, but more broadly, across the entire spectrum of human space activities (Cebrowski & Raymond 2005). The concept of *operationally responsive space* capabilities emphasised the paradigm of the small, the fast, the light and the many, rather than the large, the few and the expensive, in developing space capabilities. It demands an ability to launch satellites rapidly and responsively to support a specific operational task.

Cebrowski and Raymond (2005:71) noted that what can be termed ‘strategic space’, such as advanced Tier I satellites emerging from Cold War programs, are limited in their ability to maintain space superiority in a new operational environment that’s characterised not by predictable bipolar competition but by rapid and often unexpected change, multiple state and non-state participants, and accelerating technological innovation:

> … the mission criticality that grew out of the Cold War, and the very high cost of our sophisticated and highly capable space systems, lead to high consequences of failure. The required corresponding risk-mitigation strategy places a premium on expensive, long lasting, heavy, multi-mission payloads. These same attributes also force larger, higher-cost launch vehicles, with low launch rates and significant mission assurance overseas … operational and tactical capabilities are based on mere afterthoughts.

Innovation, developments and upgrades

Simply put, the high cost of strategic space systems means that, once deployed, they can’t keep pace with technological innovation occurring back on Earth. A large satellite will have a 15-year lifetime, which means it’s based on a developmental model more akin to mainframe computer evolution than the rapid innovation now occurring in Silicon Valley for 21st-century mobile devices and smartphones—a paradigm that best suits Space 2.0. Given the potential offered by new manufacturing processes, 3D printing, virtual prototyping and mass production to rapidly develop, manufacture and improve the capability of small satellites and CubeSats, the distinction between ‘old space’, epitomised by Tier I strategic space capabilities, and ‘new space’ or Space 2.0 Tier III technology couldn’t be sharper.

Australia can pursue its own unique approach to exploiting an operationally responsive space solution aimed at providing direct space support for the ADF’s theatre-level joint warfighting role. It might be a set of small satellites or a swarm of networked CubeSats that perform a discrete task, such as ubiquitous communications support. A small satellite capability might be a vital aspect of providing a sovereign ADF ISR capability, alongside high-altitude UAVs such as the MQ-4C Triton, in which the satellite provides broad maritime domain awareness that cues a closer look at targets of interest by the UAV. This would be in addition to the space capabilities, mentioned above, emerging from the commercial sector. Such a capability would also contribute directly to greater burden sharing with US-provided 'strategic space' and reduce our dependency on those foreign-provided strategic space capabilities, freeing them up for US operational demands while maintaining the ADF's ability to mount joint operations that depend on access to space.

The burden sharing goes both ways: the US would be able to use Australian sovereign space capabilities for tasks that Australian spacecraft are better positioned to provide. An emphasis on developing satellites that provide coverage of the equatorial low Earth orbit (EqLEO) region 15 degrees north and south of the equator, as well as polar orbits, would be most relevant, particularly for maritime domain awareness, and would contribute equally to Australian and US defence interests.

Such satellites will have much shorter life spans than traditional large designs, but that's a benefit rather than a disadvantage. The business model for operationally responsive space capabilities advocates rapid innovation and updates of space capabilities, rather than stagnant capabilities that can't be easily updated until the next generation of expensive 'strategic space' systems is deployed perhaps a decade later. Because commercial space launch systems are able to deploy multiple CubeSats on a single rocket booster, a constellation of CubeSats can be rapidly updated, replaced, expanded or reconfigured. New CubeSats that have more capable sensors or communications technology can be integrated directly with existing satellites, replacing them if necessary or merely expanding the operational capability of an existing CubeSat swarm. The ability of the constellation to be networked and fly in formation to produce common output, akin to radio telescope interferometry, would potentially allow these new space capabilities to produce useful military information at significantly reduced cost in comparison with traditional single Tier I satellites (Davis 2016b).

This type of approach implies common satellite designs that can be produced quickly on a production line and kept as a 'space reserve' ready for rapid launch in a crisis. In time, they might even be 3D-printed as needed. CubeSats and small satellites lend themselves to this approach, and the best way to achieve a ready space reserve would be through also investing in a sovereign space launch capability for Australia.

Australia should embrace the disaggregation of space support. This could be achieved through a transition from sole dependence on a small number of foreign-owned and foreign-operated high-end Tier I satellites to a multi-tier mix comprising:

- existing satellite systems, such as the WGS system, and advanced ISR satellites
- the use of commercial satellite systems in Tier II when appropriate
- the development of a sovereign space capability based on large numbers of small Tier III satellites (up to 150 kilograms)
- networked constellations ('swarms') of CubeSats, which are developed and built locally and then launched into orbit by an Australian commercial launch provider.

In this way, Australia would contribute a greater part of a solution, be it to provide for our own defence or to support an ally, either to reconstitute space capability if a high-end satellite is destroyed or disabled by an adversary or to contribute as a coalition partner to a multinational operation by expanding available satellite bandwidth.

Without this solution, Australia can only sit passively and look on, depending on the US to provide our needs and with no ability to respond if critical space capabilities are attacked.

Australian space launch capability

One of the most visible aspects of Space 2.0 is the emergence of re-usable launch technology. Moving away from expensive, expendable rockets towards re-usability to lower the costs of getting into space is a key objective of US companies such as SpaceX and Blue Origin, which are already flying or demonstrating re-usable rockets. SpaceX's Falcon 9 and Falcon Heavy are already flying, and Blue Origin's New Glenn booster is set to fly by 2020. The development of airborne launch capabilities such as the Scaled Composites Stratolaunch by Stratolaunch Systems Corporation and Virgin Orbit will add greater flexibility to space launches by allowing launches on demand from any latitude (Stratolaunch 2016).

Advances in 3D printing and new rocket engine technology are allowing low-cost expendable launch systems exemplified by New Zealand's Rocket Lab's Electron rocket, which can launch 150-kilogram payloads into LEO and uses an advanced Rutherford engine that can be 3D printed in a single day (Rocket Lab 2018). In the US, ARCA's Haas 2C is powered by an advanced 'aerospike' engine and is designed to deliver 100 kilograms to LEO at the cost of US$1 million per launch at 24 hours' notice (ARCA Space 2017). US company Vector is developing its Vector-R and Vector-H boosters, which are designed to support the CubeSat and small satellite market, can deliver satellites ranging from 60 to 125 kilograms into LEO for between US$1.5 million and US$3.5 million per launch, and have re-usable first stages (VSS 2018).

On the horizon is the development of hypersonic propulsion based on scramjet engines. That may lead to single or dual stage to orbit 'spaceplanes' that offer airline-style levels of operating efficiency and further reductions in cost (Davis 2014). The UK's Reaction Engines Inc., is developing its synergetic air breathing rocket engine (SABRE) as the basis of its proposed Skylon spaceplane (REI 2018). Boeing has been selected by the US Defense Advanced Research Projects Agency to build the Phantom Express XS-1 experimental spaceplane, which comprises a re-usable winged first stage and an expendable upper stage that can place 2,200 kilograms into LEO for around US$5 million per launch, which is comparable to the cost of Rocket Labs' Electron expendable booster. An initial goal for XS-1 is 10 flights in 10 days and lowering launch costs by a factor of 10, while replacing delays for launch with launch on demand (Foust 2017).

At the 2017 International Astronautical Congress, SpaceX head Elon Musk updated his plans for the BFR re-usable rocket, making it a smaller and more flexible design (Musk 2017). The BFR now can deploy large payloads (150 tonnes) into Earth orbit, delivering either very large and complex satellites or large numbers of traditional satellites in a single launch. In the military context, its very low cost, responsive launch rate and high payload would reinforce the value of operationally responsive space for supporting military operations, particularly if one launch can put 20 or 30 satellites into orbit. Whereas in the past armed forces had to wait years for a single satellite to be launched on a single rocket, now, provided satellites are available, they can be launched *en masse* and on demand.

The transformation of launch capabilities and the shift away from expensive and wasteful expendable boosters (apart from launches of very light payloads) signifies highly visible change under Space 2.0. In the same way that commercial air travel was transformed in the 1960s when jet engines replaced propellers, new approaches to space launches that maximise re-usability, minimise cost and emphasise responsiveness will transform the space sector for commercial and government users in the 21st century in a way that will clearly benefit the developers and operators of CubeSats and small satellites.

Australia is well positioned—both geographically, because of our Southern Hemisphere location and proximity to the equator, and technologically, because of the potential for us to leapfrog more traditional approaches to space launches and exploit re-usable and responsive launch capabilities—to develop a local space launch capability as part of a sovereign space industry. This would add to Australian defence self-reliance in space and allow us to launch satellites on an 'as needed' basis, rather than wait for an overseas launch provider to decide when an Australian satellite needs to be launched. Two elements—a space launch facility and a sovereign launcher development industry—are essential if we want to maximise our ability to compete globally to strengthen our space self-reliance.

Two companies—Gilmour Space Technology and Equatorial Launch Australia—are prime contenders to become future Australian space launch providers and, together, deliver both of the two essential components (GSLS 2017; Zillman 2017; Hughes Jones 2017):

- Gilmour is developing two launch vehicles. The first is a smaller 'sounding' rocket designed to place a 130-kilogram payload up to 150 kilometres into a suborbital trajectory, while the Eris orbital launcher will be designed to place a 380-kilogram satellite into a 350-kilometre LEO. The target for the first flight is the fourth quarter of 2020 (GSLS 2017).
- Equatorial Launch Australia proposes to establish the Arnhem Space Centre, which could support a variety of customers wishing to launch payloads into EqLEO from the Northern Territory (ELA 2017).

At the same time as private space launch companies are vying to launch a rocket from Australia for the first time since the heyday of Woomera in the 1950s, the prospect of re-usable spaceplanes is on the horizon. The University of Queensland Centre for Hypersonics is doing research on scramjet-based hypersonic propulsion that could one day propel an Australian spaceplane at sufficient speed to make it a viable, fully re-usable and highly responsive space launch capability (CfH 2017a, 2017b; UQ 2015).

By developing a sovereign space launch capability, Australia would be able to support the US and other allies by providing a rapid reconstitution capability to ensure resilience in space in the face of emerging counter-space threats and capabilities. Advanced manufacturing methods, such as 3D printing of components for launch vehicles and satellites, could be exploited to give us a 'surge' capability for space support. This would be an entirely new way for Australia to burden share with the US, or to provide space leadership to regional allies.

CHAPTER 6

Burden sharing in orbit—the strategic benefits of sovereign space capability

Embracing Space 2.0 to build sovereign Australian space capability is not a means to replace strategic US space support (Tier I systems), but would allow Australia to complement US capability and burden share in orbit. Space is a contested and congested global commons, so there's a strong incentive to build space resilience against adversary counter-space threats. Large, complex Tier I satellites are increasingly vulnerable to both hard-kill anti-satellite systems and soft-kill counter-space capabilities. The limited number of these systems raises the possibility of a 'Space Pearl Harbour' that leads to the catastrophic collapse of space support in a crisis (Davis 2016a).

Space resilience can mitigate that risk. It has traditionally been done through limited hardening of satellites, the use of 'silent spares' (replacement satellites already in orbit), and better space situational awareness, which Australia directly supports with facilities in Exmouth, Western Australia. However, the traditional measures don't totally solve the problem. Satellites can be hardened only so much before cost and complexity make the process prohibitively expensive. Silent spares are as equally vulnerable as active satellites. Space situational awareness, while providing useful intelligence and ensuring that culpability for counter-space operations is known, ultimately allows the US and its allies to merely watch as an adversary attacks their satellites, with limited means to avoid an attack in progress.

Australia can do more to share the burden in space if we move decisively away from a policy of dependency. The ability to rapidly reconstitute lost space capabilities and the disaggregation of those capabilities reduce the likelihood of an adversary successfully carrying out a decisive counter-space campaign at the outset of a conflict. Those factors reinforce the ability of the US and its allies to enhance deterrence in space so that an adversary chooses not to employ counter-space methods. As space becomes increasingly contested, enhancing the credibility of space deterrence becomes a vital task that ultimately can best be achieved at the coalition level. Australia could play a leading role in supporting the US in reconstitution and disaggregation. Developing space deterrence capability must be a key aspect of our space policy development in the coming years.

Multilateral space consortiums in the Indo-Pacific

An Australian space capability would also mean that the ADF could offer greater regional leadership in Asia. With key partners—for example, Japan, South Korea, India, Singapore and Indonesia—we could open up the prospect of building multilateral space consortiums that can work together on regional security issues in which space systems can play a useful role. Building such a consortium could be a staged process that leads off with closer cooperation with major Asian 'space powers'—Japan and India—and then extend to other states that are interested in participating and keen to develop their own space capabilities.

The goal would be to establish satellite constellations, operating at a multilateral level, that contribute to the achievement of common defence and national security goals and that build resilience in space against emerging counter-space threats. A multilateral constellation would strengthen dissuasion and deterrence against an adversary employing counter-space capabilities, because an attack on one satellite would be an attack on the space systems and interests of all the countries in the constellation. That's particularly the case where the satellites are networked and sharing information to provide for collective security. A collective approach to space security through multilateral constellations builds a regional space consortium in which the sum of all parts makes it stronger than individual actors standing alone.

An obvious first step would be for Australia to seek closer collaboration with Japan in space. Japan has developed sovereign space capabilities but remains dependent on the US, particularly for missile early warning and other functions relevant to ballistic missile defence. Japan lives under the threat of potentially imminent nuclear attack from North Korea. If that threat isn't bad enough, Tokyo also confronts a rapidly growing and increasingly assertive China that challenges Japanese interests in the region, particularly in the dispute over the Senkaku/Diaoyu Islands in the East China Sea, but also increasingly threatens Japanese maritime commerce traversing the South China Sea. In a statement in 2015, Japanese Prime Minister Abe stated:

> The security environment surrounding Japan is getting tougher, and the importance of space is getting bigger for safeguarding our security. China is rapidly strengthening its space capabilities and developing anti-satellite weapons. It is said to be developing devices that obstruct satellites' functions with laser beams. (Rajeswari 2015)

In 2015, Japan released a new Basic Plan of Space Policy, which folds space policy into national security policy in a way that enhances the US–Japan alliance and seeks to respond to China's growing capabilities. Whereas in the past Japanese space policy was consistently civilian focused, in line with the country's postwar constitutional constraints, under the new policy it's seeking to develop space situational awareness capabilities and ISR for maritime domain awareness, double its ISR satellite constellation to eight, and develop space-based missile early warning (Kallender-Umezu 2015).

Japan's move to a dual-role space program, serving both civil and military needs, is a big step forward for Tokyo and a huge opportunity for Australia. Andrew Davies and Rod Lyon (2015) noted that 'there's scope for cooperation in applications such as remote sensing and surveillance, in civilian or military applications, or both', and made a point that 'the coincidence of longitude between the two countries means that the footprint of polar low earth orbit satellites covers areas of immediate interest to both several times a day. And the footprints of geostationary satellites covers both.'

In establishing a multilateral space consortium, the starting point should be at the bilateral level through strengthening cooperation between Canberra and Tokyo in a manner that not only takes advantage of common security interests, but exploits advances in Space 2.0 technologies (Davis 2016c). That would establish a framework to which other partners could be added over time. An obvious step would be a multilateral constellation of small, low-cost CubeSats that are networked so that they can share data and provide information akin to that from a larger satellite but at considerably lower cost.

As the number of partners increases, each could contribute either ground facilities or additional CubeSats and small satellites to build a collective space capability. Such a constellation would allow flexible operations for supporting ubiquitous communications or maritime domain awareness, either for national purposes or to support and enhance coalition interoperability. It would also contribute to regional counterbalancing against China, enhance dissuasion against Chinese counter-space capabilities, and contribute to greater burden sharing with the US. With an Australian space launch facility in the north being developed by Equatorial Launch Australia, Japan could benefit from launching its own satellites into important EqLEOs from Australia to directly support coalition tasks such as maritime domain awareness in the South China Sea.

There are two challenges here—one diplomatic and the other technical. Such a partnership wouldn't exist in a vacuum, even if the satellites operate in one. In geopolitical terms, a Japan–Australia collaboration in space would be seen in the context of the broader geopolitical outlook dominated by a rising China that directly threatens Japanese security interests. Australia would need to make the policy judgement, perhaps as part of a deeper trilateral security partnership with Tokyo and the US, that our interests are served by more direct support for Japan in a future crisis, even one involving China. Beijing would be certain to react negatively and argue that a space partnership between Australia and Japan, or one also involving the US, is further evidence of 'containment' of China. Yet we look set to deepen and broaden defence cooperation with Japan, as evidenced by recently signed agreements between our two governments earlier in 2018 (Envall 2018).

The extension of this approach to include other partners then carries its own challenges. India would be a logical third partner (or fourth, if the US is participating), raising the possibility of a 'space quadrilateral' that builds on the recent decision to resume the broader strategic policy dialogue between the US, Japan, India and Australia under the 'Quad' (Madan 2017). As with Japan, Australian defence engagement with India, including in orbit, carries its own challenges, given India's sometimes tense relationship with Beijing and India's own national security interests and agendas. As the concept might be extended to Southeast Asian partners, such as Indonesia or Singapore, the challenges could multiply, so it will take deft diplomatic management to make space multilateralism and multilateral space consortiums realities.

The technical challenge relates to the physics of flying CubeSats in close formation and sharing information in a fractionated constellation with satellites from different states. The US originally tested fractionated constellations in which the components of a single large (and expensive) satellite were spread across multiple smaller and cheaper small satellites or microsatellites, including CubeSats, from 2006 to 2013. The 'F6' project—Future, Fast, Flexible, and Fractionated Free-Flying Spacecraft—was ultimately cancelled due to cost, poor management, and a lack of interest by the US military, not because it was technologically premature as a concept (Axe 2013).

However the benefits of perfecting formation flying shouldn't be ignored. UNSW Canberra (2017b) notes that:

> … the challenge is now to develop capability to fly such tiny satellites in formations or swarms, with sensors distributed across multiple platforms, enabling remote sensing, space situational awareness, astronomy, space science, and other activities to be achieved with greater agility and at a fraction of the cost of traditional large satellite platforms.

Success in this will demand satellites with greater autonomy than traditional platforms, able to recognise their position in space relative to other satellites in a formation and adjust accordingly to maintain formation. Understanding where each satellite is in relation to the others also requires a greater understanding of the effects of the space environment on formations, particularly those operating in LOEs. The effects of gravity, solar radiation pressure and atmospheric drag in very low orbits all come into play (Tonn 2016).

Finally, if Australia is to lead the development of a multilateral space consortium with Indo-Pacific allies, the systems of those states must 'plug and play' with Australian satellites as part of a seamless network. Data connectivity must be assured and be resilient to adversaries' efforts to jam or disrupt the operations of the multilateral constellation.

Counterbalancing China's Space Silk Road

Australia's active participation in a regional space consortium would also contribute to counterbalancing Chinese efforts to reshape the regional security environment in a way that locks its neighbours into greater dependency on Chinese space systems. Alongside its One Belt, One Road Initiative (BRI), China looks set to add a 'Space Silk Road' that would extend its soft-power influence into orbit. The 2016 Chinese White Paper on Space Policy (SCPRC 2016) emphasised the importance of China's Beidou precision navigation and timing satellites:

> With sustained efforts in building the Beidou global system, we plan to start providing basic services to countries along the Silk Road Economic Belt and 21st-Century Maritime Silk Road in 2018, form a network consisting of 35 satellites for global services by 2020, and provide all clients with more accurate and more reliable services through advancing the ground-based and satellite-based augmentation systems in an integrated way.

The White Paper then went on to specifically mention the concept of a Space Silk Road, announcing plans to establish a 'Belt and Road Initiative Space Information Corridor', which would include:

> … earth observation, communications and broadcasting, navigation and positioning, and other types of satellite-related development; ground and application system construction; and application product development.

In effect, China is seeking to establish Beidou as a 'digital glue' for roads, railways, ports and industrial parks that China builds to extend its presence and influence. Chinese provision of satellite communications, weather monitoring and earth observation would add to this vision of a Space Silk Road that overarches and underpins the BRI, and would see Chinese satellite ground stations established in Silk Road states (Anand 2016). States signing up for the BRI Space and Information Corridor would then become dependent on Chinese space support, further extending Beijing's influence along the Maritime Silk Road and the Silk Road Economic Belt. Given the importance of space to rapid development in information-based developing economies, such an outcome would mean that BRI member states' economic success would become inextricably linked to Chinese-provided space support.

In providing for a multilateral space consortium through leveraging Space 2.0 technologies, Australia and its allies and regional partners could offer an alternative to Chinese domination of the Asia–Pacific space sector. First, GPS is already fully available and can be offered to BRI states either for free or on much more competitive terms. Second, satellite communications based on V-band mega-constellations in LOE would outperform traditional communications satellites likely to be offered by China. Third, space imaging systems are already available commercially to replace Chinese systems, and Australia has a potential opportunity to contribute to the success of multilateral space consortiums that sit apart from the Chinese Space Silk Road by contributing our own satellites as part of multilateral constellations.

A Chinese Space Silk Road would add a new layer of Chinese power and control over much of Eurasia. Unchallenged, it would lock out Western companies and ensure that Beijing is the sole provider of space services to BRI states. That would ultimately lock in Chinese control of BRI economies. That's never going to be a good outcome for the US in its broader competition with China for strategic primacy in Asia, and is completely unnecessary, given the rapidly changing nature of the global space industry.

CHAPTER 7

It’s time to develop an Australian space capability

Australia has a window of opportunity to shift gears in space policy and adopt a fundamentally different path from the one that we’ve taken in the past. Rather than continue to keep our eyes firmly focused Earthwards, we’re well placed to encourage the development of sovereign national space capabilities. The objective for our future in space should be greater self-reliance in orbit and a greater ability to burden share with key allies, including the US, in space. There’s real and unnecessary risk in continuing our traditional policy of dependency on others. Space is increasingly contested, congested and competitive, and our access to space capability is not assured if we continue to rely on others to provide it. The loss of space access would be catastrophic for Australia, putting at risk both our national defence and survival as an independent nation.

This paper doesn’t advocate replacing in their entirety the high-end space capabilities provided by the US and others. Australia will still have a degree of dependency, but we can mitigate risk by strengthening our sovereign capability with investments in Tier III systems such as small satellites and CubeSats and by investing in a sovereign space launch capability. This would ensure that the ADF has a greater degree of self-reliance in orbit, as well as a greater ability to support key allies. Supporting allies is particularly important, and Australia can and should work with the US and other allies in Asia to strengthen the resilience of space capabilities in the face of growing counter-space capabilities, including anti-satellite capabilities developed by China and Russia.

We can do more than just space situational awareness, and our contribution to space resilience can be more than just offering a suitable piece of real estate for ground facilities. Space 2.0 is fundamentally changing how states and commercial actors access and use space as an environment, and we need to be responsive to that development in our policies and in the way we think about national space capabilities in the future.

Australia should adopt a bold and innovative approach to space that leads to us becoming an active contributor in orbit, rather than falling back on a traditional passive dependency that sees Australian aspirations grounded and future opportunities missed.

REFERENCES

ACSER (Australian Centre for Space Engineering Research), no date. *Biarri GPS Receiver Project*, ACSER, University of New South Wales, online.

Aerospace Corporation 2018. *Space debris basics*, Aerospace Corporation, El Segundo, California, online.

AGI (Analytical Graphics, Inc.) 2018. *COMSPOC: a space domain where everything is detected, tracked, characterized and protected*, AGI, online.

Aishwarya S 2017. 'US-developed Biarri Point satellite launched to ISS', *Air Force Technology*, 19 April, online.

Anand V 2016. *China's silk road ambitions in outer space*, Observer Research Foundation, 23 December, online.

APDC (Air Power Development Centre) 2007. *The air power manual*, 5th edition, AAP-1000-D, Department of Defence, Canberra.

APDC 2013. *The air power manual*, 6th edition, AAP 1000-D, Department of Defence, Canberra, online.

ARCA Space 2017. *Haas 2CA: orbital flight redefined*, online.

Axe D 2013. 'After $200 million, DARPA gives up on formation flying satellites', *Wired*, 17 May, online.

Benson C 2016. *The Buccaneer and Biarri CubeSat missions*, 11 March, University of New South Wales, online.

Boeing 2016. *The military satellite that avoids jams and secures comms*, video, 14 November, online.

Cebrowski AK, Raymond JW 2005. 'Operationally responsive space: a new defense business model', *Parameters*, 35(2):69–70.

CfH (Centre for Hypersonics) 2017a. *Research*, University of Queensland, December, online.

CfH (Centre for Hypersonics) 2017b. *HIFiRE Program*, University of Queensland, July, online.

Clark S 2012. 'New Intelsat 22 in orbit will serve Australian, US forces', *Space.com*, 30 March, online.

Coady D 2017. 'Rocket Lab launches first rocket into space from New Zealand site—will Australia follow?', *ABC News*, 26 May, online.

Davies A 2015. 'Australia's WGS communications—what went wrong?', *The Strategist*, 22 September, online.

Davies A, Lyon R 2015. 'Japan's new space policy—do we need one too?', *The Strategist*, 23 September, online.

Davis M 2014. 'Hypersonics and Australia's future in space', *The Strategist*, 11 February, online.

Davis M 2016a. 'Space security after Obama', *The Strategist*, 9 November, online.

Davis M 2016b. 'A strategy for Australia in space', *The Strategist*, 18 July, online.

Davis M 2016c. 'Australia in space: developing a regional space community', *The Strategist*, 4 February, online.

Davis M 2017a. 'The US thinks about space warfare', *The Strategist*, 18 October, online.

Davis M 2017b. 'Getting starry-eyed about space', *The Strategist*, 28 September, online.

Deagel.com 2007. 'Australia gets access to wideband global SATCOM system', media release, *Deagel.com*, 14 November, online.

Defence SA 2016. *South Australian Space Forum*, Adelaide, 10 November.

Defence SA, no date. *Space*, online.

Dempster A 2017. 'Just one small step for Australia's space industry when a giant leap is needed', *The Conversation*, 18 July, online.

DIIS (Department of Industry, Innovation and Science) 2016. *2016 State of space report*, DIIS, Canberra, online.

DIIS, no date. *Reform of the Space Activities Act 1998 and associated framework*, DIIS, Canberra, online.

DIIS, no date. *Review of Australia's Space Industry Capability*, online.

DIISRTE (Department of Industry, Innovation, Science, Research and Tertiary Education) 2013. *Australia's satellite utilisation policy*, online.

DoD (Department of Defence) 2016a. *2016 Defence White Paper*, DoD, Canberra, online.

DoD 2016b. *2016 Integrated Investment Program*, DoD, Canberra, online.

DoD 2016c. *Defence industry policy statement*, DoD, Canberra.

DoD 2016d. *Strategic policy document on space*, DoD, Canberra, June.

DoD 2017. *Defence Project 799: enhanced satellite ISR capability*, DoD, Canberra, online.

DoD, no date. *About AGO*, DoD, Canberra, online.

Dougherty, Kerrie 2017. *Australia in space*, ATF Press, Hindmarsh.

DSTG (Defence Science and Technology Group), no date. *Surveillance and space*, Department of Defence, Canberra, online.

ELA (Equatorial Launch Australia) 2017. *Australia's first commercial spaceport*, online.

Envall HDP 2018. 'Australia–Japan defence deal: noteworthy, not newsworthy', *The Interpreter*, Lowy Institute, 22 January, online.

Foust J 2016. 'Mega constellations and mega-debris', *The Space Review*, 10 October, online.

Foust J 2017. 'Finally, liftoff for small launchers', *The Space Review*, 30 May, online.

GSLS (Gilmour Space Launch Services) 2017. *Low cost access to space*, online.

Harrison T, Cooper Z, Johnson K, Roberts TG 2017. *Escalation and deterrence in the Second Space Age*, Center for Strategic and International Studies, Washington DC, online.

Henry C 2017. 'Australian military frustrated by out of synch space and ground assets', *SpaceNews*, 3 July, online.

Hughes Jones L 2017. 'NT space base a step closer', *NT News*, 4 November, online.

Kallender-Umezu P 2015. 'Japan begins national security space buildup', *Defense News*, 12 April, online.

Madan T 2017. 'The rise, fall and rebirth of the "Quad"', *War on the Rocks*, 16 November, online.

May D 2016. *The potential for warfare in space: Australia's response*, Defence Space Coordination Office, 18 August, online.

Mehrparvar A 2014. *CubeSat design specification (CDS)*, revision 13, California Polytechnic State University, online.

Morton, Peter 1989. *Fire across the desert: Woomera and the Anglo-Australian Joint Project, 1946–1980*, Department of Defence, Canberra.

Murphey S 2012. 'What are CubeSats?', *YouTube*, online.

Musk E 2017. 'Making life multiplanetary', presentation at the International Astronautical Congress 2017, 29 September 2017, online.

Northrop Grumman 2003. *Blue force tracking: the Afghanistan and Iraq experience and its implications for the US Army*, Northrop Grumman, Virginia, online.

Optus 2015. 'Optus extends C1 satellite contract with Australian Department of Defence', media release, 7 July, online.

Piva A, Sasanelli N 2017. *Societal and economic benefits of a dedicated national space agency for Australia*, Defence SA, August, online.

Pollpeter K, Anderson A, Wilson J, Fan Yang 2015. *China dream, space dream: China's progress in space technologies and implications for the United States*, US–China Economic and Security Review Commission, Washington DC.

Pyne C 2017b. '$500 million for enhanced satellite capability', media release, Department of Defence, Canberra, 18 June 2017, online.

Pyne, Christopher 2017a. 'Space sensor research kicks off', media release, 29 September, online.

Rajeswari PR 2015. 'Japan's space policy shift reflects new Asian realities', *SpaceNews*, 23 February, online.

REI (Reaction Engines Inc.) 2018. *The future of high speed powered flight*, online.

Riordan P 2018. 'Military deal with Japan to counter China's might', *The Australian*, 13 January, online.

Rocket Lab 2018. *Electron*, online,

SA Government, Defence SA 2016a. *Space Innovation and Growth Strategy (South Australia): Action Plan 2016–2010*, online.

SA Government, Defence SA 2016b. *South Australian space capability directory 2016*, online.

Scott J 2014. 'The case for an Australian observation satellite', The Strategist, 29 April, online.

SCPRC (State Council of the People's Republic of China) 2016. *Full text of White Paper on China's space activities in 2016*, 28 December, online.

SIAA (Space Industry Association of Australia) 2017. *Advancing Australia in Space White Paper*, 21 March, online.

Singtel Optus 2013. *C1 satellite payload information*, 6th edition, October, online.

Sinodinos, Arthur 2017. 'Turnbull government to establish a national space agency', media release, 25 September 2017, online.

SPIG (Strategic Policy and Intelligence Group) 2016. *Space*, strategic policy document, Department of Defence, Canberra, June.

Stratolaunch 2016. 'Orbital ATK and Stratolaunch partner to offer competitive space launch opportunities', media release, 10 July, online.

Swartout MA 2016., CubeSat Database, St Louis University, June, online.

Tonn S 2016. 'How swarms of small satellites could revolutionize space exploration', *Stanford Engineering*, 4 October, online.

UNSW (University of New South Wales) 2017. *UNSW Canberra space research*, December, online.

UNSW Canberra 2017a. *RAAF invests $10 million in UNSW Canberra space missions*, 29 September, online.

UNSW Canberra 2017b. *Satellite formation flying*, October, online.

UQ (University of Queensland) 2015. 'Launching Australia into space', *UQ News*, 10 August, online.

US Government 2018. 'Department of Defense', *GPS.gov*, online.

USAF (US Air Force) 2012. *Wideband global SATCOM satellite*, 8 June, online.

USCESRC (US–China Economic and Security Review Commission) 2015. *Hearing on China and the evolving security dynamics in East Asia*, USCESRC, Washington DC.

VSS (Vector Space Systems) 2018. *Launch with Vector*, online.

Welle RP, Hinkley D 2014. 'The Aerospace Nano/PicoSatellite Program', presentation to In-Space Non-Destructive Inspection Technology Workshop, 15 July, online.

White House 2010. *National Space Policy of the United States of America*, 28 June, online.

Zillman, Stephanie 2017. 'Plan to launch rockets in NT being "seriously" considered, Chief Minister Michael Gunner says', *ABC News*, 4 November, online.

NOTES

1 Research Interviews: Department of Defence, Ms Glenva Parker, Global Strategy, Strategic Policy Branch, Strategic Policy Division, 18 February 2016 and 27 September 2016; Department of Industry, Innovation and Science, Ms Anne Byrne, 13 October, 2016; Mr Trevor Power, Department of Industry, Innovation and Science, 24 November 2016; Department of Defence, Group Captain Darren May, 30 January 2017; Department of Defence, Mark Riffel, Military Strategy Branch, 3 February 2017.

2 See UNSW (2017) and the Australian Centre for Space Engineering Research (ACSER).

3 UNSW Space Research has established SkyKraft, which is a commercial company dedicated to manufacturing satellites for government and other clients. See also Pyne (2017a), online.

4 See also Harrison et al. 2017:8, online.

5 See also ‘WGS’, *Gunter’s Space Page*, no date, online, and USAF (2012).

6 See also Henry (2017), online.

7 Planet, online; Digital Globe, online; Hawkeye 360, online.

8 See also ‘CubeSat’, *Gunter’s Space Page*, online, and *Nanosatellite and CubeSat Database*, online.

9 See ‘Biarri Point / Biarri Squad 1,2,3’, *Gunter’s Space Page*, online.

10 ‘Project Biarri defence CubeSat launched’, *Australian Defence Magazine*, 20 April 2017, online.

11 ‘Buccaneer CubeSat a defence space capability’, *Australian Defence Magazine*, 18 October 2016, online.

12 See also ‘The space report 2017’, *Space Foundation*, online.

13 Fleet, online, and Gilmour Space Launch Services, online.

14 Delta-V Newspace Alliance, online.

15 SkyKraft, online.

16 SpaceX, online; Blue Origin, online.

17 See Virgin Orbit, online.

18 See also Riordan (2018), online.

ACRONYMS AND ABBREVIATIONS

ACSER	Australian Centre for Space Engineering Research
ADF	Australian Defence Force
AGO	Australian Geospatial-Intelligence Organisation
BRI	One Belt, One Road Initiative
DWP16	*2016 Defence White Paper*
EqLEO	equatorial low Earth orbit
GDP	gross domestic product
GPS	Global Positioning System
ISR	intelligence, surveillance and reconnaissance
LEO	low Earth orbit
RAAF	Royal Australian Air Force
SIAA	Space Industry Association of Australia
SUP	satellite utilisation policy
UAV	unmanned aerial vehicle
UNSW	University of New South Wales
WGS	Wideband Global SATCOM

Australia's future in space

Australia is approaching an important window of opportunity to change our approach to the use of space for defence and national security purposes and, more broadly, to the establishment of a sovereign space industry. We now have the opportunity to move from a traditional policy of dependency on others to become an active space power—one with sovereign space capabilities in orbit and an active and growing space industry sector coordinated by an Australian space agency.

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