Journal & Proceedings of the Royal Society of New South Wales, vol. 153, part 1, 2020, pp. 46–57. ISSN 0035-9173/20/010046-12

Sixty years of Australia in space

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Abstract

Australia's involvement in space activities commenced in 1957, at the beginning of the Space Age, with space tracking and sounding rocket launches at Woomera. By 1960, Australia was considered one of the leading space-active nations and in 1967 became one of the earliest countries to launch its own satellite. Yet by 1980, Australia's space prominence had dwindled, with the country lacking both a national space agency and a coherent national space policy. Despite attempts in the latter part of the 1980s to develop an Australian space industry, the lack of a coherent and consistent national space policy and an effective co-ordinating body, left Australia constantly "punching below its weight" in global space activities until the Twenty First Century. This paper will briefly examine the often-contradictory history of Australian space activities from 1957 to the announcement of the Australian Space Agency in 2017, providing background and context for the later papers in this issue.

Introduction

For 60,000 years the Indigenous people of Australia have looked to the sky, using the stars to determine their location, find their way across the land and mark the passage of the seasons and the best times to undertake specific activities. Today we would refer to this as using space for 'position, navigation and timing'.

Sixty years ago, a new generation of Australians also looked to the sky: for both military and scientific reasons, they wanted to explore space to better understand the cosmic environment in which the Earth itself exists.

What we now refer to as the Space Age, commenced in 1957, when the Soviet Union launched the world's first satellite, Sputnik-1. This paper presents a brief overview (a 'speed dating' version, if you will) of the history of Australian space activities over the past 60 years, which will provide some context for the later papers in this issue.

Launchpad: the Woomera Rocket Range

> "*If the Woomera Range did not already exist, the proposal that Australia should engage in a program of civil space research would be unrealistic*". (NAA: A1945, 227/1/39)

This 1959 quote from the Australian Academy of Science highlights the crucial role played by the Woomera Rocket Range in the inception of space activities in Australia, although the establishment of the Range itself was unrelated to space research. Woomera was founded in 1947 as a weapons development and testing facility, primarily for the United Kingdom's long-range missile program (Morton, 1989). However, managed by the Australian Defence Scientific Service (ADSS),[1] Woomera's vast downrange areas and the specialised skills in missile technology, launch and precision tracking that had

1 The ADSS was the predecessor of the today's Defence Science and Technology Group.

been developed to support the weapons testing programs there, meant that the Rocket Range was ideally placed to become the hub of early space activities in Australia.

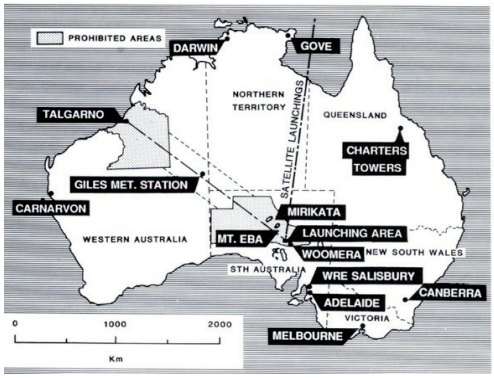

Figure 1: Location of the Woomera Rocket Range showing the extent of its downrange areas and satellite launching corridor.

The International Geophysical Year

The catalyst for Australian involvement in space activities was the IGY, or International Geophysical Year, a period of 18 months between July 1957 and December 1958 dedicated to a global scientific research program that focussed on the relationship of the Earth to its broader space environment (Doyle, 2012).

In 1955, both the United States and the Soviet Union, announced that they would attempt to launch a satellite during the IGY. Australia, and particularly the Woomera Range, were in the right place geographically and geopolitically to host tracking and data reception stations for the two networks that the United States wanted to construct around the world for its satellite program: the Minitrack radio interferometry tracking and data reception system; and the Baker-Nunn telescope tracking cameras (Tsaio, 2008). A Minitrack station was established at Woomera in 1957, followed by a Baker-Nunn camera observatory in 1958. These two facilities marked the beginning of Australia's long-term involvement in space tracking.

Space tracking in Australia

When NASA was formed in 1958, the two IGY tracking stations were transferred to the new agency. By 1969, Australia was playing host to the largest number of NASA tracking facilities outside the United States, supporting each of its three networks: The Deep Space Network, for robotic lunar and planetary exploration; the Manned Space Flight Network and the Space Tracking and Data Acquisition Network, for orbiting scientific satellites (Mudgway, 2002; Tsaio, 2008). Although funded by NASA, these stations were staffed and operated by local personnel, enabling direct Australian participation in the Unites States' space program.

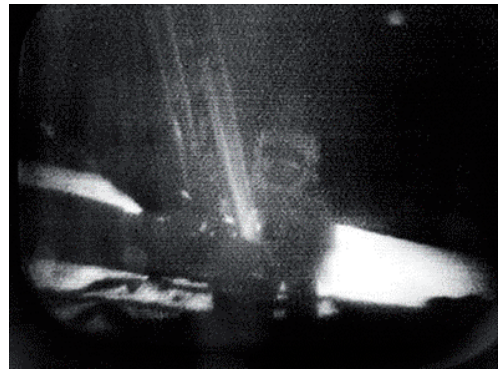

Figure 2: Armstrong stepping onto the lunar surface, as seen around the world via the Honeysuckle Creek tracking station.

The most significant space tracking event with which Australia has been involved to date was the reception of the television images of the first human mission to the lunar surface, Apollo 11. Commander Neil Armstrong's first step onto the lunar surface was received at NASA's Honeysuckle Creek

tracking station, near Canberra, while the majority of the Apollo 11 lunar television was broadcast to the world via the CSIRO Parkes Radio Telescope (Lindsay, 2001; Dougherty and Sarkissian, 2010).

One of the world's great astronomy instruments, the Parkes Radio Telescope has had a long association with NASA, assisting with its various space tracking programs. In the 1960s, its innovative design served as the prototype for the 64 metre antennae of NASA's own Deep Space Network (Sarkissian, 2001).

Today Australian involvement in space tracking programs and the exploration of the solar system continues. On behalf of NASA, CSIRO manages the Canberra Deep Space Communications Centre in the ACT. CSIRO also manages the European Space Agency's space tracking complex at New Norcia in Western Australia.

Sounding rocket programs at Woomera

Military and civilian interest in the nature of the Earth's upper atmosphere converged during the IGY, encouraging the development of sounding rockets, sub-orbital launch vehicles capable of carrying scientific instrument packages to the fringes of space, although not into orbit. Britain and Australia were among a handful of nations that developed sounding rockets during the IGY (Berkner, 1958; Doyle, 2012), both programs intended to support the missile research projects at Woomera as well as IGY scientific research. Several hundred British, Australian, European and American sounding rockets were launched from Woomera between 1957 and 1979 when the last of the sounding rocket programs ended (Dougherty, 2006).

The most significant sounding rocket program at Woomera, and the longest-lasting, was the British Skylark, first launched in 1957. Although Skylark's origins lay in defence research, it transitioned across the 1960s into a versatile tool for space astronomy (Brand, 2014). Among the research institutes to use Skylark were the Universities of Adelaide and Tasmania, which conducted ultra-violet and X-ray astronomy research that led to important discoveries in X-ray astronomy (McCracken, 2008).

The Weapons Research Establishment (WRE), the division of the ADSS directly responsible for the Woomera Range, developed Australia's first sounding rocket, the High-Altitude Research Program (HARP) in 1956. Although unsuccessful, the HARP rocket demonstrated Australian innovation with the earliest-known use of glass fibre reinforced plastic (fibreglass) in the space sector (Ordway and Wakeford, 1960; Dougherty, 2017).

HARP's more-successful successor, the Long Tom, paved the way for an extensive program of Australian upper atmosphere research, much of it conducted in conjunction with the University of Adelaide. The early WRE sounding rockets were Australian designed but composed of surplus British rocket motors. Across the 1960s, the Australian-made content of the WRE sounding rockets increased, with the first 'all-Australian' vehicle, Kookaburra, becoming operational in 1968 (Dougherty, 2006).

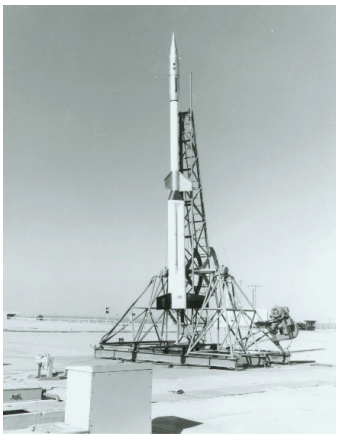

Figure 3: Long Tom, the first successful Australian sounding rocket developed by the Weapons Research Establishment.

Australia's first satellites

With its involvement in NASA space tracking and the sounding rocket programs at Woomera, by 1960 Australia was considered a leading spacefaring nation (Poirer, 1960). In 1967, the confluence of defence and scientific interest in the upper atmosphere that had helped launch Australia into space activities, enabled the development of its first satellite, Weapons Research Establishment Satellite-1, (WRESAT-1).

WRESAT's origins lay in a joint US/ UK/ Australia defence research program known as Project SPARTA (Special Anti-missile Research Tests, Australia), which was conducted at Woomera in the mid-1960s. Ten US Redstone rockets were brought to Australia for this program, but ultimately only nine were needed. The United States' SPARTA team generously donated the spare vehicle to Australia, so that the country could launch its first satellite (Morton, 1989; Dougherty, 2013).[2]

The WRESAT satellite was developed and constructed by the WRE, with the Physics Department of the University of Adelaide providing the scientific instrument package. This was designed to complement the WRE/ University of Adelaide sounding rocket program, providing a comparison from orbit to the data obtained via sounding rocket. (Lloyd, 1988; Dougherty, 2013).

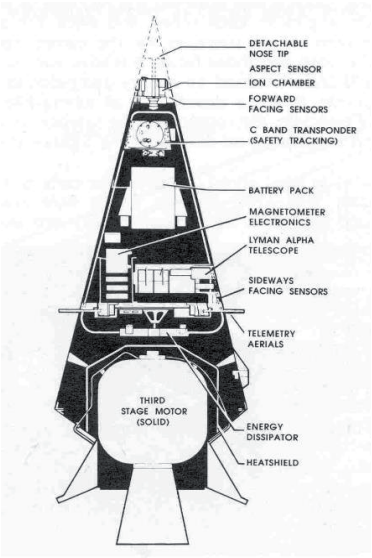

Figure 4: Cutaway view of WRESAT-1, showing its interior layout.

WRESAT-1's successful launch on 29 November 1967 gained Australia entry into the 'Space Club' as one of the earliest nations to launch its own satellite.[3] The battery-powered satellite operated successfully for five days, providing useful data for comparison with sounding rocket results.

2 Redstone vehicles had been used to put both the United States' first satellite into orbit, and its first astronaut, Alan Shepard, into space on a suborbital flight

3 Australia's place in the order of national satellite launches is a complex issue. It is more fully discussed in Dougherty, 2017

In 1968, the WRESAT team received Fairchild Australia's Planar Award for outstanding achievements in the Australian electronics industry. All those involved in the program anticipated that there would be further WRESATs. However, having gained the international kudos of a national satellite launch, the Gorton government had no interest in funding further satellites and WRESAT-1 was never to be followed by WRESAT-2 (Dougherty, 2013).

Although it was the first to be completed, being commenced in March 1966 (before WRESAT was even on the drawing-board), Australia's second satellite, Australis-OSCAR 5 was not launched until 1970. The world's first amateur radio satellite created outside the United States, Australis was the brainchild of a group of students at the University of Melbourne, who had been tracking the Project OSCAR (Orbiting Satellite Carrying Amateur Radio) amateur satellites. Its design incorporated several innovations for a small satellite, including the first use of a passive magnetic attitude stabilisation system and the first command system, enabling the satellite to be switched on and off, thus saving its limited battery power (Mace 2017).

After several delays in finding a launch for the satellite as part of Project OSCAR, Australis finally made it to orbit on 23 January 1970. It was designated OSCAR 5, as the first in a revived amateur radio satellite program under the newly formed Radio Amateur Satellite Corporation (AMSAT). Launched in conjunction with a NASA weather satellite, Australis-OSCAR 5's high orbit means that it will remain in orbit for approximately 1,000 years (Mace, 2017).

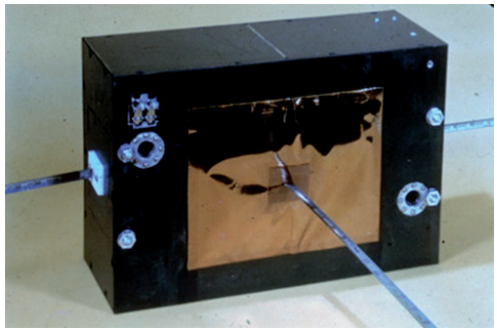

Figure 5: Australis-OSCAR 5 ready for launch. Note the antennae made from steel measuring tape.

Lift-off from Down Under: Europa and Black Arrow

In 1955, Britain commenced the development of Blue Streak, a medium-range ballistic missile intended to be tested at Woomera. The WRE undertook a massive extension of the Range and its facilities to accommodate the program. However, whilst in development, Blue Streak became essentially obsolete as a weapon and was cancelled in 1960. This resulted in serious embarrassment to the British and Australian governments (Morton, 1989; Hill, 2001).

In order to recoup its investment on the missile, the British government proposed it to European nations as the first stage of a collaboratively developed launch vehicle that would provide an independent satellite launch capability for Europe. Out of this proposal grew the European Launcher Development Organisation (ELDO). Britain provided the Blue Streak missile as the first stage for ELDO's new Europa launcher. France provided the second stage; West Germany the third stage and Italy developed the test satellite the vehicle would launch. Australia provided the launch pads at Woomera that had been originally developed for the Blue Streak missile, while Belgium and The

Netherlands provided the electronics and downrange tracking station at Gove, in the Northern Territory (Krige and Russo, 2000).

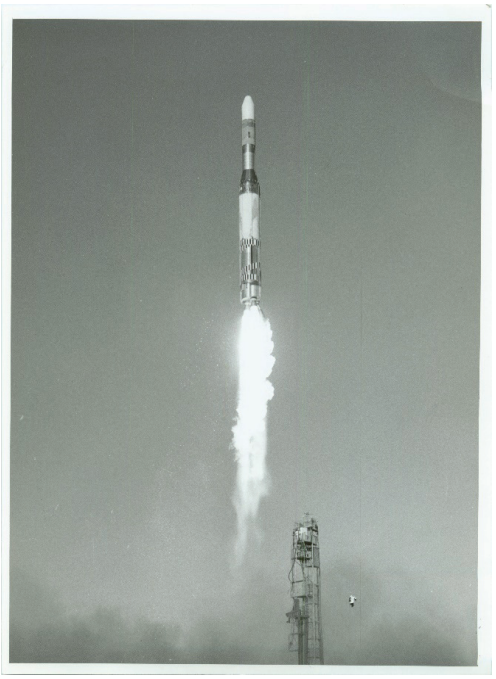

Figure 6: Europa F-8 ELDO launch from Woomera in November 1968.

Some critics considered this consortium approach to launcher development a recipe for disaster (Krige and Russo, 2000), and despite ten test launches from Woomera between 1964 and 1970, ELDO was never able to successfully launch a satellite from Australia. After Britain withdrew from ELDO in 1968, leaving France the dominant partner, the ELDO program was transferred to the French launch facility at Kourou, in French Guiana, in 1970. The program was, however, no more successful at Kourou and ELDO collapsed in the early 1970s (Krige and Russo, 2000; Hill, 2001). The European Space Agency (ESA), was born in 1975 from the ashes of ELDO, and it can be argued that it was understanding the mistakes made by ELDO allowed ESA to operate successfully and become one of the world's major space agencies.

After withdrawing from ELDO, Britain made one final attempt at developing its own satellite launch vehicle, designated Black Arrow. Derived from the reliable Black Knight defence research rocket used at Woomera for several years, the Black Arrow program was cancelled for financial reasons shortly before its fourth test launch. However, as the vehicle was ready, this launch was allowed to proceed.

On 28 October 1971, Black Arrow R3 successfully placed the Prospero satellite into orbit, the second satellite launched from Woomera. Despite this success, the Black Arrow program was not re-instated, and the United Kingdom remains to this day the only nation to have developed a satellite launch capability only to then give it up (Hill, 2001).

Australian adoption of satellite applications

The first applications satellites, so called because they apply the advantages of an orbital perspective to assisting with tasks on Earth, were launched by the United States in 1960. By the latter part of that decade, communications and weather satellites were beginning to become part of daily life, while Cold War militaries and maritime commerce were utilising the first navigation satellites.

Recognising the advantages of space applications for a vast and sparsely populated country, Australia was an early adopter of these satellite technologies. Today it is considered "one of the world's heaviest and most sophisticated users of space services" (CSIRO, 2015).

Australia became a founding member of the International Telecommunications Satellite (INTELSAT) consortium, which was created in 1964 to provide a global satellite telecommunications network. Australia would become INTELSAT's sixth-largest shareholder and play an important role in the control and monitoring of its satellites (Barrett, 1991).

Figure 7: The original Cassegrain horn antenna at the first Australian INTELSAT satellite Earth station in Carnarvon, Western Australia.

In the late 1970s, Australia also became a founding member and major shareholder of the INMARSAT (International Maritime Satellite) consortium (OTC, 1981), while Australia's first national domestic satellite communications system, AUSSAT, was established at the beginning of the 1980s. The first AUSSAT satellites were launched in 1985, but the system was privatised in 1992 to become the Optus communications company as a competitor to Telstra. INTELSAT and INMARSAT were also privatised within a decade of AUSSAT's privatisation, ushering in a new global telecommunications regime. (Dougherty, 2017).

The Bureau of Meteorology installed its first weather satellite image receivers at the beginning of 1964, which had an immediate and profound impact on weather prediction in Australia. The first satellite photo showing the whole of Australia in one image was received from NASA's Applications Technology Satellite-2 in 1967 (Griersmith & Wilson, 1997). Australian meteorologists have remained at the forefront of the interpretation and application of weather satellite information, and today receive data from Japanese, Chinese, NASA and NOAA (National Oceanographic and Atmospheric Administration) meteorological satellites to provide weather predictions and support climate change research (Dougherty, 2017).

Remote sensing, which uses satellites to look down on the Earth to understand and manage the environment and natural resources, was also a field in which Australia was an early adopter and an important pioneer (McCracken, 2008). Groups within CSIRO and the mining industry began using data from the Landsat-1 satellite not long after its launch in 1972. An archive of Landsat images of Australia was established in 1975, and the first Landsat receiving station outside the United States was opened near Alice Springs in 1980 (McCracken, 2008). Suitably upgraded, this facility now receives data from NASA, NOAA, French and ESA satellites, in addition to the Landsat series (Dougherty, 2017).

Management of early Australian space activities

Australia's initial involvement in space activities came about, not in response to a deliberate decision by the government to engage with space (as was the case with other nations), but as a result of external

factors (in the case of space tracking) and the perceived requirements of the defence sector (in the case of the sounding rocket programs). Consequently, there was from the outset, no government commitment to the idea of a national space policy or a co-ordinated national space program (Dougherty, 2017).

Proposals for the establishment of a national space program from the Australian Academy of Science and the WRE were rejected across the 1960s as too costly. (Dougherty, 2017). Neither the Menzies Government, nor its successors, saw the need to establish a national space program or invest in the space sector, beyond those space applications that would provide a national good benefit or support defence and national security (Dougherty, 2017).

Although there was some Cabinet level discussion in the early 1960s about allocating the management of Australian civil space activities to a single government department or entity such as the CSIRO, bureaucratic infighting brought these proposals to nought (Dougherty, 2017). The WRE, with its management of Woomera, the NASA tracking stations and the Australian sounding rocket program, effectively became a de facto space agency, although the Bureau of Meteorology, OTC and CSIRO continued to manage their own space-related activities independently.

Consequently, when Britain decided in 1970 that it would cease weapons testing at Woomera in 1980, there was no space sector 'authority' to argue against the Australian Government's decision to cease the sounding rocket program and wind the Range down, since it had no particular use for the facility.

This resulted in a doldrums period from 1975 until the mid-1980s, by which time the development of the AUSSAT satellite system had sparked a new interest in developing a national space industry.

Making Space for Australia

The establishment of AUSSAT, coupled with a growing use of space applications (particularly remote sensing), generated a new enthusiasm in Australian industry for the possibility of becoming a major supplier, or even prime contractor, to future generations of AUSSAT or other national satellites.

In response, the CSIRO Office of Space Science and Application (COSSA), was established in 1984 and quickly became a driving force in developing Australia's expertise in remote sensing. (McCracken, 2008). Under COSSA's leadership, three remote sensing instruments were developed that flew successively on European remote sensing radar satellites ERS-1 (launched 1991), ERS-2 (launched 1995) and Envisat (launched 2002) (Dougherty, 2017).

The Hawke government commissioned a report from the Australian Academy of Technological Sciences, into whether Australia should establish a space industry. The outcome of the Academy's review was presented in the 1985 report *A Space Policy for Australia*, also known as the *Madigan Report*, after the Chair of the working committee, which put forward the basis for a comprehensive national space policy. It recommended that a national space agency should be established, to support the development of a national space program and a local space industry.

The Hawke Government, however, did not fully adopt the report's recommendations. Although it created the Australian

Space Office (ASO) in 1987, this was not an independent agency, as recommended by the report, but a unit with the Department of Industry, Technology and Commerce, specifically focussed on developing an Australian space industry: Its slogan was "Making Space for Australia". The ASO was also critically underfunded for the tasks required of it, having an annual budget of around $4 million, instead of the $25 million recommended in the report (Madigan, 1985).

Figure 8: The Endeavour Space Telescope (in cylinder front left) in the cargo bay of the Space Shuttle.

Despite these drawbacks, the ASO had some small successes, the best known of which was the Endeavour Space Telescope. Funded by the ASO, the Endeavour telescope was built by a new Australian space company, Auspace, that was spun out of research at the Mt. Stromlo Observatory. When first conceived, Endeavour was a cutting-edge ultraviolet space telescope. However, its space qualification flight on the US Space Shuttle was delayed as a result of the *Challenger* accident in 1986. By the time it had made two qualification flights, in 1992 and 1995, other instruments had already surpassed its performance and the opportunity for commercialisation was lost (Dougherty, 2017).

Commencing in 1986, several proposals were put forward for the development of a commercial spaceport in northern Australia, to gain a foothold in the lucrative satellite communications industry. Large satellites required launch facilities near the equator in order to place them in geostationary orbit. In addition, it was hoped to capture some of the multiple launches that would be required to service the multi-satellite constellations (some proposed to number many hundreds of satellites) in Low Earth Orbit that were planned for early mobile phone networks.

Locations on Cape York, around Darwin, and on various islands to the north of Australia or in Papua New Guinea were proposed, many planning to use newly available cheap Russian launch vehicles. However, none of these projects ever came to fruition came to fruition, nor did other proposals promoting the revival of Woomera as a launch site for polar-orbiting satellites.

Lost in space?

When the Howard Government came to office in 1996, it terminated the ASO and all its space-related projects, as the new government's view was that the space sector was like other high-technology industries and it was not necessary to allocate specific support for the development of a local space industry. It did, however, pass the Space Activities Act in 1998, the world's first formal legislation specifically covering commercial space launch operations. This provided a legislative framework under which proposals for commercial launch facilities could be regulated (Siemon and Freeland, 2010).

In addition to terminating the ASO, in August 1996 the Howard Government also restructured COSSA, creating from it a new Co-operative Research Centre for Satellite Systems, responsible for a new small satellite program, FedSat (Federation Satellite). FedSat was designed to build on existing national research experience and industry capabilities through the production of a small demonstrator satellite as a celebration of the centenary of Australia's Federation. Although construction delays meant that FedSat was not launched until 2002, the project was a modest success, with the satellite functioning until 2007 (Dougherty, 2017).

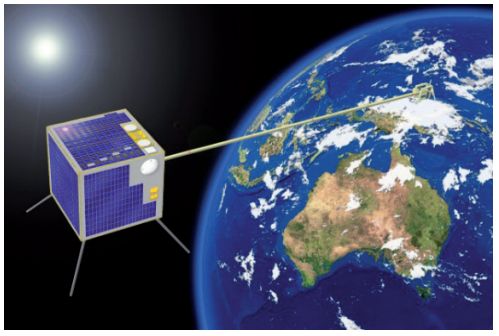

Figure 9: An illustration of FedSat in orbit above Australia.

Despite the FedSat project, the Australian civil space sector languished in the early 2000s, prompting one commentator to lament that Australia was "punching below its weight" in space activities (Kingwell, 2005). A growing call from the struggling Australian space sector for a national space policy and a national space agency, eventually led the Senate's Standing Committee on Economics to review the state of Australia's space science and industry sector. The outcome of this review was the 2008 report *Lost in Space? Setting a New Direction for Australia's Space Science and Industry Sector*. Like the earlier *Space Policy for Australia* report, it recommended the creation of an Australian space agency and a co-ordinated national space policy (Siemon and Freeland, 2010).

The Rudd Government, while not fully embracing the report's recommendations, established the Australian Space Research Program (ASRP) in 2009, which allocated $40 million to support technology demonstrator and education projects that could lead to viable economic programs for utilising space to the benefit of Australia.

Some of the projects supported by the ASRP did go forward to further commercial development. It also enabled the growth of Australia's now-recognised expertise in space situational awareness. In 2013 Australia's first formal space policy, the narrowly focussed *Australia's Satellite Utilisation Policy,* was released under the Gillard Government (Dougherty, 2017).

However, the ASRP was terminated and the Satellite Utilisation Policy left in limbo when the current Liberal government came to office in 2014.

The New Space Paradigm

Around the beginning of the last decade, a new space paradigm emerged. Sometimes referred to as NewSpace or Space 2.0, this entrepreneurial movement has been inspired by commercial space pioneers such as Elon Musk and Jeff Bezos and driven by young entrepreneurs who want to take advantage of modern miniaturisation and digital technologies. Over the past decade or so, these technologies have revolutionised what can be accomplished in space with relatively small budgets, enabling the production of very small, cheap, effectively expendable satellites that can be launched on light, cheap launchers. Satellites the size of a loaf of bread now offer capabilities that

previously required a multi-billion dollar satellite launched on a multi-billion dollar rocket (Dougherty, 2017).

This Space 2.0 paradigm has been adopted very rapidly by the entrepreneurial space community in Australia. While some local NewSpace companies have already flowered and died, as is the nature of start-ups and entrepreneurial companies, others are now well established and forming part of Australia's 'new space age', with satellites in orbit and commercial products in the marketplace.

This rapid transformation of the civil space sector, with its entry costs now significantly lower than in previous decades, provides real opportunities for a wide range of Australian companies, especially small and medium enterprises, to become involved in the global space industry. The realisation that the Australian economy was failing to capture a significant share of a global space industry worth approximately $350 billion in 2017 (Bryce, 2017) led to a reappraisal of Australian space engagement by the Turnbull Government. It came to recognise the need for a national space agency to act as a 'front door' to the world for the Australian space sector.

Consequently, at the 2017 International Astronautical Congress in Adelaide, the government announced its intention to form the Australian Space Agency (Sinodinos, 2017), which came into being on 1 July 2018.

After sixty years that have seen the Australian space activity wax and wane, lacking policy direction and effective coordination, the formation of the Australian Space Agency offers the opportunity for this country to enter into a new era of Australian space activity, which has the potential to far surpass any previous achievements.

Acknowledgements

Figures 1, 3, 4 and 6 are original WRE photographs and diagrams provided by Defence Science and Technology Group. Figure 2 photo of monitor at Honeysuckle Creek tracking station by Ed von Renouard, courtesy of www.honeysucklecreek.net. Figure 5 courtesy of Owen Mace. Figure 7 photo by Graham Watts; courtesy of www.honeysucklecreek.net. Figure 8 NASA. Figure 9 courtesy of Glen Nagle.

References

Barrett, W. (1991) "OTC's involvement in space", *Proceedings of the International Aerospace Congress and Sixth National Space Engineering Symposium, Melbourne*, Institution of Engineers Australia, Canberra, Australia, 1–11.

Berkner, L. (ed). (1958) *Annals of the International Geophysical Year, volume VI: Manual on rockets and satellites*. Pergamon Press, London, UK.

Brand, R.H. (2014) *Britain's first space rocket: the story of the Skylark*, New Forest Electronics, Fordingbridge, UK:

Bryce Space and Technology (2017) *Global Space Industry Dynamics*, Research Paper for the Department of Industry, Innovation and Science, Australian Government.

Commonwealth Scientific and Industrial Research Organisation (CSIRO) (2015, 15 June), *Deal with Europe blasts Australia into the space economy* [press release].

Dougherty, K. (2006) "Upper atmospheric research at Woomera: the Australian-built sounding rockets," *Acta Astronautica*, 59, 54–67.

Dougherty, K. (2013) "WRESAT: Australia's first satellite," in Harlow, J. (ed.) *History of Rocketry and Astronautics*, vol. 39, American Astronautical Society/Univelt, San Diego, CA, USA, 237–260.

Dougherty, K. (2017) *Australia in Space*, ATF Press, Adelaide, Australia.

Dougherty, K. & Sarkissian, J. (2010) "Dishing up the data: The role of Australian space tracking and radio astronomy facilities in the exploration of the solar system," in Ciancone, M. (ed.). *History of Rocketry and Astronautics*, vol. 33, American Astronautical Society/ Univelt, San Diego, CA, USA, 285–314.

Doyle, S. E. (ed.) (2012) *The International Geophysical Year: Initiating International Scientific Space Co-operation*, International Astronautical Federation, Paris, France.

Griersmith, D. & Wilson, J. (1997) "Satellite meteorology", in Webb, E. (ed.) *Windows on meteorology: An Australian perspective*, CSIRO, Melbourne, Australia 253–274.

Hill, C. (2001) *A Vertical Empire: The History of the UK Rocket and Space Programme, 1950–1971*, Imperial College Press, London, UK.

Krige, J. & Russo, A. (2000) *A History of the European Space Agency, 1958–1987, vol. 1 — ESRO and ELDO, 1958–1973* (ESA SP-1235), European Space Agency, Noordwijk, The Netherlands.

Kingwell, J. (2005) "Punching below its weight: Still the future of space in Australia," *Space Policy*, 21, 161–163.

Lindsay, H. (2001) *Tracking Apollo to the Moon*, Springer-Verlag, London, UK.

Lloyd, K. (1988) *Upper Atmosphere Research*, Australian Government Publishing Service, Canberra, Australia.

McCracken, K. (2008) *Blast off: Scientific Adventures at the Dawn of the Space Age*, New Holland, Sydney, Australia.

Mace, O. (2017) *Australis-OSCAR 5*, ATF Press, Adelaide, Australia.

Madigan, R. (1985) *A Space Policy for Australia: A Report Prepared for the Minister of Science by the Australian Academy of Technological Sciences*, Australian Academy of Technological Sciences, Melbourne, Australia.

Morton, P. (1989) *Fire Across the Desert: Woomera and the Anglo-Australian Joint Project, 1946–1980*, Australian Government Publishing Service, Canberra, Australia.

Mudgway, D. (2002) *Uplink–Downlink: a History of the Deep Space Network, 1957–1997* (NASA SP 2001–4227) National Aeronautics and Space Administration, Washington DC, USA.

National Archives of Australia: Department of Defence (III), Central Office; A1945, Correspondence files; 227/1/39 Australian Space Research Programme, 1960; "Cabinet agendum on space research prepared by D. Cameron, Minister in Charge, CSIRO, 9 June 1960" NAA: A1209, 1958/5710;.

Ordway, F.I. & Wakeford, R.C. (1960) *International Missile and Spacecraft Guide*, McGraw-Hill, New York, NY, USA.

Overseas Telecommunications Commission (OTC) (1981) *Annual Report 1980/81*. Overseas Telecommunications Commission, Sydney, Australia.

Poirier, B. (1960) "Four nations lead foreign progress," *Missiles and Rockets*, October 3, 25.

Sarkissian, J. (2001) On *Eagle*'s wings: The Parkes Observatory's support of the Apollo 11 mission, *Publications of the Astronomical Society of Australia*, 18, 287–310.

Siemon, N. & Freeland, S. (2010) "Regulation of Space Activities in Australia," in Jahku, R. (ed.) *National Regulation of Space Activities*, Springer Science & Business Media, Berlin, Germany.

Sinodinos, A. (2017, September 25) *Turnbull Government to Establish National Space Agency* [press release].

Tsaio, S. (2008). *Read You Loud and Clear: The Story of NASA's Spaceflight Tracking and Data Network* (NASA SP 2007–4232), National Aeronautics and Space Administration, Washington, DC, USA.