Rapid Response Information Report

1 July 2021

What are the growth areas in domestic STEM skills to support jobs in the space industry, and how can these be addressed by the tertiary (university and relevant VET) sector?

Summary

- Through significant growth in the number of people with scientific, engineering and technical skills, Australia can develop, operate and support space systems and meet the Australian Government's goal through the creation of 20,000 new jobs in the space sector over the next decade.
- Skills in human factors, including cognition, performance, decision-making, governance frameworks, law, regulation and ethics, and engaging with space technology and its applications, will also be beneficial.
- Of the 319 skills used in the space industry in Australia, a recent survey found that all but nine are experiencing some level of shortage. Current tertiary education approaches are to concentrate on producing graduates with a wide range of generic but transferable STEM skills, rather than space-specific skills, and may provide a mechanism to meet current skill shortages.
- Skill shortages are affecting the space industry globally and represent potential growth areas for Australia as a provider of skills training.
- 10-15 university-based specialist training centres focused on space skill development are emerging. Skills development also occurs in the public sector through targeted defence and strategic capability building.
- Most specialist skills training is performed on the job in the industry locally or overseas. To deliver 20,000 new space-related jobs by 2030, around 300 new qualified scientists and 900 engineers, as well as 800 non-STEM graduates, are required to be trained each year for a decade.
- Australia has a solid base for space research in universities, public research agencies and private institutions, which can help supply the industry with a skilled workforce.
- Engaging education and training providers in workforce and training planning can assist in addressing the needs of the space industry.

Workforce planning and development have been identified as a top strategic risk to the ongoing growth of the Australian space industry.[1] Australia's space industry has difficulties attracting and retaining the required skilled workforce and building the requisite international partnerships to enable ongoing growth.[2]

Paraphrasing the Australian Government definition, the Australian space industry is: *a set of space-related activities along the space value chain. It is part of the broader space economy. It includes all actors (private, public and academic) participating in the production, operation, supply and enablement activities for the space sector. It does not include non-space activities such as food production using precision agriculture techniques.*[3]

What skills are needed to support jobs in the Australian space industry?

The Australian space industry will benefit from a broad range of skills, including science, technology, engineering and maths (STEM) and humanities, arts and social sciences (HASS) skills, such as:

- technical skills (for jobs in engineering, design, programming, aeronautics, fabrication, cyber security, and robotic and autonomous systems)
- operational skills (machining, data analysis, navigation, satellite control, remote operation, situational awareness, electrical and mechanical technicians, and space safety)
- support skills (visualisation, communication, management, regulation, law, space medicine and habitat design, sales and marketing, policy, research and research commercialisation)
- downstream skills (data science, artificial intelligence and machine learning, real-time signal image and video processing and translation to other industries).

This year, the SmartSat Cooperative Research Centre (CRC), supported by the Australian Space Agency, undertook an analysis providing evidence of space skills supply gaps.[4] 319 skills were identified as being used in the space industry, of which nearly all are currently experiencing some level of shortage. In addition, 86 were identified as skills requiring attention due to current shortages or imminent demand or insufficient training provider capacity.[4]

It is not possible to accurately quantify the skills demand based on current information. As far as can be determined, the SmartSat analysis is the only space industry job skills taxonomy in existence globally.[4] Moreover, the economic and occupational data on the space sector in isolation from other, more traditionally distinguishable sectors, is relatively poor – given that current statistical definitions do not recognise space as a discrete sector. This is due in part to the small scale of the industry and its high crossover with related industries such as transportation, instrumentation, communications equipment, navigation equipment, and software and business services.[5–7]

A growing space sector will likely draw on skills in fields where Australia already has strong capability, such as autonomous robotics and remote sensing in the mining industry.[8–10] Australia's expertise in medical research and remote-area medicine could be leveraged into a space life science sector, with flow-on benefits for telehealth, general practice in low-resource environments and improved health management in low physical activity environments.[11,12] Australia's strong astronomy and astrophysics research base can transfer many of its skills and technologies to the space sector.

Many of the skills required are generalist and transferable. The SmartSat CRC identifies 46 skills that are "…abilities that improve human performance and facilitate effective interactions between people".[4] These skills include interpersonal, leadership and communications skills, as well as creativity, decision-making, adaptability and self-management. These skills are not considered to be in shortage, but there is a "pervasive and ubiquitous" requirement for these skills to be applied in the space industry, as in all industries.[4]

These findings are mirrored in international jurisdictions growing their space industry capabilities.[13–16] Well established space agencies, like NASA, are reporting both persistent skills shortages and the lack of a STEM and HASS workforce, as well as concerns about a wave of generational retirements.[16] The UK Space Agency, despite a mature space industry, reports skills shortages for software and other engineers, as well as in artificial intelligence and machine learning.[13] For the Scottish space industry, studies highlight the importance of both regional and national level funding for skills development.[17]

Table 1 presents a schema, based on interpretation of the SmartSat CRC report, with informed contributions from the listed experts of likely skills required by tertiary qualification level. The skill requirements listed do not infer the quantity required. It provides an indication of possible skill needs across Australian Qualification Framework (AQF) levels. This is not an exhaustive listing of skills needs for the sector and does not consider all transferrable skills such as, for example, fabrication and machining known to be integral to space manufacturing.

Table 1: Skill requirements by AQF level.

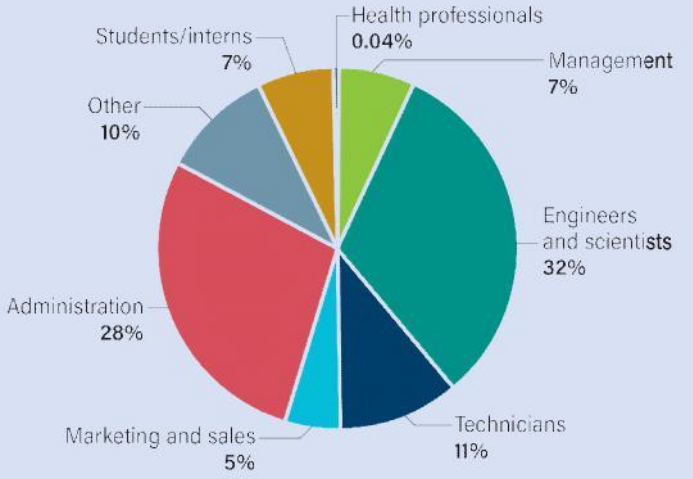
	Vocational (AQF 1 to 6)	Degree (AQF 6 to 8)	Higher Degree (AQF 9 to 10)
Manufacturing and core inputs	• Engineering drawing • IT support (software, networks, clouds, software as a service) • Electronics technical support • Optoelectronics technical support • Radiofrequency technical support • Mechanical engineering technical support	• Physics • Mathematics • Electronic and electrical engineering • Mechanical/aerospace engineering: • Computer science incl. software engineering, networks, cyber security	• Systems engineering, integration and testing • Manufacturing systems engineering • Software defined system design and development • Modelling and simulation technology • Sensor design and development • Accurate timing technology and systems • Thermal and radiation effects and processes
Space operations	• Modelling support • IT support (software, networks, clouds, software as a service) • Electronics technical support • Optoelectronics technical support • RF technical support • Mechanical engineering technical support	As above, plus: • Psychology • Neuroscience • Law • Contracting • Research and professional ethics • Social sciences, including international relations, public policy and management	• Operations and systems analysis • Reliability and risk analysis • System design, analysis and control • Robotic and autonomous systems • Detection and tracking systems design • Data, telemetry and communications link design and development • Satellite monitoring and maintenance • Spectrum security • Information and cyber security
Space Applications	• IT support (software, networks, IoT) • Information management support • GIS technical support • Electronics technical support • RF technical support	As above, plus: • Systems and application programming • Environmental protection • Health and welfare • Geophysics • Geography	• Signature measurement and modelling • Geospatial information algorithm and system (GIS) development • Signal, image and video processing • Data analytics • Systems analysis and engineering • Modelling and simulation • Information management and security

Skills development in the Canadian space sector and Australia

Canada has a similar population, GDP, economic structure and political system and is often used as a comparator with Australia.

In 2018 the Canadian space sector's workforce numbered just under 9,600 full-time equivalent (FTE), of which 61% were STEM qualified, and 64% had a bachelor's degree or higher. One-third of the workforce comprised engineers and scientists. This workforce was evenly divided between upstream (R&D, manufacturing and launch) and downstream (space infrastructure, Earth observation) sectors and supported another 11,300 jobs in the broader economy.[18]

For Australia to meet the Australian Civil Space Strategy target of 20,000 new space-related jobs by 2030, extrapolation against the structure of the Canadian space industry shows 61 percent of the new jobs will require STEM degrees, in occupations as engineers and scientists, managers, marketing, administration and others. In addition, 800 non-STEM graduates will be needed annually.



Occupation types in the Canadian space industry (% of total)
Source: Canadian Space Agency, State of the Canadian Space Sector, 2019

When traditional levels of international recruitment resume, there is potential for a small proportion of specialists to be recruited from overseas. Opportunities also exist to recruit domestic students at the tertiary level.

Defence is a significant driver of space skills

Defence and strategic capability are core to the Australian space sector. Defence is currently the major developer and user of a skilled space workforce.[19] The *2020 Defence Strategic Update*, for example, announced a budget of $7 billion over 10 years for strategic space defence and $3 billion for geointelligence[20], dwarfing public investment in civil space capabilities at this time. Defence relies on training STEM graduates and postgraduates in the necessary skills as a critical mechanism to furnish the defence space capability.[21]

Space is a 'dual-use' sector, with defence and civil applications often operating together. There are synergies and opportunities for cross-fertilisation between defence and civil space – in terms of capability, access to research and infrastructure, critical materials, need for standards, specialised skills and attracting staff.[22]

HASS skills

There is a role in the space industry for HASS, such as anthropology, archaeology, philosophy, ethics, sociology, tourism, languages, law, architecture and the creative arts especially due to Australia's partnership with NASA on the Moon to Mars mission. These fields offer methods and theories about how people accept, use and interact with space technology, systems and environments, which feed into effective mission research and design, exploration and discovery, technical development and communication and service delivery.[23] Direct applications of anthropological, archaeological and ethnographic work are the study of remote area communities and adaptations to analogous environments.[24–31] These include Antarctic research stations, remote telescope sites, remote mining camps, underground habitations, offshore and undersea operations and other analogue environments (for example, the Pilbara).

Space operations occur in an international regulatory and legislative context, and Australian space law, foreign policy and international relations expertise are necessary to address space-based international issues. For example, the proliferation of satellite constellations, and their impact on optical and radio astronomy, is increasingly driving a need for planning, regulation and risk mitigation.[32]

Gender and diversity in the space industry

Diversity is a significant consideration for a successful space workforce utilising all of the nation's available talent[33]; for example, 20% of Australia's current space research industry workforce is female, mirroring low STEM gender and cultural diversity observed in disciplines such as physics and mathematics.[34–37] There are very few Indigenous people in the space sector.[38] Programs such as the Indigenous-led ground station in Alice Springs[39], supported by Indigenous Business Australia, seek to develop the Indigenous workforce and capture existing Indigenous knowledge and expertise.

How are Australian space industry skill needs currently being addressed?

Employers in civil space – both public and private – rely on acquiring specialist space expertise locally and from overseas, from amongst university PhD and Masters graduates or generalist STEM graduates with transferable skills. Often recruits need to be skilled up by employers.[4]

56% of respondent organisations surveyed by the SmartSat CRC recruit people locally with relevant general skills and train them internally in the specialist area. 46% recruit specialists from overseas. However, overseas space programs have also reported shortages in critical fields, placing increasing demand on the global space workforce.[13, 16]

Tertiary education (university and VET sector) responses have been concentrating on producing STEM graduates rather than specialists at the undergraduate and VET levels. This reflects a system concentrating on the provision of foundational skills. Industry and vocational education providers have been providing specialised training alongside an emerging domestic university capability in higher degree space courses.

What is the role of vocational education and training (VET) in addressing the skills requirements of the space industry?

Space is a relatively new industry in Australia, and there are very few bespoke VET training courses. VET training provision is industry-led. In the space industry, demand from either defence or inclusion of space-applicable occupations in national or state/territory skills-needs lists helps guide training provision in VET. There are, at present, no space industry-specific courses listed on myskills.gov.au. VET offers training options that could be used to pursue a career in the space industry, such as drone piloting,[40]

robotics,[41,42] electronics, and communication engineering[43] and computer systems engineering.[44] VET has developed capabilities relating to the aerospace and defence industries. For example, in Western Australia, Southern Metropolitan TAFE has existing programs in the automation of heavy automotive, light automotive and mine-site equipment. The design, prototype and application of sensors for data analysis could be suitable for space industry needs and space technologies in aligned industries.[45]

States and territories are investing in generic STEM education programs across the education sector, which develops a skilled workforce and can provide employment pathways to the space industry.[46] This investment supports the acquisition of foundational STEM skills that can be pivoted to meet space (and other STEM related industry) needs.[47]

In Australia, the extent of demand for a VET qualified workforce met by offering space-specific courses, as distinct from general STEM training, is unknown. For example, in the UK it has been estimated that 20% of space industry jobs are technical.[48] The US Bureau of Labour Studies estimates that 15% of job openings in the decade between 2014 and 2024 would be for technicians.[49]

How is the university education sector addressing the skills needs of the space sector?

The university sector currently supplies STEM-literate graduates and specific high-level skills. Bachelor level graduates have increased in some fields of interest but decreased in others (Table 2).

Table 2: Undergraduate completions in space skills area (2015-2019)[50]

DOMESTIC STUDENT COMPLETIONS						
	2015	**2016**	**2017**	**2018**	**2019**	**Change 2015-2019 (%)**
Mathematics/mathematical sciences	307	324	350	371	497	+62%
Physics/physics and astronomy	125	85	109	95	83	-34%
Mechanical/aerospace engineering	1190	1167	1214	1174	934	-22%
Electronic and electrical engineering	705	693	810	949	980	+39%
Computer science/information technology	3536	3542	3837	4084	4404	+25%
Psychology	4787	4892	4911	5258	5402	+13%
Neuroscience	570	626	611	568	495	-13%
Geophysics	6	5	9	5	5	-17%
Geography	21	11	5	5	6	-71%

The university sector also supports short-term upskilling. The University of South Australia has a short intensive course run in collaboration with the International Space University (France) since 2011.[54] The Australian National University, as an example, recently introduced an executive 'pathfinder' course, introducing people from many sectors to the space industry, and short credentialed courses in relevant skills such as data analytics and data engineering.[51,52,53] This is part of a pivot among universities to address short-term, high-tech skills gaps, with university consortia forming to offer rapidly developed courses to meet the needs of stakeholders across all elements of Australian space, including defence, civil, commercial, manufacturing and services sectors.

Around 10-15 space training centres have been identified by a desktop scan in Australian universities,[55–57] as well as new degree offerings,[58,59] advanced training centres,[60] industry PhD scholarships and internships[61–66] and research initiatives[67–68] – although these capabilities are small and discrete.

Existing advanced research capabilities also develop specialist skills needed in the industry through the training of PhDs. Australian space and planetary science, in citations, is ranked equal with Japan at 8th globally, comparable to Canada and well above China and Russia.[69] Australia contributed to 7% of the world's publications in space science between 2013 and 2017.[70]

How can Australian space industry skills needs be satisfied?

The VET and university degree systems are designed to respond to industry and student demand, though the pipeline can take time to develop. Micro courses, micro-credentialing and non-accredited executive training, may offer options to fill this gap.[71] There have been some interventions promoting space industry specific skills formation targeting higher degree skills and space education and inspiration more broadly, including:

- In 2017 the Australian Research Council funded the **ARC Training Centre for Cubesats, Uncrewed Aerial Vehicles, and Their Applications (CUAVA)** to train the next generation of workers in cutting edge advanced manufacturing, entrepreneurship, and commercial space and uncrewed aerial vehicle applications.[60]
- The **SmartSat Cooperative Research Centre**, a consortium of universities and other research organisations, is partnering with industry to develop advanced telecommunications and IoT connectivity, intelligent satellite systems and Earth observation next-generation data services.
- The **International Centre for Radio Astronomy Research** (ICRAR) is a joint venture between the University of Western Australia and Curtin University, supported by the WA state government. Primarily focused on astrophysics, Centre expertise can also be applied to space situational awareness and the development of passive sensors for spacecraft. Importantly, it co-locates expertise in engineering, astrophysics, data science and sensor communications.
- Opened in 2021 in Adelaide, **the Australian Space Discovery Centre** is a national facility where people can learn about space and Australia's role. It includes a careers hub, an operational mission control centre, a space gallery, and information on STEM education options.
- Since 2015, **Defence, Science and Technology** group (DSTG) has run a STEM Cadetships program that has recruited 80 high-performing STEM students direct from university into Defence, some of whom will work in space science.
- In 2021, the Australian Research Council **Industrial Transformation Research Program** has identified space as one of nine priorities for funding commencing in 2022.

The above initiatives lack scale. However, the creation of the Australian Space Agency, the identification of space as a national manufacturing priority, the strategic space defence initiative, construction approval for the Square Kilometre Array and cooperation with NASA on space exploration through the Australian Space Agency Moon to Mars initiative, are all expected to provide the sector with confidence to maintain effort and investment. The Australian Civil Space Strategy, coupled with the space industry strategies recently released by NSW, South Australia and Queensland to strengthen and grow their local industry, provides opportunities to engage education and training providers in workforce planning.

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Conflicts of interest declaration

This briefing incorporates input from Australian experts directly involved in research on Australia in space. Many of these contributors and reviewers have worked directly on studies and reports cited in this briefing. Contributors and peer reviewers are drawn from a range of institutions, initiatives and fields, and collectively provide an independent and authoritative perspective on this topic.

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