

AUSTRALIAN SPACE

OUTLOOK

2020 EDITION

INTERVIEWS

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MINISTER FOR INDUSTRY,
SCIENCE AND TECHNOLOGY

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ANTHONY MURFETT

DEPUTY HEAD,
AUSTRALIAN SPACE AGENCY

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JAMES MORHARD

DEPUTY ADMINISTRATOR, NASA

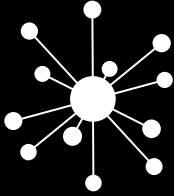
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**US/AUSTRALIA SPACE
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ARTEMIS & MOON TO MARS

**SPACE SITUATIONAL
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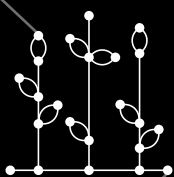
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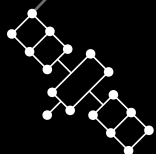
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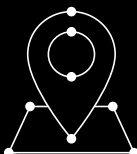
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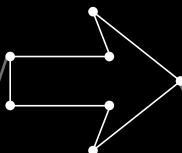
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AUSTRALIAN SPACE

OUTLOOK

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AUSTRALIA'S
NORTHERN
TERRITORY

**THE
TERRITORY**
BOUNDLESS POSSIBLE



The Hon Karen Andrews MP

Minister for Industry, Science and Technology

Space inspires a sense of wonder about the endless possibilities of what is outside our world as we know it. There are exciting discoveries to come and new dimensions to be explored.

But space also means business.

That is why the Coalition Government established the Australian Space Agency in July 2018 and has invested almost \$700 million in the space sector since 2018.

Industrial opportunities are growing rapidly. The global space sector is forecast to exceed \$1 trillion dollars in value by 2040 and we want to ensure that Australian businesses and people reap the rewards.

Australian businesses are already doing well in space, but we want them to soar further to achieve our ambitions. To do this we are creating strong international and national connections, building upon our strengths, filling in infrastructure gaps and providing commercial support.

The next exciting frontier is the \$150 million Moon to Mars initiative which will accelerate the growth of the national space sector by providing opportunities for Australian businesses to enter international supply chains, increasing demand for new capabilities, creating inspiration and enabling spin-out technologies for economic growth. This funding is focused here in Australia to support business, academia and researchers to participate and demonstrate Australian capabilities on a global scale.

By leveraging our competitive strengths, addressing our challenges and engaging with risk, we aim to triple the size of the national space economy to \$12 billion and create another 20,000 jobs by 2030, with further jobs and economic growth from spill over effects.

Our strengths in advanced communications, robotics and automation make our lives easier and help in times of need. From Earth observation technology helping emergency workers plan for bushfires and farmers manage their crops, to optical communications and precision health improving connectivity and service delivery for rural and remote communities. Our investments in space will also result in new technologies that will improve our lives here on Earth.

Education at all levels is central to our efforts to build our space industry, particularly the study of STEM subjects. Opening in early 2021, the Australian Space Discovery Centre in Adelaide will be the epicentre of activity, providing STEM education, engagement and inspiration for Australians, and helping grow a future high-tech workforce.

As the sector grows, space is becoming accessible to more and more people. Australia's space industry will embrace the work of traditional trades through to advanced manufacturing. Metal fabricators and electricians working on equipment and systems for space craft, space stations and satellites have a key role to play in the space industry, as do robotics engineers and data scientists supporting space activities and infrastructure.

To ensure the space industry transforms and thrives, collaboration across government, industry and the research sector is essential. The Morrison Government is determined that our nation will be at the forefront of developments in space technology and that we all experience the benefits.

The Hon Karen Andrews MP
Minister for Industry, Science and Technology





SPACE. OUR NEXT FRONTIER.

With the arrival of the Australian Space Agency, RMIT is responding to the growing demand for new space capabilities for Australian industry including telecommunications, aerospace and defence. RMIT's Sir Lawrence Wackett Centre, together with experts from geospatial sciences, aerospace engineering, advanced manufacturing and other key areas create a powerful alliance; delivering trusted technologies, policy and business solutions, expert advice and workforce skills development.

Through our commitment to industry best practice, transdisciplinary collaboration and cross-sector partnerships, RMIT is supporting the growth of Australia's high-tech economy. We have expertise in every stage of product development; from concept design and testing to policy and implementation, making us the partner of choice. The calibre and diversity of this expertise attracts researchers, designers, manufacturers, policy makers and business people from government and industry, as well as students from around the world who undertake fellowships, higher education studies and internships with RMIT.

But that's just the beginning. Building on our top-rated Aerospace Engineering program, in 2020 we launched our new Bachelor of Space Science – a program that is the first of its kind in Australia.

To find out more about how RMIT is shaping Australia's future and helping to grow industry visit rmit.edu.au/defence

WORLD-LEADING UNIVERSITY CAPABILITIES IN THE AUSTRALIAN SPACE INDUSTRY

Photo: ©Thales Alenia Space / E. Briot



RMIT University partners with industry to transform the aerospace and defence industries through innovation, technology and research.

The Sir Lawrence Wackett Centre at RMIT University exists to bring together aerospace and defence research from across the University, including disciplines in business, law, social science, finance, science, health, engineering and design. We support the transformation and growth of Australia's Defence, Aerospace and Transport Systems industries and, for more than 20 years, we've partnered with industry to conduct fundamental and applied research into aerospace related science and technologies.

Australia is well placed to contribute to the next generation of space science and engineering developments. We have a strong university sector with world-leading research capabilities, and extensive geography and excellent test centres that are well suited to space and high-altitude research.

Through its international connections and partners, Australia has access to a wide range of existing space capabilities and services, including communications, surveillance, navigation and weather services. We have the capacity to do things differently and the appetite for developing innovative technology to find increasingly cost effective, competitive and sustainable solutions.

There are opportunities for disruption and innovation in the development of rapid and responsive launch services. It's easy to see the benefit of a rapid launch service that can provide surveillance sensors or communication links in the management of natural disasters, such as bushfires or storms, assisting in search and rescue missions or for defence and national security purposes. Development of this service will be enabled by advances in hypersonic propulsion technology and high temperature materials technology.

The development of high-altitude, long-endurance vehicles, also called pseudo-satellites, presents another

opportunity for disruption in the industry. These light vehicles use solar PV technology and can fly above atmospheric weather over a specific place or region to provide continuous service, unlike orbiting satellites, which are limited by their own revisit time. Three international aerospace companies – Airbus, Thales and BAE Systems – are working on this technology in Australia. In 2018 Airbus established the world's first high altitude pseudo-satellite flight base in Wyndham, WA, due to the site's largely unrestricted airspace and reliable weather.

RMIT is well placed to support these opportunities for innovation. One of our great strengths is the breadth of our offerings. Our programs and capabilities can support all facets of space research and operations, as well as the human elements of interfacing with autonomous machines – from solar power and atmospheric modelling to communications and artificial intelligence.

The Sir Lawrence Wackett Centre supports industry transformation and innovation by providing expert advice, delivering high quality technological policy and business solutions, and supporting capability development in critical areas of education and training, all in RMIT's world class facilities and research centres.

Through the Centre, RMIT has a trusted relationship with the aerospace and defence industry and our research spans all defence sectors, including maritime, aerospace, land, digital and human domains. We have a long record of working with industry to build things that work.

75%
of satellite constellations connecting
people are built by Thales

INTERVIEW WITH

ANTHONY MURFETT DEPUTY HEAD, AUSTRALIAN SPACE AGENCY



We're at T-plus 18 months. Does Australia's new space agency have ignition? Does it have liftoff? Is it rocketing downrange?
By **Jamie Seidel**.

According to the Deputy Head of the Australian Space Agency, Anthony Murfett, all systems are go.

"We're well on the right trajectory to hit our target – to triple the size of the space economy and create 20,000 new jobs by 2030," he says in an interview with *Australian Space OUTLOOK*.

"We achieved liftoff on 1 July 2018. We know that because we watched the momentum build. In the first year, there were over 100 million cumulative

views or mentions of the agency in the media. From a standing start, that's phenomenal. So we know the nation is behind us."

Now, it is a matter of establishing the long-awaited agency in orbit. "What we've got to focus on is delivering, and showing Australia what we can do."

But space, Murfett says, is not easy. Nor is achieving the agency's lofty goals. "There is a natural orbit decay that can pull us crashing back to Earth," he says. "What we need to do as an agency is constantly make the trajectory adjustments to make sure we stay in orbit – and a big part of that is connecting with the community, and explaining why and what we're investing in."

The past year has been a busy one, positioning the Australian Space Agency as a facilitator both nationally and internationally.

"If I look back over our significant achievements so far, the first thing that comes to mind is the Australian Civil Space Strategy," Murfett says.

"It outlines a 10-year pathway for how we will to transform and grow the space sector.

"We're very clear on our four strategic space pillars: open doors internationally, increase national capability, promote a responsible space sector culture to ensure safety here on Earth and in space, and also inspire the next generation and build a future workforce."

OPENING DOORS

Internationally, 2019 was a big year for the Australian Space Agency with nine new arrangements put in place. "The pinnacle, was a Letter of Intent with NASA, to support the Prime Minister's announcement of a \$150 million investment to fuel the growth of Australian businesses so they can thrive in international supply chains and join NASA on its campaign to return to the Moon and travel to Mars," Murfett says. "Australian industry and researchers will be able to access the \$150 million through grant-based programs, with the first grant opportunity expected to be announced by June 2020."

The European Space Agency (ESA) signed a letter of intent identifying opportunities for Australian engagement; an arrangement with New Zealand was also put in place. And countries such as Germany have been keen to explore partnerships.

"What was very clear is that the world has embraced us with open arms," Murfett says. "And the biggest role we at the Australian Space Agency can provide is opening those doors so we can highlight and showcase what we can achieve."

Murfett says the agency had found those doors already ajar due to the broad reach and reputation of expatriate Australians in the international industry. "Actually, we've already brought some back into the agency," he says. "We had Australians

INTERVIEW WITH

ANTHONY MURFETT DEPUTY HEAD, AUSTRALIAN SPACE AGENCY

working in space overseas. We're now able to attract them back because, one, we have a space agency, and two, we've got significant investment behind it. We've got a very bright future contributing to this global endeavour."

So, what do the next 12 months look like?

"Internationally, the biggest thing we will be focusing on is the Moon to Mars initiative – and the Australian Government's \$150 million investment," Murfett says. "We've begun consulting on the design of the program. We've travelled around the nation to get people's views on how it should work. We want to identify the areas of potential investment and ensure we get feedback. Funding for this initiative commences from the middle of 2020. So that's a big focus for us."

COORDINATING THE NATION

Back at home, the Australian Space Agency has been opening up a dialogue with Australian businesses and universities.

"One of the reasons we're here in Lot Fourteen [Adelaide] is that, literally, we can walk around and talk to industry partners here at our headquarters," Murfett says. "But it's not just about our headquarters. It's about what we do across the nation."

So far, the Australian Space Agency has gathered 16 Statements of Strategic Intent. "These are companies

highlighting where they see space investment opportunities. We've now signed these with companies such as Thales and Lockheed Martin, and home grown companies including Gilmour and Myriota (who are in our building) – this really showcases the great capabilities that we have."

Work on cementing the Australian Space Agency's presence is also proceeding at pace. "We have a \$19.5 million Space Infrastructure Fund. This will fund new or improved infrastructure including a new Mission Control Centre, which is on the ground floor here at Lot Fourteen. And that's a \$6 million investment. Applications for that project closed February. We'll assess those and get that project operational in 2021."

But Adelaide's Lot Fourteen is just a springboard. The Australian Space Agency has a mandate to grow the space industry across the nation.

"We have a Robotics, Automation and AI Command and Control Centre, which is in Western Australia," Murfett says. "The infrastructure fund is about identifying and investing in the building blocks Australian industry needs to participate in the space environment. The Australian Space Agency has looked at capabilities necessary to support industries all around the nation. The Robotics, Automation and AI Command and Control Centre, for example, is in WA because we saw a real opportunity to leverage the expertise they have in the mining sector."

Another is in Tasmania – the industry is already playing a role in orbital tracking.

"Every six months, Dr Megan Clark AC, Head of the Australian Space Agency, and I travel to all states and territories," Murfett says. "We talk with relevant government agencies and premiers, all the relevant ministers, and visit specific sites so that we can see where the investment opportunities are and understand their activities. We really are a national agency."

Another program – the \$15 million International Space Investment initiative – has recently closed submissions. These are now under assessment.

"This initiative aims to help stimulate and provide support for companies seeking to engage with international space agencies. It is a way to showcase what we can do internationally," Murfett says.

RESPONSIBLE SPACE

It is quickly getting very crowded above our heads: humanity has sent some 9,200 spacecraft into orbit since 1957. Most are in low Earth orbits and only about 2,200 are still working.

It is projected up to 57,000 new satellites will be shunted into our skies by 2029.

How can Australia ensure there is enough space up there for us, too?

"The long-term sustainability of space is an important issue," Murfett says. "One of the values of the agency

is to be responsible, and we're working in the United Nations' (UN) COPUOS (Committee on the Peaceful Uses of Outer Space) on what are the norms of behaviour and what are the long-term sustainability requirements needed to make sure space remains accessible."

COPUOS has recently adopted 21 new guidelines for responsible exploitation of space and these are already flowing into Australian legislation.

"We've started to weave in the implementation of those guidelines," Murfett says. "So, if you're planning on putting up a CubeSat, for example, do your de-orbit parameters consider the sustainability of the space environment? It's something we're going to have to monitor."

Space used to be the exclusive domain of government agencies; not any more. Now it is for businesses small, medium and large.

That is what the Australian Space Agency will support. And regulate.

"There are five UN space treaties that support space activities," Murfett says. "The overarching one is the Outer Space Treaty. As we've now seen this evolution of space from the realm of governments to businesses, it means governments' now need to consider the responsible use of space, which often means establishing an appropriate regulatory environment."

The Australian Space Agency is constantly considering the

regulatory environment.

"We're continuing to work on renewing the legislation to balance entrepreneurship with safety," Murfett explains. "Space activities have to be safe, but there is a balance to encourage growth. We also need to ensure there is communication with other affected areas – such as astronomy."

"We're very clear on our four strategic space pillars: open doors internationally, increase national capability, promote a responsible space sector culture to ensure safety here on Earth and in space, and also inspire the next generation and build a future workforce."

Our overcrowded sky, he says, is in itself an opportunity. Part of the solution will be new technologies to clean it up. "How do you move defunct satellites? Can you actually recover them? What are the ways to do that? Coming back to our values, of being a responsible user of space, we do need to think about these issues."

INSPIRING THE NEXT GENERATION

It is not just STEM; it is not just entrepreneurs. The Australian Space Agency is striving to inspire the whole Australian community and Murfett says the excitement is palpable.

"At Lot Fourteen, we've got the SmartSat CRC, the Institute of Machine Learning, Stone and Chalk, and Myriota and Neumann Space. This innovation precinct is growing ...

and soon you'll see Mission Control and the Australian Space Discovery Centre on the ground floor of the McEwin Building. You can really feel the excitement of the inspirational message that space can provide," he says.

Usually, you do not have a space agency without mission control. But this one is going to be different. "The

Australian Space Agency, compared to other space agencies, has a very different mandate," Murfett says. "It's about enabling the industry to deliver an outcome.

"So what we're going to do here is not necessarily for the agency itself. It's actually capability for business so that they can control, adjust and check their satellites from a central location. Multiple companies won't need to build their own mission controls."

Its ground-floor location near Adelaide's parklands is also going to be open to the public.

"We want that public interface," Murfett says. "We want people to be able to see what's going on – when appropriate. Obviously the room will be shuttered if there are any confidential activities underway. But it's about providing a public face and

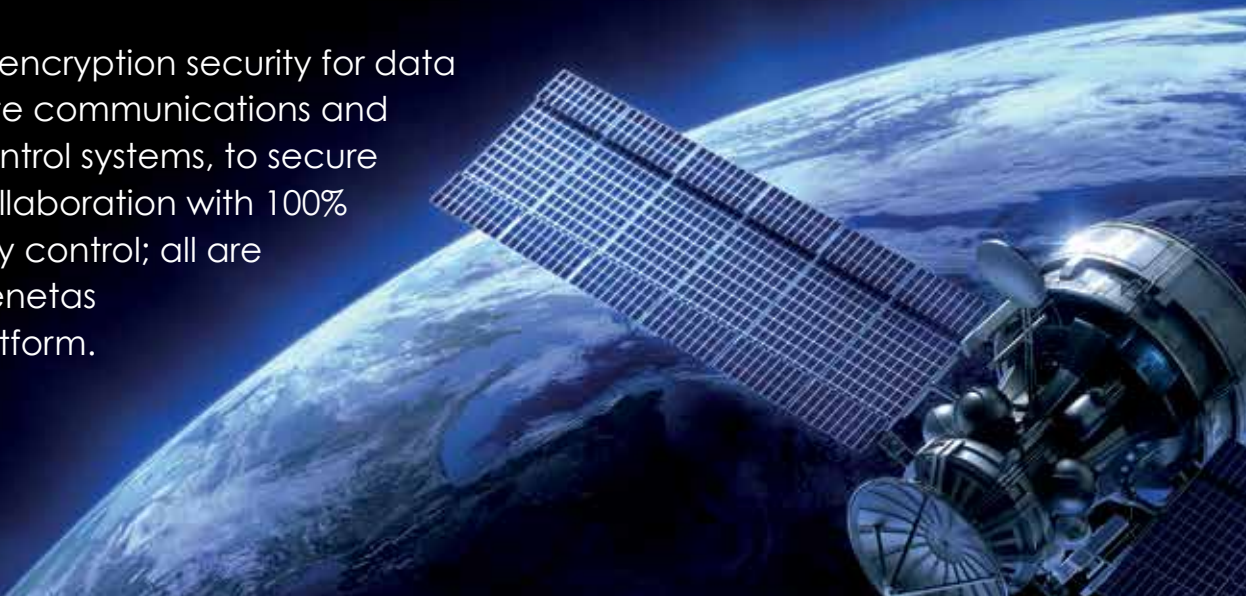
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INTERVIEW WITH

ANTHONY MURFETT DEPUTY HEAD, AUSTRALIAN SPACE AGENCY

getting them to feel and touch space. We want to do exciting things like show feeds of what's happening in space."

The adjoining Discovery Centre will enable children to explore the challenges and feel the excitement involved.

"One of the exhibits – because we're working with Questacon – could be that they're able to control a robot to get that feel for automation," Murfett says. "And maybe we might try and introduce lag so they can feel what it's like to have a signal delayed by a great distance. We want to be ambitious in this because we want to engage."

TO THE MOON AND BEYOND

"By establishing the Australian Space Agency, the federal government has made a very clear signal to the nation and the world that we see space as a priority," Murfett says. "From an investment perspective, that provides business confidence. Businesses are, therefore, more likely to pay attention because they know space is an area of opportunity."

Now, the Australian Space Agency is working to determine how it can best help. How can it fast-track businesses to engage in international supply chains?

"We have companies such as XTEK who produce a particular type of carbon fibre manufacturing that's now thinking about space because it's an opportunity," Murfett says. "There are companies such as Nova Systems, who were already kicking goals before we

came along, but we can now be part of the narrative to help them do their jobs. EOS Space Systems the same."

And for the Australian Space Agency, that means helping Australian businesses get space qualified.

"We've got an industry. It's been looking to engage in space supply chains, develop space technologies. But sometimes the only way you can do that is by having space heritage,"

"It's about how we extend a base of support to other companies so they can get the heritage necessary for them to participate – how we get them space qualified to engage in the supply chain."

Murfett says. So, the Australian Space Agency will conduct an audit of what facilities are available around the country to identify opportunities.

"At the moment, for example, we have areas such as Mount Stromlo," he says. "The Australian Instrumentation Technology Centre has a range of facilities including a vacuum chamber, so they're able to test if equipment works in a vacuum. But we need other facilities to ensure Australian businesses can test whether their equipment will work in space."

That is all before getting to space.

The Australian Space Agency wants to turn such testing and accreditation gaps into investment opportunities. "Now companies like

Myriota and Fleet have launched and gone to space and are getting that heritage," Murfett says. "It's about how we extend a base of support to other companies so they can get the experience necessary for them to participate – how we get them space qualified to engage in the supply chain."

The Moon to Mars initiative is the first significant test. Exactly what direction NASA ends up taking is not likely to be an issue for Australia, Murfett says.

"We're focused on NASA's plans as they've proposed, however the philosophy would still be the same: if they were to change their objectives – say a direct trip to Mars – then we'll ask, what are the capability gaps that need to be filled? What skills can we provide?"

It is all about finding ways to work with space 'primes'.

"One of our concepts is leveraging the Joint Strike Fighter program where the government worked closely with primes to understand the requirements, the standards etc. and made sure the companies here in Australia had those capabilities."

"What we've seen is that because the Agency is here on the ground, the whole sector is now orientated to help support our vision. We've set up a strategy to lay the foundations for industry to grow. Here's a path forward that the world is paying attention to. And that's opening doors. So I think we're on the right trajectory." ■

SPECIAL INTERVIEW WITH

JAMES MORHARD DEPUTY ADMINISTRATOR, NASA



In 2019, US President Donald Trump tasked the National Aeronautics and Space Administration, more commonly known as NASA, with an accelerated program to return to the moon and land humans on the lunar surface again by 2024.

Known as Artemis – the twin sister of Apollo and goddess of the moon in ancient Greek mythology – the program will place humans on the moon for the first time since the last Apollo mission 45 years ago and it will use new technologies and systems to explore more of the lunar surface and sub-surface than ever before.

Artemis will also differ from earlier lunar missions in that it will include the first woman and man on the lunar South Pole, and the program will also be used as a stepping-stone in the future journey of humans to Mars in the mid-2030s.

The program will use NASA's new Space Launch System (SLS) rocket, together with the Orion spacecraft, with the uncrewed mission (Artemis I) scheduled in 2021 followed by the manned launch of Artemis II in 2022/23. The first lunar landing will be performed by the crew of Artemis III in 2024.

According to NASA, Artemis will demonstrate new technologies, capabilities and business strategies which will support future exploration, including the manned mission to Mars. It will also "continue American leadership" and expand US global economic impact, as well as establish a strategic presence on the Moon.

During a visit to the United States by Prime Minister Scott Morrison in September 2019, the recently created Australian Space Agency (ASA) signed an agreement with NASA to enable Australian technologies to support the US program.

Under the agreement, technologies developed by Australian industry will have the potential to be a part of the launch systems, vehicles and instruments to enable US astronauts to travel to the Moon, and later to Mars, and the Morrison government is investing \$150 million to deliver capabilities for the NASA missions.

To explain the two programs in more detail and to provide an insight into exactly what NASA's partnership with Australia means to the organisation, Deputy Administrator James Morhard

agreed to answer *Australian Space OUTLOOK's* questions.

Morhard began his career as an analyst, working for the Secretary of the US Navy and has also served on the US Government's Senate Appropriations Committee, becoming Chief of Staff in 2003 and later serving as the Deputy Sergeant at Arms in the US Senate.

Following his nomination as NASA's 14th Deputy Administrator by President Donald Trump, he was sworn in on 17 October 2018 and is today responsible for assisting with the final decision-making process, as well as representing and articulating the agency's vision.

Can you explain in more detail why the Artemis and Moon to Mars programs are so important and what NASA's goals are?

James While Mars remains NASA's horizon goal, we have first set our sights on the Moon so that we can prove out the many processes and systems needed to get to deep space. Artemis is the name of our new lunar exploration program and includes all our upcoming activities on and around the Moon.

We will send the first woman and next man to the Moon by 2024, landing where no humans have ever been before: the lunar South Pole. At the Moon, we will use robots and humans to find water and other

critical resources needed for long-term exploration. We will investigate the Moon's mysteries and learn more about our home planet and the universe.

Today, we have crew members living and working aboard the International Space Station, which is something we've continued to do for almost 20 years. If there is an emergency on station, we can safely get our crew home in a matter of hours. Plus, our astronauts aboard station are in constant contact with mission control on Earth. At the Moon, we will become more autonomous by learning how to live and operate on the surface of another celestial body days away from home. We will also use the Moon to prove the technologies and systems we need for deep space exploration before sending astronauts on missions to Mars, which now can be a three-year roundtrip.

Ahead of a human return to the lunar surface, we will send a suite of science instruments and technology demonstrations to the lunar surface through commercial Moon deliveries. We call this initiative Commercial Lunar Payload Services or CLPS. Our first two deliveries are targeted for delivery in July 2021 on commercial landers, and we plan to send future payloads to the Moon about twice per year through 2028.

Can you provide more detail of the specific aims of Artemis and Moon to Mars and what progress you have made to date?

NASA has been called to accelerate our lunar exploration plans and land American astronauts, including the first woman and the next man, on the Moon by 2024. We're committed to achieving this goal. Through the Artemis program, we will go to the Moon in a way we have never gone before – with innovative new partnerships, technologies and systems to explore more of the lunar surface than ever before. Then we will use what we learn on the Moon to send astronauts to Mars in the mid-2030s.

From a technical standpoint, to ensure that 2024 landing is a reality, the key pieces of our architecture are now all in play. Perhaps our biggest technical challenge is getting the landers ready for the 2024 Artemis III mission. We recently published a formal request to industry to design, develop and demonstrate the lander that will take the first woman and next man to the Moon. The proposals were received on 1 November 2019 and awards are expected in March 2020.

In May 2019, we awarded a contract to Maxar Technologies for the first element of Gateway, a command module in orbit around the Moon, that will provide power, propulsion and communications to the lunar outpost.

NASA also continues its negotiations with Northrop Grumman for the initial habitation capability, which we call HALO (habitation and logistics outpost). We recently closed a solicitation for logistics supply services to deep space, including the lunar Gateway, which will support expeditions to the surface of the Moon, and again we're hoping to make an award, or awards, early this year.

NASA is also developing the spacesuits our astronauts will wear during the initial human landing on the Moon. We are seeking additional input from industry on spacesuit production and services for future surface missions.

Can you provide some insight into how you believe these space programs will be of benefit to humankind?

We believe there are many reasons to go back to the Moon. With the Artemis program we will demonstrate new technologies, capabilities and business approaches needed for future exploration into the solar system, including Mars. We will establish American leadership and a strategic presence at the Moon while expanding our global economic impact and broadening our international and commercial exploration partnerships. At the same time, we hope to inspire a new generation and encourage careers in

SPECIAL INTERVIEW WITH

JAMES MORHARD DEPUTY ADMINISTRATOR, NASA

science, technology, engineering and mathematics (STEM).

As mentioned, the key goal for Artemis is demonstrating and perfecting capabilities on the Moon that we need to get our astronauts to

Mars. In parallel, we will establish a long-term presence on the lunar surface while conducting scientific research and pursue ways to use the Moon's resources to further our objectives. Our growing community of international

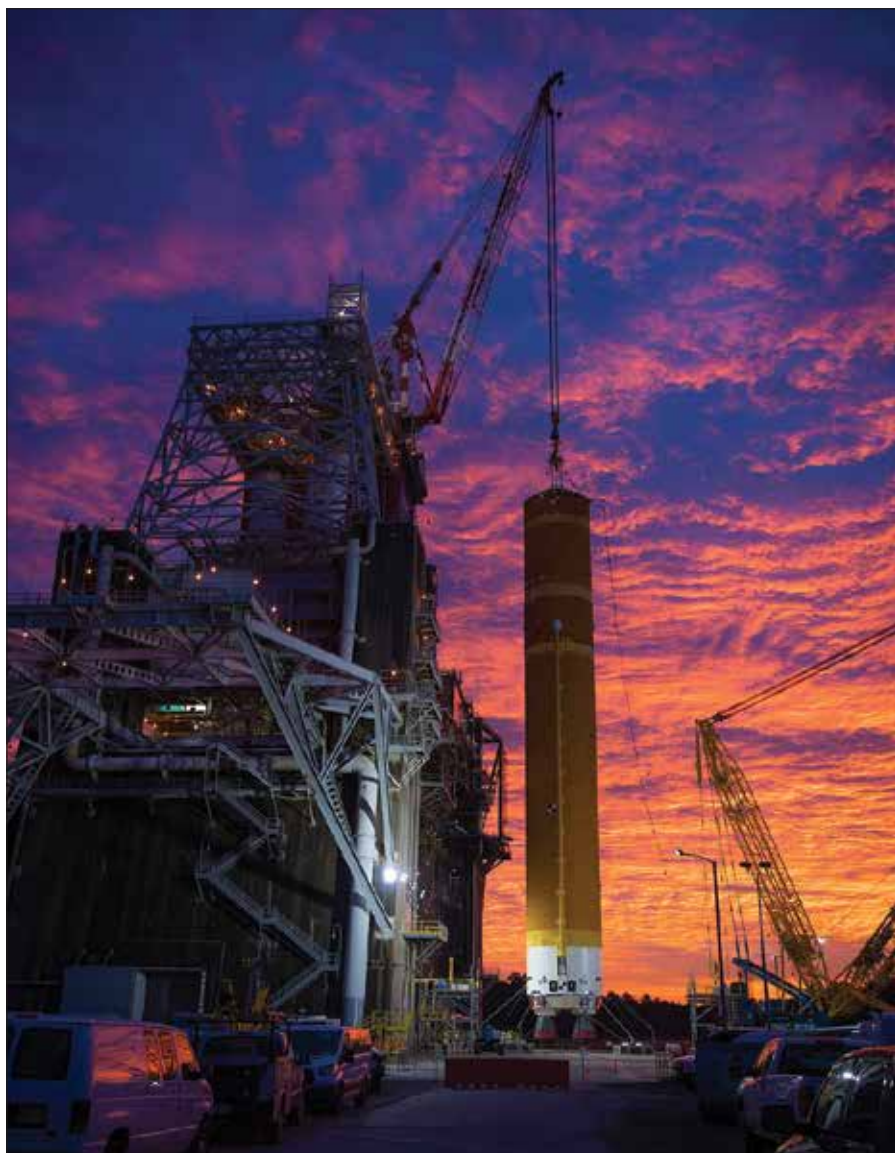
and commercial partners including Australia will be vital to furthering human exploration and technological and scientific advancement in space.

Will the Space Agreement between NASA and Australia, announced in September 2019, initially be for Artemis only, or will it benefit both programs?

On behalf of NASA, I signed a joint statement of intent to cooperate in space exploration with the Australian Space Agency. We are committed to exploring new potential cooperation across several domains including NASA's plans to return to the Moon and on to Mars. Areas of mutual interest to both countries regarding the Moon and Mars include robotics, automation, remote asset management, space life science, human health and remote medicine. We are pursuing a framework agreement to enable closer collaboration and will have additional details on that framework in the future. Also, the United States continues to be interested in the long and storied efforts of Australia that began with our earliest space programs.

What does the agreement between Australia and the US mean, both from a program, and a 'benefit to country' perspective and can you provide details of Australia's contribution so far?

We are committed to exploring new potential cooperation across several



domains including NASA's plans to return to the Moon and on to Mars. Recognising the long history of successful cooperation between NASA, and as a tribute to the long tradition of working closely with Australia in space activities, I along with Dr Megan Clark (Head of the Australian Space Agency) signed a joint statement of intent on 21 September 2019. While it is not an agreement to cooperate in space exploration, it should be seen as a vehicle used to identify prospective areas of cooperation that are of mutual interest and benefit to both Australia and the United States. These areas of cooperation could be formalised in legally binding agreements in the future

These new activities will build on the existing successful cooperation dating back to the 1960s between NASA and the Commonwealth Scientific Industrial Research Organisation (CSIRO) for tracking and communication of NASA missions through the Canberra Deep Space Communication Complex (CDSCC) at Tidbinbilla, as well as the Data Relay Satellite facilities in Alice Springs, Northern Territory, and Dongara, Western Australia. The CDSCC serves as an integral component of NASA's Deep Space Network.

From a NASA perspective, what value does the partnership with Australia bring to the two endeavours?

We look forward to advancing our respective interests. We foresee potential Australian contributions in areas of mutual interest such as robotics, automation and remote asset management, which builds on a unique history of space cooperation between the US and Australia that dates back to the Apollo era.

As I said at the time of signing our joint statement, we are honoured by

"We are honoured by the commitment of our friends from Australia to support our efforts to return humans to the Moon by 2024 with the Artemis program. The strong relationship between NASA and the Australian Space Agency affirms NASA's commitment to establish sustainable exploration with our commercial and international partners by 2028."

the commitment of our friends from Australia to support our efforts to return humans to the Moon by 2024 with the Artemis program. The strong relationship between NASA and the Australian Space Agency affirms NASA's commitment to establish sustainable exploration with our commercial and international partners by 2028.

Our joint statement further strengthens the relationship between Australia and the US and broadens

the community of free nations joining NASA in further exploration of the Moon, Mars and beyond.

Australia has some unique geology, particularly in remote regions such as the Pilbara in Western Australia. Can you provide details of the work recently undertaken in that region and how it is hoped it will be of benefit to NASA's programs?

The Apollo astronauts visited areas of geologic interest on Earth before venturing to the Moon. More recently, our scientists did similar due diligence in the Pilbara outback. The Pilbara is home to the oldest confirmed fossilised lifeforms on Earth, called stromatolites. With a better understanding of how those fossils came to be here – and the nearby geological signposts that help point the way to them – NASA and our partners will be more prepared when hunting for signs of life on Mars.

In August, the Mars 2020 and ExoMars rover science teams honed their skills in the Australian outback, where the rocks are of similar age to the terranes on Mars. This trip helped with preparation for missions to launch to Mars next summer in search of signs of past life on Mars. We expect the results from the Australian astrobiology expedition will have positive, long-lasting ramifications in humanity's hunt for evidence that we are not alone in the universe. ■



AUSTRALIA'S FIRST SPACE INCUBATOR PROGRAM ATTRACTS GLOBAL STARTUPS

Katrina Albert from Canadian space-robotics company Lux, wanted to launch into the Australian market, so she decided to google 'Australian startup space program'.

Up popped the six-month, tailored Venture Catalyst Space program from the University of South Australia's Innovation & Collaboration Centre (ICC).

Now in its third year, the program supports space startups to validate and test their products side by side with Australia's growing space industry, creating a thriving ecosystem and complementing the work of the industry's existing 60+ space industry companies, and the Australian Space Agency, which calls Adelaide home.

The team of two Co-Founders (Katrina Albert and Vincent Lachance) were accepted into the program and then applied for the pilot 'Supporting Innovation in South Australia Visa', which expedited their application and they soon found themselves boarding a plane to set up their business in Adelaide.

Katrina says their company has grown immensely through the program with the team hiring their first employee, successfully testing their first minimum viable product and securing their first clients.

"We definitely underestimated the value in the program's connection to stakeholders and the level of enthusiasm around space in Adelaide. Being connected in a city where space is the main topic of conversation is both exhilarating and very good for business."

"Being a free program with a stipend and one that does not take any equity or IP was also a big positive for us."

Associate Director of the ICC, Jasmine Vreugdenburg says the program offers a \$10,000 stipend, potential relocation grants and a range of support services for companies.

"The value of the program for the founders is access to the space community in Australia as well as mentoring, office space and a small stipend which combined, helps the companies set up operations. We can also provide support and sponsorship for the SISA visa which is exclusive to founders setting up a company in South Australia."

Accepted participants of the program are also connected to a global pool of mentors.

"Companies that are part of our program get access to a wonderful pool of mentors who are either well connected in the space industry or have deep entrepreneurial experience and are willing to openly support the companies on a pro bono basis."

"With the support of our partners, we are continuously improving the way we support founders; their success is our success."

Applications for Venture Catalyst Space are now open globally via:
icc.unisa.edu.au

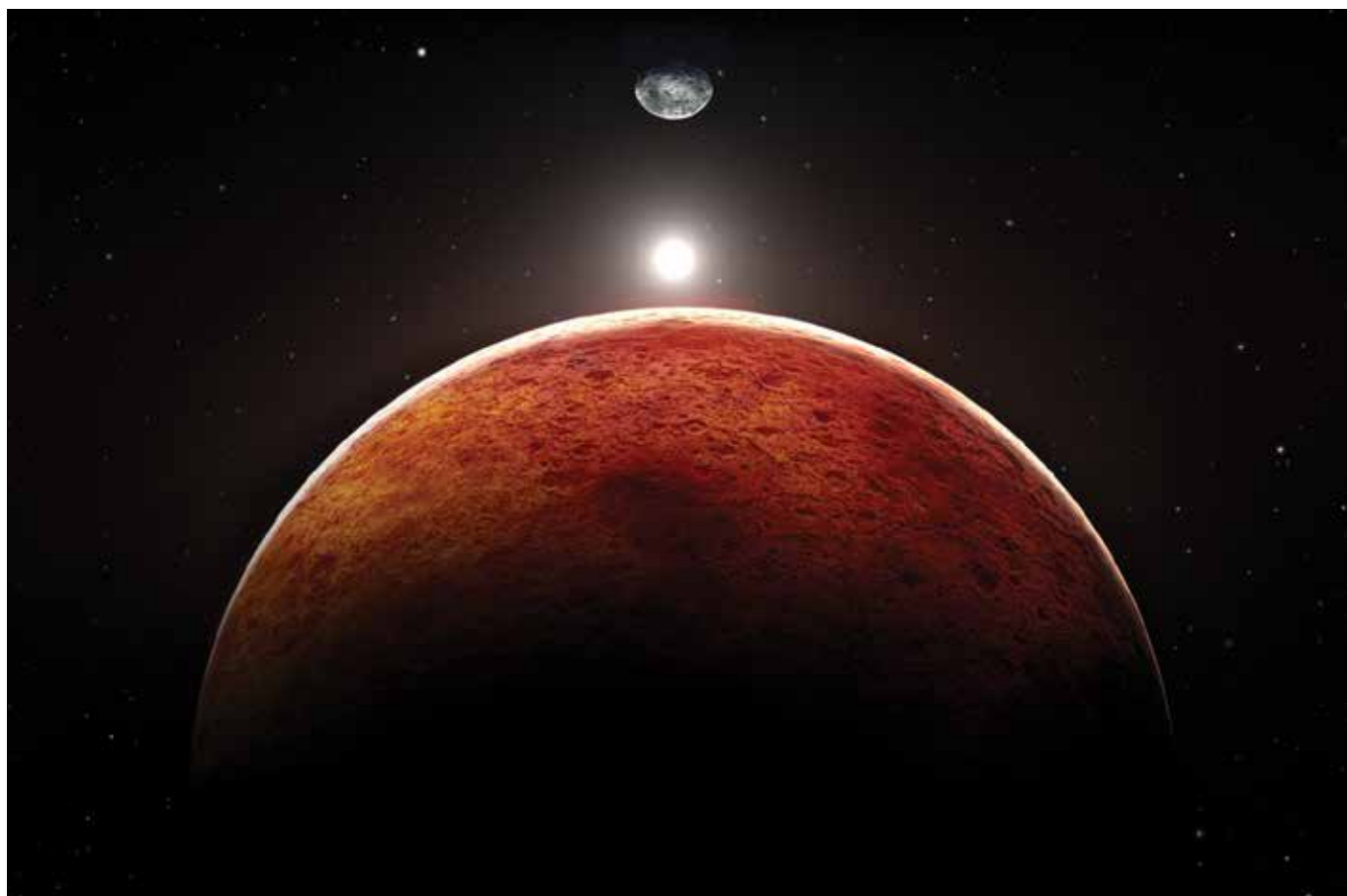
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AUSTRALIA'S INVOLVEMENT IN NASA'S MOON TO MARS PROGRAM

Australia has committed to spending \$150 million with local businesses to support NASA's ambition to return to the Moon and on to Mars. A by-product of the local spending will be a boost to Australian industry and academia, to foster new ideas and create high-technology jobs. By **Nigel Pittaway**.

In September 2019, the Australian Space Agency signed a letter of intent with NASA to seek opportunities for Australian industry co-operation on technologies that will be critical to the United States' endeavour to travel to the Moon and to Mars in the next two decades.

Under the partnership agreement, Australia has committed to spending \$150 million with local businesses over five years and, according to Karen Andrews, Minister for Industry, Science and Technology, the funding will support Australian industry and academia to foster new ideas and create high-technology jobs to cement relationships with NASA on the programs.

The deal also provides an opportunity to support local businesses to become more competitive in bidding for work as part of the global supply chains of the international space industry. When witnessing the signing in Washington on 21 September 2019, Prime Minister Scott Morrison said the aim was to triple the size of Australia's space industry to \$12 billion, creating an additional 20,000 positions by 2030.

"The government's support means Australian businesses and researchers will have an opportunity to showcase their immense knowledge and capabilities in projects that can support NASA's Moon to Mars missions, such as Project Artemis and the Lunar Gateway," Morrison said.

PROJECT ARTEMIS

Named after the goddess of the Moon (and the twin sister of Apollo) in ancient Greek mythology, Project Artemis is NASA's lunar exploration program which aims to land American astronauts – including the first woman – on the Moon by 2024.

Sustainable lunar missions are expected to follow by 2028 and the lessons learned will underpin future manned missions to Mars. The Artemis missions will use NASA's Space Launch System (SLS) rocket and Orion Multi-Purpose Crew Vehicle (MPCV) to reach a Lunar Gateway, which will orbit the Moon and send expeditions to the lunar surface in a new crewed landing system. The Orion spacecraft will then carry the astronauts from the Lunar Gateway back to Earth at the end of each mission.

Prior to the first human mission to the lunar surface, NASA will fly two missions around the Moon in order to test its deep space exploration systems. A suite of instruments and a technology demonstration mission will travel to the surface of the Moon using commercial delivery systems.

The uncrewed Artemis I mission will launch in 2021 to test the SLS/Orion combination and this will be followed by the first crewed flight, Artemis II, in 2022. Artemis III will deliver the first astronauts to the surface of the Moon in 2024 and future missions will follow at the rate of around one a year.

To accomplish Artemis and the future Mars exploration missions, NASA will collaborate with a series of commercial and international partners, including Australia.

AUSTRALIAN SUPPORT TO NASA

Australia's involvement with the US space program predates even the formation of NASA, with support for the Explorer I and Vanguard I satellites launched in 1958, as part of the International Geophysical Year (IGY).

These missions were supported by a number of tracking stations around the world, including two located at Woomera in South Australia. Since the formation of NASA in October 1958, Australia has provided support for its deep space and human spaceflight missions, including the Mercury, Gemini, Apollo and Skylab series.

Today, support is still provided through the Canberra Deep Space Communications Complex at Tidbinbilla, just outside the capital, as part of NASA's Deep Space Network. From

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an industry perspective, the recently created Australian Space Agency will foster ongoing opportunities for local businesses to engage with NASA on the Artemis and Mars missions in the future.

AUSTRALIAN SPACE AGENCY

The Australian Space Agency was formed on 1 July 2018 and is the national agency for the development of a local commercial space industry. The recent signing with NASA is intended to foster innovation and skills and provide a mechanism whereby they are able to showcase their intellectual property and capabilities and hopefully increase Australia's share in the global space market, currently estimated to be worth around US\$350 billion.

With the signing of the Joint Statement of Intent in September, the Australian Space Agency will engage closely

with NASA to identify how Australian companies can best support the forthcoming missions, and local expertise in technologies such as robotics, artificial intelligence, automation and Earth observation technologies are likely to be at the forefront.

Anthony Murfett, Deputy Head of the Australian Space Agency, says that the focus of the \$150 million announced with the signing of the joint venture is to engage local business capability, technology and know-how into the international supply chains.

"Our purpose is to grow and transform the Australian space industry, which goes back to our main purpose which is to triple the size of the space economy and create another 20,000 jobs before 2030," he says.

"What we're very mindful of as well is the investments we make in

our space technologies also have an application here on Earth for other parts of the community."

One such example is optical lasers in advanced communications systems for use in space, where lower latency is needed and which, if proven successful, has the potential to improve communications capabilities here on Earth.

The Australian mining industry is already at the forefront of automation, with technologies ranging from autonomous drilling equipment through to the operation of entire railway networks. Murfett says space exploration will also benefit from automation and robotics, and Australian industry development in such areas has the potential to pass further advancements to sectors such as resources and manufacturing.

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"The other example we have is remote medicine and space life sciences. Human spaceflight is increasing and the US is looking to return astronauts to the Moon. This means we need to make sure people are safe. Australia has world-class expertise in things like remote medicine. So, again, if we improve how we treat patients in remote locations like space, this can be used to improve our regional health system," he adds.

"We're very mindful that we have to grow these industries in the first instance, but we need to show how these investments improve and connect with all parts of the community."

In terms of which Australian technologies will benefit from the initial \$150 million investment, Murfett says the Australian Space Agency sees a definite opportunity in robotics and automation, where local expertise is world-renowned.

"There's also in-situ resource utilisation. We need to be mindful of our international obligations and the Moon treaty. But, from our perspective, it's a scientific exploration of that technology. And again, it's huge – Australia really does punch above its

weight in robotics and automation," he says.

The organisation is also looking at the use of artificial intelligence and machine learning platforms, and again in areas such as data analysis and the digital mapping of celestial bodies. Murfett says this is an area where Australia already has a lot of expertise, pointing out for example that Geoscience Australia's Digital Earth Australia platform has 30 years of Landsat satellite data in an easy to use format.

"We need to understand the lunar surface, we need to understand the surface of Mars. So, let's take our know-how on data manipulation and data analysis and apply it to there," he explains.

"The thing that is really clear to us is that the agency has been here for just 18 months, but Australia has long-established world-class capabilities which we can contribute to the future and I think that's exciting."

A VISION FOR FUTURE AUSTRALIANS

It is not just Australian industry that is set to benefit from an increased engagement with NASA on Moon

to Mars; there is also significant potential from a science, technology, engineering and mathematics (STEM) education standpoint as well.

Murfett says the initial benefit of participating in the Moon to Mars program is the message it conveys to young Australians about the role Australia is likely to play, fostering a broad engagement.

"The second part relates to having goals that are tangible. We can get in early and explain where we think the future is headed so that we can encourage children to go down the right study pathway," he explains.

"We can also use 'space' to support engagement in a range of other STEM subjects. And then, even if you don't get into a space career, you're going to have life skills, which are going to be relevant, no matter which way you go forward."

The involvement also makes it clear that there is a future for Australia in the domain and this will hopefully resonate both with parents of students and the broader community.

"It's clear there is a future for Australia in space and it's actually going to be a generator of jobs. The opportunities provided by Moon to Mars will be tangible. It will be something tangible, whether it is in AI or robotics – those skills are what we're going to need," Murfett adds.

"We want to point to the Moon or the sky and tell them, Australia has technology out there that is contributing. When you see the twinkle in kids' eyes when they realise they can be part of that, that alone is priceless."

AUSTRALIA'S UNIQUE POSITION

A further benefit to NASA's vision is Australia's unique geography which, in remote areas such as Western Australia's Pilbara region, can provide real research and training opportunities, particularly when it comes time to reach out beyond the Moon to Mars. For example, in August 2019, the European

Space Agency's ExoMars (exobiology on Mars) and NASA's Mars 2020 rover teams rehearsed their operations in the Australian outback, where the geology is a similar age to the terranes found on the Martian surface.

The Pilbara has been studied for decades to better understand the evolution of life on Earth to help us understand the potential for the evolution of life on Mars

Australia is part of NASA's Deep Space Network and organisations such as CSIRO, Australia's national science research agency and the predecessors of Geoscience Australia have been contributing to international space research since the 1960s. Due to our geography, Australia is home to the only dishes that can communicate with NASA's Voyager 2 spacecraft, which was launched in 1977 to explore the outer planets in our solar system.

"There is also research such as that with QUT (Queensland University of Technology), which is involved with the 2020 Mars Rover and there are companies supporting the development of virtual reality testing for space activity. There are things that are already underway, but as part of a bottom-up process, and we're now establishing a top-down boost to this, through things like Moon to Mars," Murfett says.

"Our focus is about how to get our industry to contribute. For example, one of the ways NASA works is that it awards a contract to a prime contractor – for example for the Orion space capsule. But they have supply chains which need components, skills and capabilities. There are gaps in those supply chains that Australia can fill and they are in areas of Australian expertise, like robotics and automation. What we're doing is identifying the gaps where

Australia can play its role. We've got a strong skill base, we've got capabilities, and we can identify where the gaps are and plug our capabilities into those gaps."

At the signing of the joint statement in September 2019, Prime Minister Scott Morrison said it would contribute to the already strong alliance between the US and Australia. "We're backing Australian businesses to the Moon, and even Mars, and back. We're getting behind Australian businesses so they can take advantage of the pipeline of work NASA has committed to," he said.

"We've partnered with the US in almost all of their missions to space for the last 60 years and this (\$150 million) investment paves the way for the next 60. The growing amount of space sector work and innovation will also inspire the next generation to see the future of a career in these fields for the long term." ■



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In addition to building the mission control centre for NASA in Houston, Texas, KBR has trained astronauts, prepared their space suits, supported the operations of the International Space Station and launched satellites

– among many other projects spanning the full spectrum of the space industry.

Whether on the ground or in space, KBR’s innovative solutions help solve the complexities of human spaceflight and robotic space exploration, safely and efficiently.

Last year, KBR appointed distinguished NASA Centre Director Todd May as Senior Vice President for Space and Mission Solutions for its Government Solutions US business.

May came to KBR after a 28-year career at NASA, culminating in a role as director of NASA’s Marshall Space Flight Centre in Huntsville, Alabama, where he was responsible for an annual budget of over US\$3 billion.

In his KBR role, May supports the company’s enterprise space initiatives and oversees a systems engineering division which services a variety of defence and civilian customers.

As Australia ramps up its commitment to the space industry through the formation of the Australian Space Agency, May has also turned his attention to Australia and discussed KBR’s potential involvement in the local industry on a multi-stop visit last year.

KBR is already active in the defence sustainment area, with major contracts with the Royal Australian Navy, and can leverage that presence and its long experience in the global space

industry to the development of the local industry in Australia.

"Seeing Australia step up now and create its own space agency and wanting to get involved in the Artemis mission to the Moon is exciting to me," says May, who has a connection to the country through his Australian grandmother.

"The country has a history with space, going back to the Apollo program and the radio telescopes and the Woomera range, so there is a heritage there and it's exciting to see it come back."

While it is early days for the Australian Space Agency, May already sees several areas where KBR's expertise and experience could help in the development of the local industry.

"We would be interested in supporting the development of an operations centre at the Lot 14 facility in Adelaide, and we have spoken to the agency about our capabilities in that area," he says.

"We are also interested in looking at the viability of a launch facility in Australia, as we have deep experience in launch site development and operations through our work at NASA's Kennedy Space Center and Wallops Flight Facility.

"We recognise it is still fairly early in the game in Australia, but we have the capabilities and the experience so we are definitely interested in having a whole range of conversations and seeing how we might participate and help the ASA achieve their goals."

Australia, says May, also has the potential to collaborate and contribute to international space programs, such as Artemis, through its proven expertise in areas such as mining.

"Australia has a strong heritage in mining innovation and one of the things which is important on the Moon if you go there and establish a presence there is using the resources you have there in situ," he says.

"You would have to live off the land, so to speak, as much as you could.

Resource utilisation such as harvesting hydrogen for fuel might be one example where Australian expertise could come into play to supply resources for missions."

Communications was another area in which Australia could play a part, as the technology evolves towards optical communications which harness light.

"There are also synergies between the work Australia is doing in deep space exploration, and these technologies can be commercialised down on the ground," says May.

While the cost of launching satellites is coming down, allowing more nations to launch, space is increasingly an area for international collaboration, and this is where Australia could also become involved.

"I think that even the US, with its long history of space flight, understands that it needs to be an international effort now and we need all the capabilities we can get," says May.

"There are many ways to participate in space, and a country needs to get its strategy together and play to its



Todd May

strengths, and that is what Australia is now doing."

After a career in the space industry stretching back decades, Todd May says the industry is now at an exciting point where many technologies have been proven, new technologies are being implemented and new ambitions are being set.

Humans are about to begin partnerships with robots which could have innovative applications in space, and commercial and private operators are entering the flight industry.

"Two different commercial companies are now getting to the point where they will deliver astronauts to the space station under commercial service contracts, and that is unprecedented," he says.

"We are moving forward with the new human lunar lander, and there is a clear path to get human boots back onto the moon.

"And after many hard years the James Webb Space Telescope is nearing completion and, just like Hubble before it opened up the universe, James Webb is going to go even further and give more detail outside of our solar system, answering more questions for us."

The space industry, says May, could be about to experience a phenomenon like that of Moore's Law, which posits that once a certain amount of knowledge or capability has been achieved then future growth is rapid and exponential.

"I think what could really change the game is our computing capabilities, as quantum computers give us the ability to do more in-depth analytics and look again at a lot of the data we have collected from satellites which is in storage," he says.

"It's an exciting time in the space industry. Technology always pushes us to new frontiers and the very prospect of exploring propels us forward." ■

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Innovative Use of Space Data

SPACE: IS IT FOR YOU?



By **Linton Smith & Damien Farrell, Frazer-Nash Consultancy Ltd.**

As a nation, Australia prides itself as the lucky country – a land of wealth and toil with opportunities for all. Through initiatives like the Space Agency Moon to Mars Program, there is an opportunity to prove we are also the ‘clever’ country.

Our emerging space industry has a bold and daring mission with significant opportunities to shine on the international stage. Is this our Apollo mission?

The Moon to Mars Program indicatively provides opportunities through which society will achieve

more, working together for a common goal, than we ever would individually.

What will those opportunities look like? And how does Australia help humankind reach out into the heavens?

Firstly we need to continue partnering and collaborating with others, bringing our Australian perspectives, knowledge, skills and our technology to the fore.

Many of the problems to be solved for a successful colonisation of Mars are steeped in the societal problems we face here on Earth. Clean and abundant air and water; secure shelter from the elements; resilient, reliable and renewable food sources; sustainable power and energy, the list goes on. By solving these challenges for a human Mars

mission, we will likely bring new solutions for us here on Earth.

So, do you need space? Is the emerging space sector for your organisation? What can you contribute? How do you get involved? The answer to these questions can be difficult to ascertain in the emerging and dynamic sector that is Australia’s space industry. It can be difficult to navigate the various regulatory, space-enabled services, governance and funding requirements to develop your concepts and take advantage of space. Being able to efficiently get to a decision point is as important for your success as it is for the Moon to Mars Program.

Where do you start? The answer: with your organisation and its mission, values and goals. If these align with those of an opportunity such as the Moon to Mars Program, you go to the next step, defining what your organisation can do. Once you have decided then you need to identify the routes to funding and support needed to progress your concept. This can be conceptually simple but difficult to execute given the other challenges your organisation may be facing. This is where a space savvy and multi-disciplined engineering and technology consultancy such as Frazer-Nash can assist. Support from the right people at the right time can help you navigate space for the right outcome to you and your organisation. You might even contribute to a sustainable future in the process. So, remember you are not alone.



AUSTRALIA AT THE FOREFRONT OF SPACE SITUATIONAL AWARENESS

The useable orbital space around Earth is becoming more crowded with man-made objects, increasing the risk of collision. To minimise this risk, the US and other countries – notably Australia – are investing large amounts of money in technologies to enhance SSA. By **Nigel Pittaway**.

In early September 2019, the European Space Agency had to manoeuvre its Aeolus Earth observation satellite to avoid an imminent collision with a recently launched SpaceX Starlink satellite, an occurrence which highlights the importance of timely and accurate space situational awareness (SSA) data.

While most people think of the cosmos as a vast, empty space, which it is on a cosmological scale, useable orbital space around the Earth is becoming exponentially more crowded with man-made objects – ranging in size from the large telecommunications satellites operating in geostationary orbit far above the Earth, to the

smallest flake of paint dislodged in low Earth orbit (LEO) during the ascent phase of a vehicle.

The abovementioned near miss is therefore not such a remote possibility after all – indeed, in January another near miss in LEO threatened to add tens of thousands more objects into the domain. One collision in 2009 alone reportedly added 30% to the amount of space debris in the cosmos and the sheer number of satellites now being launched each month exponentially increases the probability of collision – and each collision in turn potentially adds thousands more items to the growing number. This exponential effect is known as the

Kessler Syndrome and to minimise this risk, the US and other countries – notably Australia – are investing large amounts of money in technologies to enhance SSA.

WHAT IS SSA?

Space situational awareness can be best described as a catalogue of the location and nature of objects in Earth orbit and the environment, which has taken a great deal of effort to develop. It is continually updated to maintain accuracy of orbital information as well as after each launch (or collision). The threat is not just from man-made objects: natural space debris and the cosmic weather patterns can significantly increase the risk of collisions with satellites, spacecraft and even humans, when astronauts are conducting extravehicular activities or space walks.

According to the Australian Government's Department of Foreign Affairs and Trade (DFAT), SSA "describes the monitoring and tracking of orbiting space-based objects such as satellites and debris using ground-based radar and optical stations. SSA allows operators to track the orbits of satellites, predict and take action to avoid potential collisions between space objects such as manned spacecraft, the international space station, satellites, and debris, and monitor de-orbiting objects crashing to Earth. SSA can also provide information on whether certain actions in space are deliberate or accidental and attribute those actions".

SSA is becoming increasingly important as the cost of accessing space is reducing and is not just the domain of governments and multinational corporations, making it a more congested environment as a result. "Ultimately, SSA enables decision-makers to institute appropriate measures to manage vulnerabilities and mitigate threats – for example,

by re-positioning satellites to avoid collisions with other objects," the organisation says.

The United States Air Force runs America's Space Surveillance Network (SSN), which is responsible for the production and maintenance of the aforementioned space debris catalogue and actively monitors in the region of 25,000 individual items.

WHY IS SSA IMPORTANT?

The speed at which an object orbits the Earth varies with its distance from the surface of the planet, but the numbers are astonishing. In low Earth orbit, for example, speeds are generally around 30,000 kilometres

as SpaceX in the US, the underlying conditions for the aforementioned Kessler Syndrome are also increasing. LEO is most at risk from this, simply because it has the lowest volume and the highest density of objects within it, but also because every satellite placed into geostationary orbit (GEO) first passes through the regime on its journey away from the Earth. The risks to objects in GEO are also significant, as they operate in a narrow band, where geostationary effect applies, and there are many large satellites within that band.

"While I wouldn't say that the Kessler Syndrome is inevitable, it will occur if we don't have effective space

The sheer number of satellites now being launched each month exponentially increases the probability of collision – and each collision in turn potentially adds thousands more items to the objects in orbit.

per hour, reducing to around 11,000 kilometres per hour in geostationary orbit.

Professor Craig Smith, CEO of Canberra-based SSA specialists EOS Space Systems, provides some context of the risk to satellites from even the smallest fleck of paint travelling at such hyper-velocities. "There are around 25,000 to 30,000 pieces of space debris down to around 10cm in size currently being tracked by the USAF, and there's an exponential increase of the number of objects as the size reduces further," he explains. "There are between 500,000 and one million dangerous objects and, because these are travelling at speeds of around 30,000 kilometres per hour – or 10 times the speed of a bullet – even a one-centimetre object can absolutely devastate a satellite."

With the move towards large constellations of much smaller satellites, known as nanosatellites, and the sheer volume of launches planned by commercial space companies such

traffic management (STM), or if we are not acting with the best intent or to be the best custodians of that orbital regime. Space is finite, but it's still very large and if we are extremely careful in our custody of objects in orbit – making sure we understand their positions at all times – then absolutely we can manage the space environment," adds Dr James Palmer, CEO of Adelaide-based Silentium Defence.

"To avoid collisions, you have to start with good quality information, knowing what those objects are and when those conjunctions are going to occur – and with a higher confidence than we currently have – is the absolute foundation. That's why SSA is one of the underpinning pillars of STM."

AUSTRALIA'S CONTRIBUTION TO SSA

The US Space Surveillance Network is predominantly a collection of ground-based radars and optical sensors which



are complementary capabilities that gather data that is then transmitted to the Joint Space Operations Centre (JSpOC) in California, where it is processed and incorporated into the master Space Objects Catalogue and made available to the global space community in unclassified form.

Australia is geographically well-placed to contribute to the SSN primarily because sensors located within the continent can provide a field of regard of around one-eighth of the celestial sphere.

With most of the SSN sensors located in the northern hemisphere, Australia – with its relatively benign weather patterns, stable political system, emerging space industry and a high level of technological maturity and innovation – is a valuable partner in the delivery of quality SSA data.

The Australian Department of Defence is a significant contributor to SSA capability and it currently operates a C-band Space Surveillance Radar (SSR) in conjunction with the

United States Air Force, located at the Harold E. Holt Communications Centre at Learmonth, near Exmouth in Western Australia.

The radar was previously located in Antigua in the Leeward Islands and gradually relocated to Australia from 2014, achieving final operational capability (FOC) at Exmouth in March 2017.

Its contribution to the SSN is in the provision of both southern and eastern hemisphere coverage, accurately tracking and identifying several hundred objects of space debris and satellites every day which will lead to improved positional accuracies and predictions.

In addition to the radar system, Defence is also acquiring an optical space surveillance telescope (SST) which was previously in operation in New Mexico and is now in the process of being recommissioned at Learmonth. The capability is being acquired under Project AIR3029 Phase 2 and the purpose-built building,

constructed at a cost of \$97.2 million, to house the SST and its 270-tonne rotating dome was handed over to Defence in March 2019. Initial operational capability (IOC) is expected to occur during 2021.

Australian industry has been supporting SSA in some form for more than three decades and is at the forefront of emerging technologies which have applications for future surveillance capabilities.

EOS Space Systems has been providing SSA data to Defence, and in turn to the SSN, for over 35 years, using locally developed laser tracking expertise at its facilities at Mt Stromlo, outside Canberra, and at Learmonth. At the present time, the company is the only Australian commercial provider of qualified SSA data; however, Silentium Defence, founded in Adelaide in 2017, is developing a complimentary capability using cutting-edge passive radar technology, which it says is on track for consideration as part of Defence's forthcoming Joint Project 9351 Phase 1 indigenous SSA sensors program, due in the early 2020s.

OPTICAL TRACKING

Canberra-based EOS Space Systems is a segment of the parent Electro Optic Systems, founded in 1983, and today operates seven SSA sensors across its facilities at Mt Stromlo and Learmonth, including the world's only autonomous space laser tracking system.

"EOS provides tracking and characterisation of space objects with accuracy and sensitivity exceeding most current standards for military or commercial space operations. Our ground-based space tracking infrastructure employs Australian designs for high accuracy beam director telescopes, high-power laser systems, diffraction-limited imaging systems and high accuracy timing and positioning systems," explains CEO Professor Craig Smith.

"We develop and integrate fully autonomous network control software for space sensor networks, providing 24/7 autonomous space situational awareness, object characterisation, high accuracy orbit determination and orbital projection, as well as automated conjunction assessments with integrated collision probability elimination."

The company's network currently tracks 10,000 space objects every week and under an agreement signed in December with the newly created Australian Space Agency, it plans to establish further laser ranging sensors across Australia to increase the number of objects tracked to 100,000 per week.

"Detection and tracking are the first steps in space domain awareness. You want to know not just where an object is, but also what it is, where it's going and what its purpose is. So, we are developing characterisation systems that can determine more about the object," Prof. Smith adds.

"Sometimes there are satellites masquerading as space debris, effectively hiding in the space debris field, and the ability to track them very accurately allows us to determine what a natural and un-natural manoeuvre is."

EOS' systems will also operate closely with Defence's 3.5-metre SST, which is intended to search the GEO band every night for new objects. "Our systems will follow up on the objects that the SST finds and provide more data, changing it from a detection to an orbit. A single detection tells you there is an object that is not already in the catalogue, and you need to continue tracking it and determine its orbit so it can be added to the catalogue," Prof. Smith says.

PASSIVE RADAR TRACKING

Passive radar uses reflected radio frequency energy already broadcast

into the atmosphere to track objects, and Silentium Defence is at the forefront of this technology, with its Maverick S-series system now under development.

The Maverick S-series uses RF energy broadcast by sources such as commercial FM radio stations to determine the range, location and track of an object in space and is weather-agnostic, able to operate on a 24/7 basis.

"We can make a contribution to SSA because of the field of view we have and the fact that we measure range directly, as radars do, which gives us better quality orbital information on a much faster turnaround than sensors which don't provide range information," explains CEO Dr James Palmer.

"We are building and maturing our Maverick S series, which is focused on SSA and we're demonstrating the ability to monitor very wide arcs of the sky to discreetly measure the range of an object in LEO and provide orbital estimations, with no prior information."

Silentium Defence demonstrated the Maverick S-series system at the SpaceFest exhibition, held at the Woomera Test Range in Coondambo, South Australia in March 2019.

"We have demonstrated to Defence that we can monitor objects in orbit, we can derive orbits [and] we can monitor very wide arcs of the sky – conceivably the whole sky – all the time," Dr Palmer adds. "We have the ability to detect, track and monitor objects that are already in the catalogue and will be able to find objects that are not currently reported, for example newly launched satellites. Once we find them, we can then determine information for inclusion into the catalogue.

"It leverages pre-existing sources of RF energy and the beauty of FM radio is that it's a 24/7 signal source." ■

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EOS SPACE SYSTEMS: AUSTRALIAN SPACE SPECIALISTS

EOS Space Systems is currently the only local commercial provider of qualified SSA data and has been operating for over 35 years. By **Nigel Pittaway**.

Australia's EOS Space Systems, a division of Electro Optic Systems, has been a critical provider of satellite tracking and space situational awareness (SSA) capability for more than 35 years.

At present, the company is the only local commercial provider of qualified SSA data and for the first two-thirds of its existence, its only customer was the

United States Government. Today the company supplies critical data to other customers around the world, including the Australian Department of Defence.

The company's SSA systems are based on technologies developed in Australia that are fully operational and interoperable with the US Space Surveillance Network (SSN) and it also provides a range of other services, including space debris management, missile defence capability, optical communications systems, space products, and research and development capability.

The parent company has also developed a Defence Systems division using spin-off technology from the space sector, a large part of which is its Remote Weapon System (RWS)

products. The RWS was developed in the 1990s and continues to enjoy significant export success, contributing to EOS's total export sales of around \$250 million in 2019, making it the largest Australian-owned defence exporter.

To learn more about EOS Space Systems, Australian Space OUTLOOK spoke with CEO Professor Craig Smith at the inaugural Defence and Security Equipment International Japan (DSEIJ) exhibition held recently in Tokyo.

COMPANY GENESIS

EOS was founded as a private space company in 1983 by Dr Ben Greene, who previously worked for the Australian Government in what is now known as Geoscience Australia.

Dr Greene is still head of the parent company, which was first listed on the Australian Stock Exchange (ASX) in 2003.

The company's initial expertise was in ground-based technologies for tracking objects in space. Today its SSA services include the development of an independent Australian space object catalogue, optimised sensor scheduling, accurate and reliable correlation of tracks, object characterisation and identification, data analytics and the development of simulation tools for mission planning.

"EOS was initially formed to perform space-related work, such as satellite tracking and laser ranging to satellites. Around the mid-1990s we were laser ranging to satellites that had a retroreflector on them so, to perform orbit determination, we were able to measure their range using short pulses of very low power, with a precision of about 1mm and an accuracy of 10mm all the way out to geostationary orbits," Prof. Smith says.

"This has many applications, including geodesy, which is Earth science, finding out where the mass of the centre of the Earth is. Laser ranging is a key to determining the International Terrestrial Reference Frame."

The initial customer for this work was the US (and later Australia), but today many nations contribute geodetic data and, because very highly accurate determination of satellite orbits can be obtained, EOS is also involved in the calibration of Global Navigation Satellite System (GNSS) satellites, such as the US GPS, Chinese BeiDou, European Magellan and Russian GLONASS constellations.

"We are still providing the capabilities we brought to the market back in the 1980s today, the laser capability, integration of high-performance beam directors and then the Command and Control (C²)

systems that bring it all together. Even back in the 1980s we were working at the quantum level of single photon detection," Prof. Smith explains.

"Furthermore, we have developed almost all the capability in-house. Where there are already third parties making equipment that we need, then we buy it. We don't develop equipment that isn't unique to us, so we can focus on where we apply our skills to develop new products or integrate other manufacturers' equipment in new ways."

"We're taking raw tracking data and turning it into useful, useable information, rather than just noting that there's something there. Our customers want to know where it's going and why it's there, so we are creating actionable information."

On 30 September 2019, the company announced it had established a Space Communication Systems business segment, which added a third arm to the company (behind Space Systems and Defence Systems). The following day, it announced it had agreed to acquire Brisbane-based EM Solutions (EMS), which will form part of the new division. EMS is a world leader in stabilised satellite communications (SATCOM) terminals for on-the-move communication.

"EOS and EMS are together developing optical communications capabilities for high bandwidth ground-to-space communications," Prof. Smith says. "But that only works when it isn't cloudy so, to get a more efficient uptake of that capability, you have to layer traditional RF or microwave communications systems on top and we are integrating

that capability with EMS's existing packages and we're also looking at hybrid/RF communications as well."

CAPABILITIES AND SERVICES

SSA remains the primary focus of EOS Space Systems, not least because space has become a very congested environment and the risk of collision between two objects – especially in low Earth orbit (LEO) – is not insignificant.

To accomplish this, the company maintains two sites, one at Mt Stromlo near Canberra and the other at Learmonth in Western Australia. The ground-based tracking infrastructure uses the company's Australian-designed beam director telescopes, high-powered laser systems, enhanced imaging systems and high accuracy timing and positioning systems.

The company also develops and integrates fully autonomous network control software for space sensor networks and operates a suite of SSA sensors optimised for use in the Asia-Pacific region.

"We have a contract with the Australian Department of Defence to provide data for them and also for the US, because the US Air Force runs the SSN. The Australian DoD does a lot of tracking of its own, and so we provide



Professor Craig Smith



data to them and they in turn pass some of it to the US Government,” Prof. Smith explains.

“At the moment they’re not asking for us to track everything, they’re tracking specific things of interest, at specific times. They give us a tasking list and we look at each object, analyse the data and then pass it to them, but we’re also looking to expand that data to a full catalogue capability in the not-too-distant future. The location of our tracking sites gives us a good distribution in longitude – they are optical systems and therefore don’t work efficiently when it’s cloudy, so we like to have large distributions.

“We’ve also been working with partners in the Space Environment Research Centre (SERC) for Space Environmental Research on capabilities to remotely manoeuvre objects from the ground. We can track objects very accurately with our laser tracking systems and we can determine if they are likely to collide. If you know those details accurately, you don’t have to do very much to

the orbit to stop that collision from happening, because the two satellites only occupy the same bit of three-dimensional space for a millisecond.

“We are using another high-power laser beam to transfer energy from the beam onto the object, which then slows it down. If two objects are on a collision path, you just slow one down a little bit and they pass safely.”

EOS Space Systems has developed all its analysis tools in-house and the data processing is automated and performed within a data repository at its network control centre in Canberra. After the data analysis – which includes orbit determination and prediction, collision prediction and threat warning analysis – is completed, it is then distributed to the customers.

“We’re taking raw tracking data and turning it into useful, useable information, rather than just noting that there’s something there. Our customers want to know where it’s going and why it’s there, so we are creating actionable information,” Prof. Smith adds.

In addition, the company provides both services and systems to a number of countries around the world, including high-performance beam directors for large aperture telescopes, which have applications in both space tracking and astronomy.

“We’ve delivered around a dozen beam directors to different customers around the world, including the US, Japan, China, India and Thailand. We also perform tracking services – for example the USAF has its own tracking network but it doesn’t have very much in the southern hemisphere and, to accurately determine orbits you really need southern hemisphere data as well, otherwise you bias your orbit determination solution to their location, rather than true,” Prof. Smith says.

“There are also some orbits that are better seen from the southern hemisphere and of course, we’re in a strategically important longitude in the geostationary band, and we can see everything from about Hawaii over to the Middle East, where the US

doesn't have many assets in that area. So, we provide data to governments and we're looking at establishing commercial services for other customers – including here in Japan and for Germany and other allied countries."

CURRENT FOOTPRINT

Overall, the EOS Group currently employs over 350 people with the space segment accounting for around 40 of that number, and while space is a growing business, it is the defence side of the house which generates the lion's share of revenue.

Professor Smith says that, while growth in the space business is not occurring rapidly it is nevertheless steady, and he notes significant interest generated by the recent creation of the Australian Space Agency.

"I think the creation of the Australian Space Agency was absolutely necessary – we would have other countries' space agencies come to us, asking who they should speak with, because there was no-one in Australia that represented Government. Many of those agencies cannot actually deal with companies directly and need to work on a government-to-government basis, so there was just no engagement with Australia because there was nobody to engage with," he reflects.

"If nothing else, the Agency has created that front door for people to come to and talk and I think that will have benefits."

A recent example of the company's success is the signing of a Strategic Intent and Co-operation Agreement between the Australian Space Agency and EM Solutions in November 2019, to leverage their RF and SATCOM capabilities into the emerging Australian space industry with the development of high-speed

telecommunications products for international supply chains.

In early December 2019 the Australian Space Agency also signed a Statement of Strategic Intent and Co-operation with EOS Space Systems, which will oversee the establishment of further laser ranging sensors across Australia, increasing the volume of space objects tracked by the company from 10,000 to 100,000 every week.

When making the announcement, Anthony Murfett, Deputy Head of Australian Space Agency, noted that the joint statement aligned with the Australian Civil Space Strategy, which outlines a 10-year plan to transform

the ASX200, which is Australia's largest share market index and we intend to become Australia's leading Australian-owned defence contractor. There are many large defence companies in Australia but very few of them are truly Australian-owned," he explains.

"In the space segment, there are presently no other companies providing precisely the same capabilities. There are others doing related work, tracking space objects in other ways – there are active and passive radar systems, all of which have their relative merits, strengths and weaknesses, but our systems are unique in the level of

"We don't develop equipment that isn't unique to us, so we can focus on where we apply our skills to develop new products or integrate other manufacturers' equipment in new ways."

and grow the local space industry. He also noted that space situational awareness and debris monitoring is one of the seven National Civil Space Priorities outlined in the strategy.

"This statement will assist Australia to grow its world-leading capabilities in space situational awareness and debris monitoring and space communications," Prof. Smith adds. "Our business has been at the forefront of technical innovation in space for over three decades. EOS's success is underpinned by an exceptional skilled local workforce and collaborative partnerships across government, Australian business, academia and research institutions."

FUTURE OPPORTUNITIES

Looking to the future, Professor Smith says that, overall, EOS plans to remain the largest Australian-owned defence exporter. "We plan to stay that way and our ambition is to become part of

accuracy that they are able to provide. Radars have the benefit of providing broad area surveillance but to a lower accuracy."

To underline the potential for further export opportunities, particularly in the Asia-Pacific region, EOS Space Systems exhibited its products and capabilities at the inaugural DSEIJ exhibition in Tokyo in November.

"We have been talking with the Japanese Government for some time about space surveillance and they are looking to increase their ability to monitor satellites and satellite launches," he says.

"They are ramping up their space surveillance capability and doing some of it with radar systems, but there are some things you need to do optically and that part of the world is not the best place to observe space from, given the weather patterns in the region, and we have both technology and services to offer them." ■

AT ANU, WE'RE BUILDING A QUANTUM COMMUNICATION FUTURE



World-leading optical communications researchers at ANU are leading a program to build Australasia's laser communications ground station network.

By Dr Kate Ferguson and Dr Francis Bennet.

Satellites have revolutionised our lives thanks to the ability of orbiting objects to gather and transmit vast amounts of data about the Earth, back to scientists and businesses who use technology to make that valuable data available to our wider community. Data transmissions include global navigation satellite system positional information, images of natural disaster areas and measurements of atmospheric conditions to help predict the weather.

Unfortunately, the precision instruments flown in space are currently limited in how much data they can send back to Earth. This means on-board processing and intelligent-decision-making software decides what data gets sent back.

If only a small fraction of collected data returns to Earth, what important discoveries are we missing?

RADIO FREQUENCY LIMITATIONS

Today, we rely on radio frequency (RF) communications to upload and download data from satellites. It offers many advantages: frequencies can be chosen to penetrate cloud, and wide beams allow for more cost-effective antennas that are robust enough to be deployed in harsh and remote areas.

The major drawback of RF communications is the limited data rate. It is difficult to imagine ever achieving the data rates that are available over terrestrial fibre optic networks.

GAME-CHANGING OPTICAL COMMUNICATION

Optical communications use laser

wavelengths, typically 1 to 1.5 μm , to transmit data. The shorter frequency of these wavelengths allows for greater data transmission rates but at the cost of greater complexity and pricey ground and space optical terminals. Optical wavelengths are also impacted by cloud, fog and atmospheric turbulence. However, optical communication provides added benefits that include smaller terminal sizes that use less power, lower beam divergence allowing for longer distance transmission, and the ability to carry quantum information for unhackable security.

AN INTERNATIONAL PRIORITY NOW AND INTO THE FUTURE

InSpace ensures research excellence at ANU and delivers on the priorities of the national space agency, including laser and quantum communications as one of our highest priorities. We are collaborating with several international space agencies to find ways that this type of high-speed communication can provide ultimate security using a variety of techniques where it is mathematically impossible to intercept or hack the communication channel.

ANU researchers are world leaders in this technology. Their research excellence in optical communications has them leading a program to build Australasia's laser communications ground station network. With licensing of radio frequency spectrum growing more and more difficult each day, this world-leading optical communication network will have massive implications for almost every industry: we will be able to transmit more data, at a faster rate.



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NEXT-GENERATION FACILITIES

Our optical communications capabilities are complemented by the next-generation facilities at the ANU Research School of Astronomy and Astrophysics (RSAA) Advanced Instrumentation and Technology Centre (AITC), which has decades of experience in delivering optical instruments for astronomy. These time-tested, innovative instruments and capabilities are now being used to create the instrumentation needed for optical communication, both high-speed classical communication and quantum communication.

One technique which is particularly useful for optical communications between ground and space is known as adaptive optics (AO). An AO system allows for an optical instrument to mitigate the impact of atmospheric turbulence by correcting wavefront distortions. This allows the quality of the received signal to be boosted, increasing the data rate.

ANU researchers are constructing an optical ground station for satellite communications testing that will consist of a telescope with an aperture of 70cm to allow for experiments with satellites to the Moon and beyond. The facility will support a range of experiments from quantum key distribution, quantum memories, adaptive optics and high-speed optical communications. ANU researchers are leading a national effort to bring other research telescopes together to provide a network of optical ground stations. The diverse location of these sites stretches from Western Australia to New Zealand, allowing for near continual coverage of the skies in any weather condition.

FROM DEFENCE TO FINANCE AND BEYOND

Secure communications have applications for defence, border protection, telecommunications, banking and finance. Quantum communication and encryption will enable new levels of security. Malicious actors will not be able to exploit back-door vulnerabilities. High-speed optical communications will enable new technologies to operate over long distances such as telepresence, remote robotics, mining and scientific discovery.

QUANTUM COMMUNICATIONS IN AUSTRALIA'S FUTURE

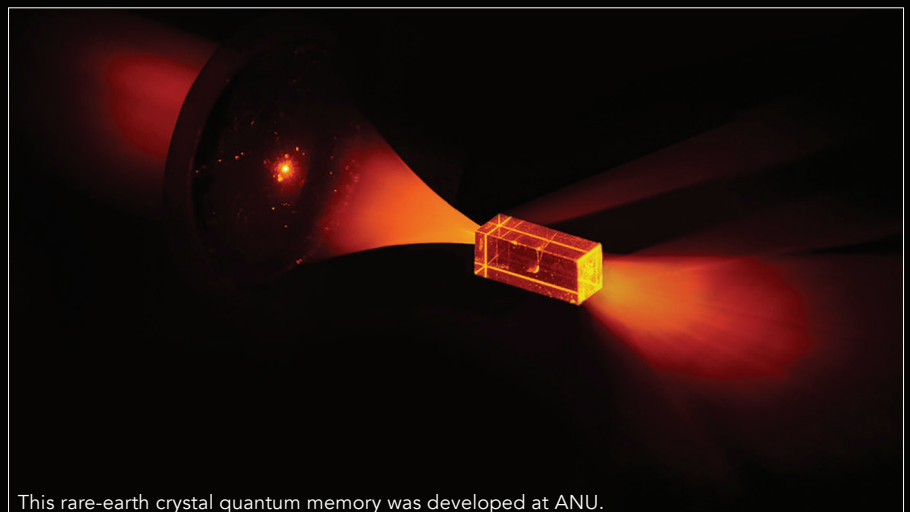
Australia leads the world in quantum communications. The capabilities of teams at ANU are creating research excellence in this field with other universities and industry partners. ANU is developing quantum communications hardware that could be easily integrated into existing telecommunications infrastructure and has demonstrated world-leading quantum memory storage times, which would allow for a global space-based quantum communications network. To demonstrate a pathway to this technology, ANU is working with its

global partners to develop and launch a quantum communication satellite.

AUSTRALIA OFFERS A UNIQUE PROPOSITION

Australia is uniquely positioned geographically and generally, has low cloud cover, making it a prime location for a global optical communications hub. We have the potential to become a global supplier of optical communications ground stations for the next generation of satellites. This will unlock a myriad of benefits across our nation. In many areas, this introduces the possibility of remote data relay using satellites which can connect remote communities or remote scientific bases in places like Antarctica. Eventually, this can also be the backbone of communication for deep space missions, such as NASA's Artemis Moon to Mars program, where data will need to be uploaded and downloaded at high speed and over enormous distances.

Australia is uniquely positioned to enable the next revolution in high-precision instruments in space. That next revolution has already begun at ANU.



This rare-earth crystal quantum memory was developed at ANU.

SERC'S SSA LEGACY

The SSA and space debris issue will continue to be a major problem for the global space industry, but SERC's research and IP will continue to help solve it long after SERC's final shutdown this year. By **Gregor Ferguson**.

In its five-and-a-bit years of existence, the Space Environment Management Cooperative Research Centre (CRC), commonly known as SERC, has tackled some "wicked" problems, according to its CEO, David Ball. Importantly, it has given Australia a strong position in the science of space situational awareness, or SSA.

Why does SSA matter? Because at the last count there were just under 2,000 operational satellites orbiting the earth. Of concern is the space debris that is in orbit with these satellites. There are an estimated 30,000 space debris objects greater than 10cm in diameter (some of which are defunct satellites and discarded rocket bodies the size of a small bus) and also an estimated 500,000 marble sized objects. In addition to the above, many more satellites are planned for launch in the coming years. Some estimates are that a further 18,000 operational satellites may be launched in the next decade. Preventing these objects from hitting each other, which could have catastrophic consequences, really matters. This was the focus of SERC when it was launched in 2014, says Ball, who was appointed CEO in 2017 and who will oversee its wind-

down this calendar year after the end of its approved funding term.

"The risk [of collision] is increasing," he tells *Australian Space OUTLOOK*. Launch and satellite costs are coming down so people are seizing opportunities that did not exist even a decade ago. Therein lies the problem. Cubesats in an orbit about 400km up tend to come down relatively quickly, he says, but there is much more activity in the 600-1,000km orbital area: planned constellations of hundreds, and in some cases thousands, of new non-geostationary communications satellites, for example. Debris and expired satellites remain in orbit much longer at that orbital altitude – for decades or centuries depending on the orbit and the characteristics of the space object. The SSA systems under development enable us to more accurately measure the orbits of space objects and forecast the evolution of this orbit which allows us to then determine where the risk of conjunctions between objects is the highest.

SERC and its research participants – the Australian National University, EOS Space Systems, Lockheed



David Ball

Martin Space Systems Company, Optus Satellite Network Pty Limited, RMIT University and Japan's National Institute of Information and Communications Technology (NICT) – have two principal research programs.

The first research program is to develop software systems to undertake conjunction analysis of space objects. Optical sensors are used to gather very accurate measurements of space objects, allowing SERC to model their conjunction risk with other space objects days and weeks ahead. The system can be used to provide a timely warning to satellite operators, enabling them to manoeuvre their spacecraft to avoid a collision with a debris object or with another operational satellite.

The other SERC research program is centred on the development of techniques to manoeuvre space debris. A collision between space objects will create more debris and junk which in turn creates even more risk of collision, says Ball. The danger is that entire orbital planes would be sterilised through the Kessler Effect, where multiple cascading collisions cause so much debris that an entire orbital plane becomes unsafe for use. Operational satellites are able to manoeuvre in order to avoid a collision; however, space debris objects, including defunct retired satellites, cannot move to avoid a collision. So, the need exists to find a way to avoid collisions between debris objects.

"That part of the research program will use high-power ground-based lasers, together with adaptive optics technology adapted from the astronomy world, to put high-power laser energy back through the telescope and onto a debris object to manoeuvre it and to avoid a collision," says Ball. "When objects are closing at 8km a second you only have to slow something down or divert it by

a small amount in order to avoid a collision." Adaptive optics systems are used to focus the laser energy into a narrow laser beam when it reaches the space object after it has passed through atmospheric anomalies such as fluctuations in air density and atmospheric turbulence.

Improvement in SSA technology and the ability to accurately measure more objects will help address the space traffic problem. That means building a catalogue of space objects of interest, mapping and calculating their orbits and predicting how these might result in collisions. The demand for computing power to calculate up to 25,000 orbits in real time is significant, says Ball. As we increase the size of the catalogue this task becomes more challenging to solve. "One of the SSA radar operators has talked about having a catalogue of 250,000 objects. That then makes your problem of conjunction analysis orders of magnitude more difficult. So there needs to be continued research into improving computational efficiency and scaling up processing speed as work to solve the space traffic management problem. The research needs to examine how we manage this data, how we process it quickly and how we efficiently provide actionable alerts to operators that are meaningful and timely."

One avenue for research would be to identify and focus on the subset of space objects that are most likely to cause a problem for a given satellite. This will require additional research into the application of artificial intelligence (AI) and machine learning to the space debris problem.

At the time of writing, the on-sky space experiment mentioned earlier has not yet happened due to delays in the supply of components needed to complete system integration. On-sky activity is anticipated during 2020; however, final integration of the

adaptive optics and high-power laser system has been delayed as a result of COVID-19.

In addition, as part of the on-sky research program, SERC will put a payload into orbit later this year, hosted on a UK-built cubesat. This payload consists of a beacon and a detector module to help SERC align its lasers and the adaptive optics system and so help improve its tracking algorithms. "The payload will measure the amount of laser power it is receiving from the high-power laser system on the ground to help measure

"A collision can create more debris and junk, which in turn creates even more risk of collision. The danger is that you sterilise entire orbital planes through the Kessler Effect, where multiple collisions cause so much debris that an entire orbit becomes unsafe for use."

how much irradiance we're achieving."

The payload will measure the 'push' it gets from a laser and therefore how much power is needed to make fractional course corrections and avoid collisions.

A first version of this payload was originally launched on an earlier satellite which unfortunately failed after launch. A second payload will be hosted on the UK Faraday-1 cubesat; unfortunately, the planned launch in late-2019 was delayed. "We're due to launch in April; however, the COVID-19 pandemic has resulted in a shutdown of all launch operations," says Ball. "We're expecting to launch in from New Zealand with Rocket Lab later in 2020 when launch operations resume."

SERC was established in 2014 and

was funded for five years. The delays in system integration, which were outside SERC's control, mean it has been granted a protracted wind-down period because some of the important IP from its research will not be available until after the space experiments.

SERC's research is important, says Ball. "The conjunction and orbital prediction software and the advances that we are making in the adaptive optics and high-power laser system development will help industry address the space debris problem. These developments will help improve the accuracy of orbit determination, deliver actionable conjunction alerts to operators and to develop mitigation techniques to prevent collisions. These are wicked problems to solve. We've made good contributions to academic research and been well recognised internationally for that."

While SERC will wind up this calendar year, its IP will be developed further, says Ball. SSA is one of the pillars of the Australian Space Agency's technology agenda, he points out, adding, "A number of our participants will continue research beyond the life of SERC. When we wind up, that activity will transition to them."

"Our participants will announce in due course their specific post-SERC activities," he says. "I can't really speak for them or for the Agency about what they may or may not do in the space debris and SSA areas. In addition, I would note that there are major Defence initiatives to address the Defence-specific SSA requirements."

SSA and the space debris issue will continue to be a major problem for the global space industry, but SERC's research and IP will continue to help solving it long after its final shut-down. ■

Australian space industry takes off...

Not only is this a time of great growth for our sector, it is also a time of tremendous opportunity. Since the last edition of *Australian Space OUTLOOK*, there have been many important activities conducted within the domestic space sector, including:

- The official opening by the Prime Minister of Australia, the Hon. Scott Morrison MP, of the Australian Space Agency's new premises at Lot Fourteen in the Adelaide CBD (these premises will also contain a Space Discovery Centre and the Mission Control Centre – to be opened within the next 12 months)
- The establishment of the SmartSat CRC (also located at Lot Fourteen)
- Emerging new technologies which continue to develop at an amazing rate – with many of our domestic companies, including a number of 'start-ups', leading the charge
- Plans for establishment of commercial launch facilities in Australia
- Tremendous financial impetus stemming from activities driven at the Commonwealth Government level

This overwhelming endorsement from the top has built public confidence in the future of the space industry. Government support has been practically demonstrated with a number of key initiatives announced or commenced in the past 18 months. Space-related programs include:

- The International Space Investment Initiative
- The commencement of new legislation rules and guidance governing launches and returns
- The development of the Satellite Based Augmentation System
- The Moon to Mars initiative

State and territory governments are also embracing the industry, with a number of state-based space strategies being publicly released recently – these strategies articulate significant commitment by various tiers of government to growing the domestic space industry.

The SIAA has experienced an unprecedented growth in membership, with members now totalling over 450 and counting – we have never before observed so much interest in space and space-enabled technologies.

The SIAA is working closely with the Australian Space Agency and other key stakeholders in the industry. The SIAA aims to ensure that it remains a relevant and professional organisation, providing opportunities for members to collaborate, and keeping members informed via timely communication. If you aren't already a member, I strongly encourage you to join and add your voice to the growing numbers within the domestic space industry.

The SIAA is very pleased to once again partner with Faircount Media Group in the production of the second edition of its flagship publication, *Australian Space OUTLOOK*. Given the success of the 2019 edition, we are confident that you will find this edition equally edifying.

David Ball

Chair

Space Industry Association of Australia

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SIAA: HELPING AN INDUSTRY TO GROW

The Space Industry Association of Australia is helping its members surf the wave of industry confidence that started to gather with the formation in 2018 of the Australian Space Agency. By **Gregor Ferguson.**

Since the formation of the Australian Space Agency in 2018, the wave of industry confidence has been reflected in the Space Industry Association of Australia (SIAA) membership which more than doubled to nearly 400 in 2019, increasing by one or two new members each day during the second half of the

year. This trend in membership growth has continued into 2020.

The Association's challenge now is to remain relevant to a wider spectrum of members, from prime contractors to individual members, says its Chair, David Ball, who is also CEO of the Canberra-based Space Environment CRC, or SERC.

"There's a tremendous amount of activity in the sector today with a lot of new start-ups commencing and Old Space moving aside for New Space for some projects," he tells *Australian Space OUTLOOK*. "But there's also a great need for Old Space in this country, so there's a need for the SIAA to straddle both elements of the sector and to continue to deliver value for our entire membership base."

That industry growth is driven in part by growing industry self-confidence and

by awareness of and access to more national and international opportunities as a result of the outreach conducted by the Australian Space Agency. The Agency's industry agenda is simple: it wants to triple the number of Australian space jobs, to about 30,000, and triple the sector's contribution to GDP to about \$12 billion a year, by 2030. New industry players and indeed entire sectors are growing in response to the falling cost of building satellites and payloads and putting them into space.

The distinction between New and Old Space reflects this new and more open space business environment. Old Space generally requires a lot of money to fund large satellites and the cost of launching them into geostationary orbit; New Space exploits the new business paradigm by building high levels of almost disposable utility into small,

cheap satellites that can be sent aloft cost-effectively.

"In New Space you see a lot of people doing smaller projects in the cubesat and smallsat area where there's lots of R&D going on," says Ball. This is the domain of new services and applications, often with a two-year horizon in a sector where innovation platforms and designs are constantly changing. There is a lot of activity and enthusiasm in this domain with several SIAA members raising capital to fund new offerings and technologies.

"Old Space is where you're building for the 15-year mission in geostationary orbit where heritage and flight proven technology is needed. This approach still has tremendous relevance and utility in mission critical, high-value applications," he says.

'DOWNSTREAM' PLAYERS

"One of the things contributing to the growth of the SIAA is the increasing awareness of 'downstream' players – companies that are not in the traditional space industry but whose products and services could not exist without in-orbit space technology – and understanding that they are actually also part of the space industry," says Ball. "Think of the finance and transport sectors, both of whose global networks rely absolutely on robust satellite services.

"One of our goals is to educate the wider community how much space touches them on a daily basis – for example, the services they use daily that rely on space – and how space is powering these applications."

He cites the investment the Australian Government is making in positioning and navigation technology through Geoscience Australia's Space-based Augmentation System (SBAS) project. Australia is going to take a leading position in precision navigation, he says, when 10cm positioning accuracy is available right across the continent and 3cm accuracy is available in its

big cities. "The spillover effects of that are quite substantial: that will really revolutionise a number of space [enabled businesses], including precision agriculture and intelligent transport systems, to name just two, where you can see the impact of that efficiency and accuracy."

The broadening of SIAA's membership base will no doubt throw up some issues: different companies will have different priorities and will approach a common agenda from different directions, and that needs to be managed.

"That becomes quite challenging," Ball acknowledges, "because, for example, you look at radio frequency

"There's a great need for Old Space in this country, so there's a need for the SIAA to straddle both elements of the sector and to continue to deliver value for our members."

(RF) spectrum allocation: we want to encourage the use of space-based services using the RF spectrum that's available. In some cases, that puts the satellite industry into conflict with the terrestrial communications industry. There are industry discussions taking place about the use of the C-Band in satellite communications, for example. It's used in this country for critical communications infrastructure, but overseas there are some governments that want to license that band for 5G purposes. So, you'll start to see competing applications with telcos wanting to provide more services in what have traditionally been satellite bands."

As some organisations are also telco-based organisations with a satellite communications component, reconciling these competing demands can be challenging. "That's part of the

balancing act – trying to understand what the best use of that resource is for the public."

And that is exactly why the Australian space industry needs a strong, coherent voice and a unifying presence in the SIAA. In 2019 the Australian Space Agency canvassed the industry about certain aspects of space launch and the SIAA spoke for the industry as a whole in some of those conversations, making sure it put across the industry's point of view. The Agency has subsequently released a draft of its partial cost recovery guidelines for Australian space launches and will consult with the industry on its draft regulations during the first and second quarters of 2020.

However, it is not always easy presenting a unified view, Ball says. The SIAA represents all industry players, but some members' positions may not align with the general consensus on specific issues; that is the balancing act for an organisation that speaks for the entire sector.

BUSHFIRES AND NATURAL DISASTERS

The SIAA is also considering the implications of Australia's horrific 2019-20 bushfire season which had a widespread impact. Certainly, the potential for space-enabled imagery and Earth observation technologies is huge. Ball agrees: "We're looking at how we can assist further in research and capability development in the natural disaster area, not just limited to bushfires but floods as well; how space surveillance can help bolster situational awareness for fire-fighting and emergency services organisations."

Often firefighters are looking for a quick reaction capability where they use infrared (IR) systems on helicopters to get a detailed view of fire-front activities. "We need to understand how satellites can supplement that. But can you gather the data quickly enough and then download it, process it and transmit it



to the front-line operations team, to be able to provide meaningful information [to a firefighter]? The speed of some of those fire fronts has been staggering – do we have a [satellite] constellation that gives sufficient revisit frequency? That's the question."

As well as the firefighters, whole communities need reliable communications and situational awareness, both during the emergency itself and in the recovery period afterwards. Space is part of the solution, he points out.

Damage to infrastructure meant the public often were not able to access online updates and warnings, which resulted in confusion and uncertainty. Some of the first responders went into bushfire zones with satellite phones; more phones were dropped in later to help initial recovery. That very quickly changed to restoration activity, where community bandwidth requirements quickly rose beyond that needed for urgent voice communications.

Since then, there has been a lot of activity on the satellite communications front, says Ball. "Satellite [communications] enables very quick recovery in emergency situations. A number of our members have been active in installing systems to replace [destroyed or damaged] telecommunications infrastructure, using NBN satellite systems to re-establish cell phone services and wi-fi hot spots to help restoration and recovery activities."

INTERNATIONAL

The SIAA maintains its international relationships, says Ball, "but I wouldn't say it's our prime role as an organisation. We were the host for IAC 2017 in Adelaide, which was extremely successful and obviously paid dividends for Australia and the industry. We have subsequently had booths at some IAC events overseas. However, the primary focus for the SIAA is to support our members through activity within Australia rather than

through activities offshore. Some of our individual members may participate in international trade shows and events, but that's not where the SIAA should be allocating its resources."

The SIAA's board works on a pro bono basis – and the organisation presently only has one paid employee. The association needs to focus its limited resources where they make the greatest difference for members of the Australian space community.

The 2019 Avalon Air Show represented a more sustainable industry development and engagement model. This was tremendously successful from a SIAA perspective, says Ball, "And it provided a great platform to get space on the agenda amongst the wider aerospace industry discussion. That was a very worthwhile exercise for our organisation."

Talks are already underway to repeat and if possible expand this at Avalon 2021. ■

A FOCUS ON SPACE



The latter half of 2019 and early 2020 has seen a surge in space-related activity in Australia, with global tech giant, Thales, partnering with the Federal Government, academia and local industry.

The Thales group, with over 80,000 employees in 68 countries, brings significant reach and expertise across a diverse range of technology markets. In space, drawing on over 40 years of experience and a unique combination of skills, expertise and cultures, Thales Alenia Space continues to deliver cost-effective solutions for telecommunications, navigation, Earth observation, environmental management, exploration, science and orbital infrastructures.

Governments and private industry alike count on Thales Alenia Space to design satellite-based systems that provide anytime, anywhere connections

and positioning, monitor our planet, enhance management of its resources, and explore our solar system and beyond. Thales Alenia Space sees space as a new horizon, helping to build a better, more sustainable life on Earth.

Recently, Thales Alenia Space signed a new €78 million (A\$128 million) contract with the European Space Agency (ESA), on behalf of the European Commission, to upgrade Europe's EGNOS satellite navigation system. EGNOS – European Geostationary Navigation Overlay Service – is a satellite-based augmentation system (SBAS) developed by the European Space Agency and EUROCONTROL on behalf of the European Commission.

Thales Alenia Space will develop a new version of EGNOS (version V242B), incorporating new advanced functionalities. The upgrade will also expand the current EGNOS SBAS coverage zone, install a new generation of reference stations, enhance system security and improve algorithms in the computation centre to boost system performance.

EGNOS is the European satellite-based augmentation system, designed to improve the performance of global

navigation satellite systems such as GPS and Galileo. First deployed in 2005, with its open service operational since 2009, the current EGNOS system was developed by Thales Alenia Space as prime contractor.

ON THE HOME FRONT

"Leveraging the type of expertise gained on large international space programs such as EGNOS can also be a win for the Australian market," says Thales Australia Director Space Business Matt Dawson. "Space is an international effort, and Thales sees the huge opportunity to get Australians involved in this exciting, dynamic and growing industry."

In early December 2019, Thales signed a joint research agreement with the internationally renowned Melbourne-based RMIT, to define a precise point positioning (PPP) service channel and standardisation of message format for use in the spatial information and positioning business sectors.

"We are very excited about this strategic initiative which underscores Australia's ability to lead aspects of international standards development, leverage international expertise and our commitment to grow the Australian space sector in line with our Joint Statement of Strategic Intent with the Australian Space Agency," says Dawson.

"The work brings together, in Australia, the existing navigation technology base of Thales Alenia Space with the expertise and experience of RMIT researchers led by Associate Professor Suelynn Choy," says Thales Australia Director Technical Strategy Michael Clark. "It reflects the commitment of Thales to contribute to the development of Australia's space sector and bring our global expertise to opportunities such as the recently announced Australian and New Zealand strategic commitment to a satellite-

based augmentation system."

VP Navigation Domain Thales Alenia Space in France Benoit Broudy notes, "Thales Alenia Space is pleased to combine its complementary skills with RMIT to develop, deliver and sustain leading-edge precise positioning solutions."

The research work will focus on the definition of a new generation of high accuracy PPP services that will be an important part of a future roadmap for the evolution of positioning services in Australia. It will also provide a technology platform from which to develop regionally scalable solutions for export into a global market via the Thales global supply chain.

Also in December, Thales teamed up with the Australian Space Agency, a move that the Federal Government says will help place Australia firmly in the international space effort, and create thousands of new jobs for Australians.

Speaking at the event, Minister for Industry, Science and Technology Karen Andrews said the statement of strategic intent and co-operation is another important step in the federal government's plan to create opportunities for Australian industry and new local jobs. "Engaging with big international players like Thales will allow Australian businesses, including our advanced manufacturers, to carve out a place in the international space supply chain," Minister Andrews said.

"Space is very much an international game and for Australia to succeed we need to play to our strengths and have our businesses and researchers working co-operatively. This statement is designed to mutually identify key areas of investment as well as potential research, development and commercial opportunities."

Minister Andrews also noted that the Federal Government plans to triple the size of the Australian space sector by 2030, creating 20,000 new jobs and adding \$12 billion to our economy each year.

Chief Executive Officer of Thales Australia Chris Jenkins says the company was looking forward to working with the Australian Space Agency and harnessing the strength of its global expertise in the space sector to build Australia's sovereign capabilities.

"Thales has been a long-term investor in Australia's advanced technology sector, through comprehensive technology transfer and close collaboration with research agencies and specialised Australian SMEs," Jenkins says. "Together, Thales and the Australian Space Agency can build and develop the Australian workforce and SME sector to meet the future needs of the growing space economy."

PLANS FOR THE FUTURE

"In Australia, Thales has demonstrated an ability to become an internationally recognised leader in domains like airspace mobility solutions (AMS), where we now export to other countries systems in air traffic management (to the point where our systems now manage 40% of the global airspace) and cyber security," says Dawson. "We are very keen to add to this portfolio aspects of

the space market. We see that Australia can become a leader by leveraging our deep international capabilities, investing in the right research, teaming with the right partners and local SME businesses, cross-pollinating with our existing world-leading Australian capabilities and applying our substantial integration and management expertise.

"We are somewhat uniquely positioned to be able to do this and we are also looking forward to participating in Australia's upcoming civil and defence program opportunities to make this a reality for Australia."

ABOUT THALES IN AUSTRALIA

Thales in Australia is a trusted partner of the Australian Defence Force and is also present in commercial sectors ranging from air traffic management and ground transport systems to security systems and services. Employing over 3,700 people, Thales in Australia invested A\$24 million in R&D in 2019 and over A\$714 million in Australian SME businesses in 2018/19. Thales in Australia has generated export revenue of over A\$1.6 billion in the past 10 years.



QUEENSLAND SET FOR LAUNCH

Queensland's geographical advantages for launch activities and satellite control, combined with funding and a new strategic plan from the state government along with a critical mass of high technology start-up companies, is positioning the state for a future in space.

By **Lachlan Colquhoun**.

Many secondary school students in Queensland are currently working on the design and construction of their own rockets as part of the \$2 million Science of Rockets STEM program.

Announced in December 2019, the Science of Rockets STEM program has the support of one of the world's largest aerospace companies – Northrop Grumman – in partnership with Brisbane-based engineering company PFi, and

aims to promote interest in science, technology, engineering and maths (STEM) learning.

The course is being rolled out to 10 Queensland secondary schools in 2020, with another 50 schools projected to join in 2021.

"Many of the jobs of the future will require STEM and the kind of hands-on experience provided by this program helps to bring these subjects alive by turning theory into practice," said Cameron Dick,

Queensland's Minister for State Development, Manufacturing, Infrastructure and Planning.

"We want students to know that if you study science, you can build a rocket and build a career in the space industry."

The program will feature a "Rocket in a Suitcase", which will be the first commercially developed rocket motor in Australia to be exported.

The rocket is the size of a carry-on suitcase, and will be used to engage with students directly on skills the space industry is looking for and the career paths on offer.

Queensland's secondary students are not the only young people in the state developing expertise in rocketry.

In 2019, a team from The University of Queensland (UQ) was the overall victor in the inaugural Australian Universities Rocket Competition.

The UQ team won the 10,000-

feet category with its Athena rocket, and placed fourth in the 30,000-foot category with a rocket named Minerva.

This activity from young people is not taking place in isolation or in a vacuum, because Queensland is the national leader in developing next-generation rockets and spacecraft and has ambitions to be a centre for the launch industry.

Queensland's geographical advantages for launch activities and satellite control, combined with funding and a new strategic plan from the state government along with a critical mass of high technology start-up companies, is positioning the state for a future in space.

GILMOUR SPACE TECHNOLOGIES

One of the early leaders in the state's rocket industry has been Gilmour Space Technologies, which was founded by two brothers in 2013 and has grown to become a pioneer in new and innovative propulsion technologies.

Gilmour Space launched Australia's first privately developed hybrid rocket in 2016, an event which was also a world-first demonstration of a rocket launch using 3D-printed fuel.

"Before focusing on rockets, we had a business running astronaut training programs for schools and the public," explains the company's chief executive Adam Gilmour.

"We felt that the Gold Coast, with its high tourist traffic and proximity to Brisbane, was well placed for that business.

"When we started building rockets, it made sense to do it right next door and things just basically grew from there."

The company's goal is to build a three-stage rocket, called 'Eris', which will blast off into a low orbit and release small satellites at an altitude of around 160km above the Earth.

'Eris' would be a three-stage vehicle with separate stages that fire individual sections, and has been designed to handle all of the satellites which are currently being designed.

The business case is that although the small satellite revolution is gathering momentum, there is still a challenge around launch opportunities and launch costs, for which the hybrid rocket concept could be a commercial solution.

Gilmour has raised around \$27 million in venture capital funds through groups such as Blackbird Ventures and CSIRO-backed Main Sequence Ventures.

"Queensland is well placed as a location for a new launch industry and that is reflected in the number of rocket companies in the state."

The company is now firmly fixed on its first orbital rocket launch, now planned for 2022, but the company's ambitions do not stop there.

"I would like to see us launching up to 12 rockets a year by 2025, and also to have launched our Eris-Heavy rocket to a Moon or Mars orbit," says Gilmour.

"Beyond that, we want to look at human spaceflight and exploration of the solar system."

Queensland, says Gilmour, is well placed as a location for a new launch industry and that is reflected in the number of rocket companies in the state. The company works with a supply chain of 300 Australian suppliers, of which more than 100 are in Queensland.

"Whilst there aren't as many space start-ups here as in other states, Queensland is home to a unique concentration of launch-related companies," he says.

"This gives Queensland a comparative advantage in launch, especially as we hope to employ more than 1,000 people in our company within the next five years."

BLACK SKY AEROSPACE

Another Queensland-based rocket company is Black Sky Aerospace, which in November 2018 – less than eight months after its inception – launched Australia's first commercial sub-orbital payloads. The launch included a collaboration with The University of Queensland, with advanced ceramic composite materials developed and manufactured at UQ forming part of the body of the rocket.

UQ PhD student Christian Kudisonga says the launch demonstrated the university's ability to create technology and materials for the state's emerging space industry.

"This is a fantastic and unique opportunity to see the application of what we are working on in the lab in a real-world scenario," says Kudisonga.

"The part we've provided demonstrates a number of manufacturing processes that I have researched and developed as part of my PhD."

Kudisonga is doing his PhD in UQ's Centre for Advanced Materials Processing and Manufacturing, which is developing ceramic matrix composites which, unlike alloys, are lighter and can handle high mechanical stresses of up to 3,000 degrees Celsius.

To test it and its customers' rockets, Black Sky uses a sub-orbital launch facility just outside of Goondiwindi, around 300km from Brisbane.

In February 2020, UK company Raptor Aerospace worked with Black Sky on Australia's first privately operated, international rocket motor test and sounding rocket launch campaign.

The collaboration came after

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QUEENSLAND'S SPACE INDUSTRY: A RICH HISTORY – A PROMISING FUTURE

Fifty years after humankind first set foot on the moon, the Queensland Government has launched a new plan to set the state's burgeoning space industry on a growth trajectory for the next five years.

Queensland has a rich history in the space race, from helping Apollo 11's monumental moon mission via Toowoomba's Cooby Creek Tracking Station to hosting an emergency landing site for the space shuttle program at the Royal Australian Airforce Base Amberley.

As the Australian Space Agency gets ready to support the Moon to Mars mission through its partnership with NASA, Queensland is on its own mission to secure more opportunities for the local space industry, domestically and around the world.

Queensland's space industry is growing at an astronomical rate of 7% each year, and there are commercial and career opportunities right across the Sunshine State.

With its track record in space, it is no wonder Queensland's \$760 million space industry already employs around 2,000 people.

But it is the future that counts, which is why the Queensland Government has released a Space Industry Strategy to maximise the potential of Queensland's expanding space industry.

Minister for State Development, Manufacturing, Infrastructure and Planning Cameron Dick says the Queensland Government's \$8 million investment in the Queensland Space Industry Strategy 2020-2025 will accelerate the industry into a new growth phase.

"The strategy leverages Queensland's key strengths in launch

activities, satellite control, space system design and manufacturing, as well as in space-enabled services such as Earth observation," Dick says.

"The opportunity for Queensland is enormous. With the right growth conditions, Queensland's space industry could support 6,000 jobs and contribute up to \$6 billion to the state's economy by 2036.

"This isn't guesswork either, it's based on economic modelling conducted by Deloitte Access Economics.

"Queensland has defined geographical advantages and industry strengths that we're ready and eager to tap into."

Queensland is close to the equator, on Australia's east coast, and has large areas free from radio traffic with high-speed internet thanks to the state's remote mining industry. It also shares a similar latitude to Cape Canaveral, where NASA and Space X launch from.

Gilmour Space Technologies founder and CEO Adam Gilmour says it is great to see Queensland commit to growing this future industry in Australia.

"The ever-increasing demand for big data is driving the world's demand for satellite services and the need to launch, build and control satellites," Gilmour says.

"With Queensland's existing industry and geographical strengths, the opportunity is huge."

Queensland could be well-positioned to launch rockets. The state's proximity to the equator means that rockets launched from Queensland can launch with the Earth's rotation and pick up an additional 460 metres per second.

Queensland is also an ideal place for new southern hemisphere

Earth stations, which require high-speed internet in radio-free areas. Queensland has this in abundance, and its location near the equator means operators can control satellites as they fly across the eastern seaboard and into the northern hemisphere.

In addition to this, Queensland has Australia's most advanced launch vehicle developers, as well as some of Australia's brightest minds in robotics and automation, all of which are in high demand as more satellites are launched and global space missions grow more ambitious.

The state also leads Australia in Earth and marine observation, which is already worth US\$20 billion to the national economy, primarily through productivity and cost savings to Australia's primary industries.

Cameron Dick says through the Queensland Space Industry Strategy, the Queensland Government is taking the state's rich space history towards a new and promising future.

"Queensland's space industry is an opportunity for everyone. Queensland is a leader in the southern hemisphere in things like aerospace manufacturing and repair, advanced manufacturing, robotics, defence industries and remote mining," he says.

"By creating the right conditions for industry growth through things like space-related infrastructure, the Queensland Space Industry Strategy is opening up new investment, business and career opportunities in an industry where the sky is not the limit."



**Queensland
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"This campaign with Raptor Aerospace is driving additional export opportunities for Black Sky's technology, whilst solidifying Australia's position as the place to conduct research and testing before undertaking expensive orbital launches."

the UK Space Agency and the Australian Space Agency announced a partnership designed to open up new trade opportunities.

Ben Jarvis, the chief executive of Raptor Aerospace, says while the UK is likely to develop space ports which would allow some of the company's commercial activities to take place in their home country, a site like Goondiwindi offered some advantages.

"Many customer payloads and test flights, where recovery of sensitive electronics after flights is critical, will need a land range to fly from," he says.

"Black Sky Aerospace has offered us access to a suitable inland site and invaluable expertise that we hope will lead to an ongoing commercial collaboration that forwards space access in both countries."

His comments were reinforced by Blake Nikolic, Black Sky Aerospace's chief executive, who said Australia was playing an increased role in the world's "space ambitions".

"This campaign with Raptor Aerospace is driving additional export opportunities for Black Sky's technology, whilst solidifying Australia's position as the place to conduct research and testing before undertaking expensive orbital launches," Nikolic says.

THE UNIVERSITY OF QUEENSLAND

Another significant Queensland contribution in the field of propulsion is the three decades of research at The University of Queensland (UQ) into hypersonic scramjet technology.

Scramjet engines are projected to be able to operate at higher speeds,

of up to at least Mach 15, and their commercial application lies in creating a launch platform which can fly to space, and reduce the cost of putting up small satellites while also reducing waste and environmental impacts.

Once again, the business case is determined by the growing satellite industry. The commercial market for satellites in the 25kg to 200kg class is rapidly expanding, but is constrained by launch costs.

From UQ's Centre for Hypersonic Propulsion a company has been created – Hypersonix – to further develop and commercialise the technology.

Hypersonix is developing a launch system called SPARTAN, which uses two booster rockets to accelerate to supersonic speed but also has the ability to return to the launch site, and to be re-used again in a craft the company calls Boomerang.

In 2015, UQ joined with some Brisbane-based start-ups to fly a scaled version of the Boomerang booster.

These tests, and further flights in

2017 – including tests at Woomera in South Australia – proved that the Boomerang could fly once its wing and propeller, used for re-entry, were deployed.

The next stage in the scramjet story is for Hypersonix to achieve a world first re-entry of the Boomerang booster from an altitude of 30km.

This technology may not be fully deployed until the 2030s, but UQ has invested heavily over a long period in its development and the state is well placed to remain a leader in game-changing space technology.

TERTIARY PROGRAMS

Other tertiary institutions in Queensland also have cutting-edge high-technology programs which have applications in the space industry.

At the Queensland University of Technology (QUT), the Centre for Robotics and the Centre for Robotic Vision have become centres of excellence for the development of next-generation robotics and automation technologies.

In July 2019, the Queensland Government announced a partnership with QUT and global leading-edge company Urban Art Projects (UAP) to create Australia's first robotics manufacturing hub.

The government is investing \$7.71 million over four years in the facility, which is called the Advanced Robotics for Manufacturing (ARM) Hub, and – together with partner investment – the total invested will reach \$18 million.

The announcement followed a report commissioned by QUT, which found that the adoption of robotics and automation in Queensland over the next 10 years could add 1.5% to state growth, a \$77.2 billion boost to gross state product, and create over 725,000 new jobs.

QUT, whose Vice-Chancellor Professor Margaret Sheil is on the advisory board to the Australian Space Agency, will itself invest \$4 million into the hub.

"This will provide expertise in high-value product development and the integration of new technologies into the manufacturing process," Professor Sheil says.

The third Queensland university participating in space is the University of Southern Queensland (USQ), where the Centre for Astrophysics operates the Mount Kent Observatory, which scours the sky and is in partnership with the University of Louisville in the US.

In 2019, the Mount Kent facility was upgraded with an array of new

technology and telescopes which will enable USQ researchers and students to be at the forefront of ongoing planet discovery work.

USQ is involved in supporting NASA's Transiting Exoplanet Survey Satellite (TESS) which is currently searching for new planets, some of them potentially habitable.

After the upgrade, Mount Kent is the only facility in the southern hemisphere dedicated to TESS support, giving it a critical role in understanding planetary systems orbiting the stars of the solar neighbourhood.

"Mount Kent Observatory is a unique research facility for the future of astronomy and space in Australia," USQ Vice-Chancellor Professor Geraldine Mackenzie said at the opening of the upgrades.

"USQ astrophysicists have contributed to the discovery of more than 100 exoplanets, with more than 30 alone in the past 12 months."

With NASA and the German Aerospace Centre, the Mount Kent facility is supporting a project to monitor the movement of space junk.

USQ is also working with Gilmour Space Technologies and Teakle Composites on a \$12.5 million project to create lightweight rocket fuel tanks.

The university has plans to open a static rocket testing facility in the Helidon area, in Queensland's Lockyer Valley.

USQ Professor Peter Schubel, who is the executive director of the university's Institute for Advanced Engineering and Space Sciences, sees that the region around Toowoomba and the Darling Downs could become a centre for the industry.

The testing site, for example, would be the only facility of its kind in Australia outside of the Australian Defence Force, and would draw rocket manufacturing companies to the region. ■



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SPACE AND OUR FUTURE: UNLIMITED OPPORTUNITIES AT WESTERN SYDNEY UNIVERSITY

Increasingly, the world is becoming dependent on outer space technology. More than ever, the exploration and use of space, and our development of space-related technologies, impact our daily lives. And the speed at which this takes place is phenomenal.

As a result, one of the most politicised and complex challenges of our time has become the need for a more comprehensive and detailed legal, regulatory and policy framework for outer space. In order to meet these challenges, all stakeholders need to work together to find a path forward.

The existing international regulatory framework, while important, cannot alone regulate the specifics of the ever-increasing range of space activities – and the possibilities that still lie before us. This presents an opportunity for governments, regulators, industry, scientists, engineers, astronomers, lawyers, entrepreneurs and civil society to work together and develop appropriate frameworks for the future.

We therefore stand at the forefront of quite remarkable technological developments that have the potential to make this coming decade a turning point for humankind's activities in

space. Among other possibilities, several countries and private entities have plans for permanent human settlement in space, space resource exploitation/utilisation on the Moon and other celestial bodies, the operation of very large constellations of small satellites, on-orbit servicing activities, commercial human spaceflight services and a ratcheting of rhetoric about space as a 'war-fighting domain'.

Coupled with this, the challenges associated with the increasing proliferation of space debris raise an imperative for us to alter the current 'business as usual' model in an attempt to address the risk of a 'tragedy of the commons' scenario in space. Such an outcome would significantly compromise humankind's capacity to garner the incredible benefits that responsible space activities might offer in the future.

Within this context, space is also a highly commercialised area. The global space economy is approximately US\$400 billion annually and is growing at 2-3 times the world economy overall. Space offers tremendous opportunities and myriad challenges – challenges that can only be overcome through innovation, expertise, knowledge and imagination.

At Western Sydney University, we educate and equip our students to meet the challenges of the 21st century, recognising the significance of technology in its conception, development, refinement and application. We understand that space-related technology, both in space and on Earth, will play a key role in the future of industry and, indeed, of humankind.

We are world leaders in the area of international and national space law and policy, and engage in cutting-edge science and research in space-related disciplines, such as neuromorphic engineering, cybersecurity, radio astronomy and innovative technology start-ups.

We understand that space is multifaceted – it is at once strategic, commercial, political, cultural, scientific, military and humanitarian. The increasing complexity of and dependence on space-related activity raises a broad range of difficult and complex issues that demand a consolidated and expertly informed approach to education, learning, research and application.

This is the Western Sydney University way. Come and join us at Western and discover your potential to make a difference in the world and in the way we will live in the future.



ADVISING FOR SUCCESS

The Australian Space Agency Advisory Group exists to give advice to the Agency on its strategic direction, and to help facilitate productive collaboration within Australia and also internationally. By **Lachlan Colquhoun**.

One day, Professor Lisa Harvey-Smith hopes to see legions of young Australians wearing T-shirts sporting the logo of the Australian Space Agency, as many today wear NASA T-shirts.

"It is a powerful logo, which looks at first glance like a map of Australia but is built on the idea of indigenous astronomy," says Professor Harvey-Smith.

"If we can inspire young people to

recognise and wear this logo then we will have had some success."

The wearing of T-shirts might belong in the world of popular culture, but if it does take off as Professor Harvey-Smith hopes, it will also mean that a generation of young Australians will have been inspired by Australia's own space industry.

Inspiring young people is a key focus for Professor Harvey-Smith in her role as the Australian

Government's first Ambassador for Women in STEM, and in her position as a member of the Australian Space Agency Advisory Group.

The Group comprises eight members with expertise spanning academic research, space law, astronomy, industry strategy and in the case of Andy Thomas, practical experience as an astronaut.

Other members of the group have led key organisations such as the Australian Research Council and Geoscience Australia, while others have experience in consulting to NASA and authored white papers on maximising the commercial value of the Space Agency.

The Group exists to give advice to

the Agency on its strategic direction, and to help facilitate productive collaboration within Australia and also internationally.

MORE THAN LOGOS ON T-SHIRTS

For Professor Harvey-Smith, an astrophysicist and author who is also the Professor of Practice in Science Communication at the University of New South Wales, success for the space agency will be measured by much more than logos on T-shirts.

"I know it sounds cute, but if kids are wearing Australian Space Agency T-shirts then it will mean we will have done a good job in really inspiring the next generation and making them feel that as an Australian citizen you can really launch yourself into space – figuratively at least – and become part of that exciting journey," she says.

"Because if we flip only 1% of our workforce into STEM roles then we will add \$57 billion to our economy in the next 10 years, so it is really important that we get this switch right for the sake of the economy."

Fewer than 10% of Australian engineering students in 2020 are female, so a key to the future – and in overcoming a national shortage of engineering skills – is to inspire more young women to take up STEM careers.

Astronomers, she jokes, often "joke that astronomy is a gateway drug" to inspiring young people with STEM.

"Kids love astronomy, and I have presented at schools around the country and it is something which gets everyone engaged, no matter what cultural background they come from," she says.

The advisory group, and the Space Agency itself, says Professor Harvey-Smith, is not so much about putting people in space, but in developing high-technology industries in areas such as Earth observation, AI and

robotics which are now a part of the wider space industry.

"Success for the Space Agency will mean jobs in the industry, in the financial turnover of the industry, and it will also translate into capturing the public imagination," she says.

"The Agency can help make sure we have the right laws and frameworks for launches and landings, and that our satellite industry can link up with other major organisations in the world who are also working on this technology."

Earth observation, for example, is one area which is increasingly more critical.

Australia has had this capability for some time but the Space Agency is an opportunity to organise and co-ordinate the capability as a peak body.

"A sovereign capability to monitor our land for bushfire and drought, to understand our soil, the oceans and the weather – these are very relatable and are actually a matter of life and death," says Professor Harvey-Smith.

"The Australian context is quite different to anywhere in the world. If the Space Agency can plug these capabilities into organisations such as the Bureau of Meteorology and the CSIRO, then we can really develop this important work in Earth observation.

"Part of my role is inspiring young people in a meaningful way which will give them tangible pathways in their studies, not just in seeking jobs but in creating jobs and having the confidence and capability to start their own ventures and adventures."

Australia, she said, needs homegrown entrepreneurs such as SpaceX founder Elon Musk, and she pointed to Flavia Nardini – the founder of South Australian satellite company Fleet Space Technologies – as a female entrepreneur who could inspire the younger generation.

"I have toured Australia with Apollo astronauts, and the theatres are packed out," says Professor Harvey-Smith.

AUSTRALIAN SPACE AGENCY ADVISORY GROUP MEMBERS

Professor Steven Freeland
Dean and Professor of
International Law, Western
Sydney University

Professor Lisa Harvey-Smith
Australian Government
Ambassador, Women in STEM
Professor of Practice in Science
Communication, UNSW
Research Group Leader, CSIRO's
Australia Telescope National
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Professor Peter Klinken AC
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Chair, AuScope Limited

Frank Robert
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AT Kearney

Professor Margaret Sheil AO
Vice-Chancellor and President,
Queensland University of
Technology (QUT)
Member, CSIRO Science Industry
Endowment Fund

Dr Andrew Thomas AO
Advisor to the SA Government
on space



"In the future I hope we can have some stories of Australian space triumphs, and I think we need these new role models and we need to see them in schools and put them at the forefront."

A MORE COLLABORATIVE INDUSTRY

The space industry, Professor Harvey-Smith said, was now much more collaborative than in the past, and even missions which were "badged" as NASA involved contributions from other agencies and companies from around the world.

"The role of the Agency is to help Australian companies which are doing great work to get their foot in the door and talk to these other agencies so we can collaborate and build up our industry," says Harvey-Smith.

"We can make the best of our position in the southern hemisphere and our huge land mass which can be used for launches and also landings, which we will see this year when a Japanese spacecraft brings a piece of a comet back to earth."

Another Advisory Group Member, Margaret Sheil, says the Space Agency can be a catalyst for the further development of skills Australia

has already built up in areas such as astronomy, robotics and automation.

"We have great strengths in these areas and the Space Agency is a great opportunity to leverage the investments we have already made," says Professor Sheil, the Vice-Chancellor and President at the Queensland University of Technology.

"Here at QUT we have the Centre of Excellence in Robotic Vision, for example, and that can have significant applications in space in helping process data collected by robots.

"We made investments in geospatial imaging and in astronomy, and all of this puts us in a very good position for a future in space."

Professor Sheil, a former chief executive at the Australian Research Council, sees the Space Agency as a way of connecting with international space programs, which were increasingly collaborative.

"When I was at the ARC we often had the question of dealing with international agencies, and we sometimes missed opportunities in the scientific area because we didn't have a central point," she says.

"The Space Agency can be that central point to aggregate our capability, leverage our research and

development and be a catalyst to bring together a whole range of opportunities."

Professor Sheil said there was significant "early momentum and enthusiasm" for the Agency; the Advisory Group was there to help capitalise on that and assist the team "in doing bigger and better things".

"Space is seen as the fun part of science," she says.

"I am involved in a lot of organisations, but whenever I tell people I am on the Advisory Group for the Space Agency people always say 'how cool'.

"So for a whole range of reasons it has a positive vibe and that will encourage young people to go into these areas."

One QUT alumni, for example, was working at the NASA Jet Propulsion Laboratory, and while this was a testimony to Australian education and expertise it was important to create an industry in Australia which young people can participate in.

Professor Harvey-Smith agrees, and says the talent flow must be "two way" rather than a brain drain.

"In a healthy two-way economy you have that talent leaving to learn and get experience but also coming back home again, and that is what we need to help build," she says.

"We need that homegrown talent to drive invention and innovation, and create strong companies which can be an example."

She herself is an example of that, having been born and educated in the United Kingdom before coming to Australia 13 years ago, where one of her first roles was working on the CSIRO's Australia Telescope National Facility's Science Program.

"Working on those telescope programs has been one of the most exciting things I have worked on in my career so far, and I had that opportunity in Australia," Harvey-Smith says. ■

SPACE: A NEW FRONTIER FOR LAW

By **Lachlan Colquhoun.**

Space is, according to one common saying, “competitive, contested and congested” but, according to Professor Steven Freeland, it does not have to be limited in that way.

Professor Freeland, a Professor of International Law at Western Sydney University, is Australia’s pre-eminent expert in space law and has advised the Australian Government, as well as a number of other governments and the United Nations.

He is a Director of the International Institute of Space Law based in Paris, a Senior Fellow at the London Institute of Space Policy and Law, and also sits on the Australian Space Agency Advisory Group.

“Space might be competitive, contested and congested, but it is also many other things at the same time,” says Professor Freeland.

“It is also communal, collaborative, commercial, cultural and co-operative, and we just have to make sure that, before anyone crosses any unacceptable lines of behaviour in space, they understand the consequences of their actions.”

Space law has had a unique development path, but is continually evolving due to the changing nature of how humans are using space, as well as the phenomenal development of space-related technology.

Today, space law needs to consider many new issues as humanity embarks on another phase of exploration and use.

Issues such as mining and property rights, tourism, space junk, the rules of war and commerce, liability and

damage now must be considered, with a vision long into the future to anticipate further developments.

The origins of space law go back to 1919, when international law recognised national sovereignty over air space, and developed further in the 1950s and 60s as the US and the Soviet Union engaged in the Cold War on Earth, and the Space Race above.

The result was a set of principles that were set out in a document known as the Outer Space Treaty, which still provides the fundamental tenets for space law today, prohibiting the placing of nuclear weapons in space and establishing that space is free for peaceful exploration by all nations. Unlike air space, it does not form part of the sovereignty of countries, but rather is a ‘commons’ for all to freely access.

“Even though the US and the Soviet Union were protagonists in the Cold War, they agreed to these fundamental principles in space, which have served us well ever since,” says Professor Freeland.

While the world does have the Outer Space Treaty, the laws of each

individual country are respected in different parts of the International Space Station, where – depending on the module of the structure – US, Japanese, Russian, Canadian and EU laws will apply.

“This is impractical for other situations, such as a potential human colony on another planet,” says Professor Freeland.

“If we are to have permanent human settlements in space and on celestial bodies then we will have to sit down and create appropriate law, and it will have to be a law written for people who are in a hostile environment and who are totally dependent on each other.”

Australia has also had its own national space law since 1998 – the Space Activities Act – the creation of which was prompted by hopes that Australia would become involved at that time in the commercial launch industry.

Professor Freeland was involved in reviewing those laws for the Government in 2015/2016 and a subsequent consultative process saw the law amended in 2018 and renamed the Space (Launches and Returns) Act.

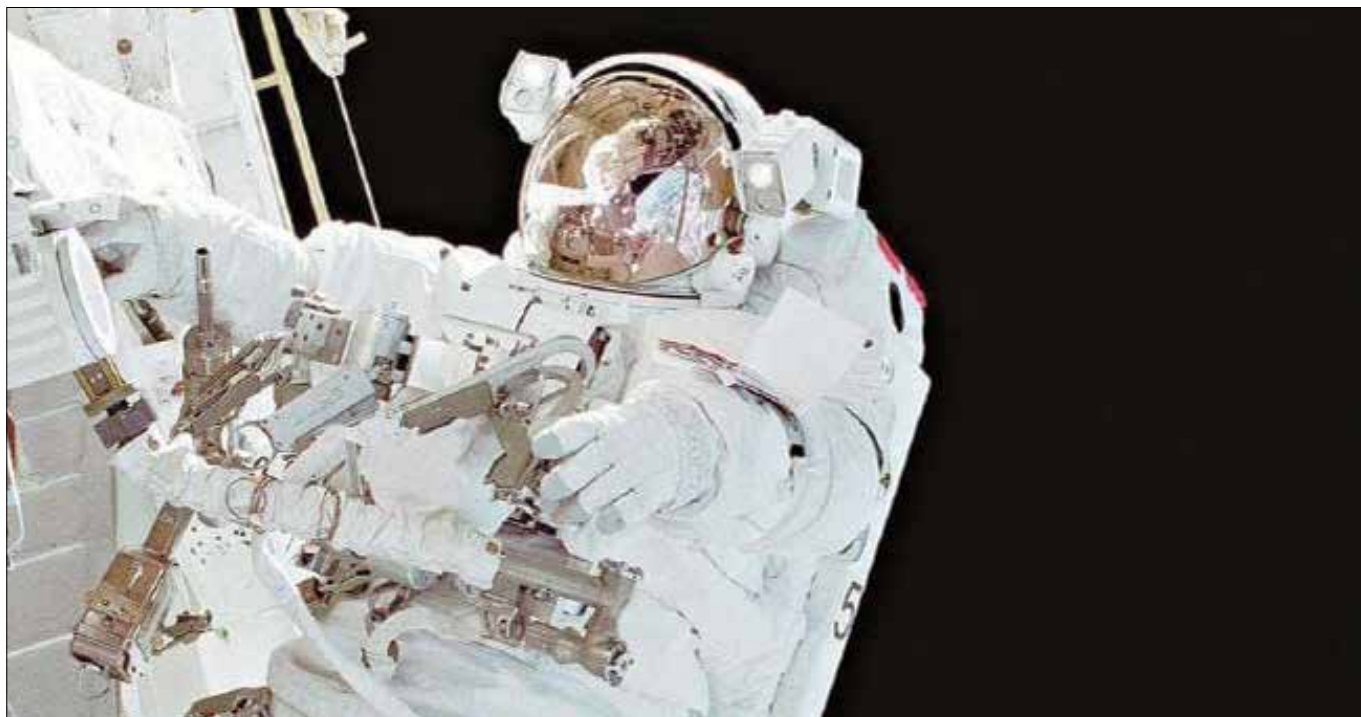
“It is now much more streamlined and approachable for many of the small entities that are involved in the industry,” he says.

“Space law really will continue to be a work in progress, as it aims to support and regulate evermore complex uses of space.

“Many people believe that the future of humanity rests on how we continue to interact with space, and it is therefore important that we retain a sense of the ‘humanity’ of space and reflect this in appropriate rules of the road.” ■



Professor Steven Freeland



ANDREW "ANDY" THOMAS AO: FIRST AUSTRALIAN IN SPACE

Andy Thomas took part in four space missions between 1996 and 2005 and has the distinction of being the first Australian in space.

By **Lachlan Colquhoun**.

As a boy growing up in Adelaide, Andy Thomas was fascinated by the World War I era Vickers Vimy biplane on display at the city's airport.

The Vimy was flown by brothers Keith and Ross Smith on an epic flight from London to Australia in 1919, a feat Thomas describes as "one of the most significant undertakings of the last century".

Perhaps it is just co-incidence, but the ancient biplane is set to be relocated in a bold new display at the airport just as Adelaide reclaims its status as a leading centre of the Australian space industry as the home of the new Australian Space Agency.

"I always found it astounding that we went from a fabric-covered Vimy biplane to landing on the moon in 50 years," says Thomas.

For Thomas, the Vimy and the 1960s activity at the Woomera Rocket Range – as it was called then – all formed part of the boyhood inspiration which began with building model rockets out of plastic and cardboard, and then took him to Adelaide University to study engineering and then on to a career with Lockheed and ultimately NASA.

As an astronaut, Thomas took part in

four space missions between 1996 and 2005 and has the distinction of being the first Australian in space.

Although he lives in Houston, where his wife is an active astronaut, Thomas still spends a lot of time in Australia, and in Adelaide, where he is a member of the Australian Space Agency Advisory Group and an adviser to the South Australian Government.

"I'm very pleased to see the creation of the Space Agency, because I have to admit there were times in the past where I actually thought it wouldn't happen, but I'm delighted it has," says Thomas.

"I think that the current generation of political leaders understood that space didn't just mean human space flight, and that it means a lot more than that.

"There is now an understanding

that there is \$300 billion to \$400 billion in space-related business around the world, and Australia has a disproportionately low share of that, but now having an agency with centralised planning and long-term strategic thinking, we can start to participate better in this sector."

Space, says Thomas, impacts on people's lives in so many ways beyond human space flight. Space is intrinsic in the technology of modern communications and media systems, for global positioning and navigation, for the monitoring of resources on earth, and for national security.

"These areas are where there is a potentially big payoff for a country like Australia, which has large spaces and open borders and a small population," says Thomas.

"Space technologies such as robotics also have significant applications in other areas, such as mining, driverless cars and trains.

"So you can make an investment in the space sector and it has parallel payoffs in the commercial sector, or you can make investments in the commercial sector which have payoffs in space."

Thomas still sees South Australia as having many natural advantages as a centre for the space industry.

"The state has a robust education sector and robust industry, and a legacy not just from the 1960s but a recent legacy of building satellites, and it has the technical expertise to develop this," he says.

"And there are geographic advantages if ultimately we want to develop a launch site for polar satellites, because anywhere on that southern coast is ideal."

The Woomera facility has also been underutilised in recent years and is a significant asset which could be part of a greater and more co-ordinated space industry, in which Australia collaborated more closely with other

countries and some of the emerging private industry participants.

"Woomera is bigger than some countries," says Thomas. "It is a unique facility for testing space-borne assets and spacecraft which can be worked a bit harder as we capitalise on the space agency."

After years of arguing in favour of greater Australian involvement in space, Thomas now welcomes what he sees as a "paradigm shift" in thinking on the issue.

"Today, it is an economic argument about developing a whole industry around space, and I'm really glad this thinking has gained some traction and we are getting involved, even if we are a late starter," he says.

"People say 'why are we spending money at NASA' as part of the Artemis program? Well I say that Australia is not spending money at NASA, we are making investments in Australia for Australians to support collaborative ventures with NASA.

"And that is a win-win for everyone. Because it means that for a modest investment Australian scientists and engineers will be exposed to all the technologies in the NASA communities so we will be able to leverage that investment and give us more bang for our buck."

Thomas has a vision for Australia to not only be a launch centre, with locations for polar satellites in South Australia and for equatorial satellites at Cape York in Queensland, but also as a participant in the industry around the next generation of smaller satellites.

"This is the so-called Space 2.0 era, and for satellites it means much smaller satellites which are cheaper to build and cheaper to launch, so come at much lower risk," he says.

Success, says Thomas, will need to be measured in jobs and industry growth, and he is urging the space agency to keep track of these metrics over time as a way of demonstrating its value not



Andy Thomas

just in the short term, but over a generation.

Finally, in any discussion with Thomas one question is inevitable. As one of the few humans – and Australians – to have visited space, what was it like?

"It is an experience of contrasts," he says.

"To get there you go through the most extraordinary ride of your life with fire and smoke and sound and vibration and tremendous acceleration.

"Nothing can compare with that. On one of my flights I looked at the faces of my colleagues and thought there could be no other humans doing anything quite like what we were doing at that moment."

After the initial rush, the experience changed completely.

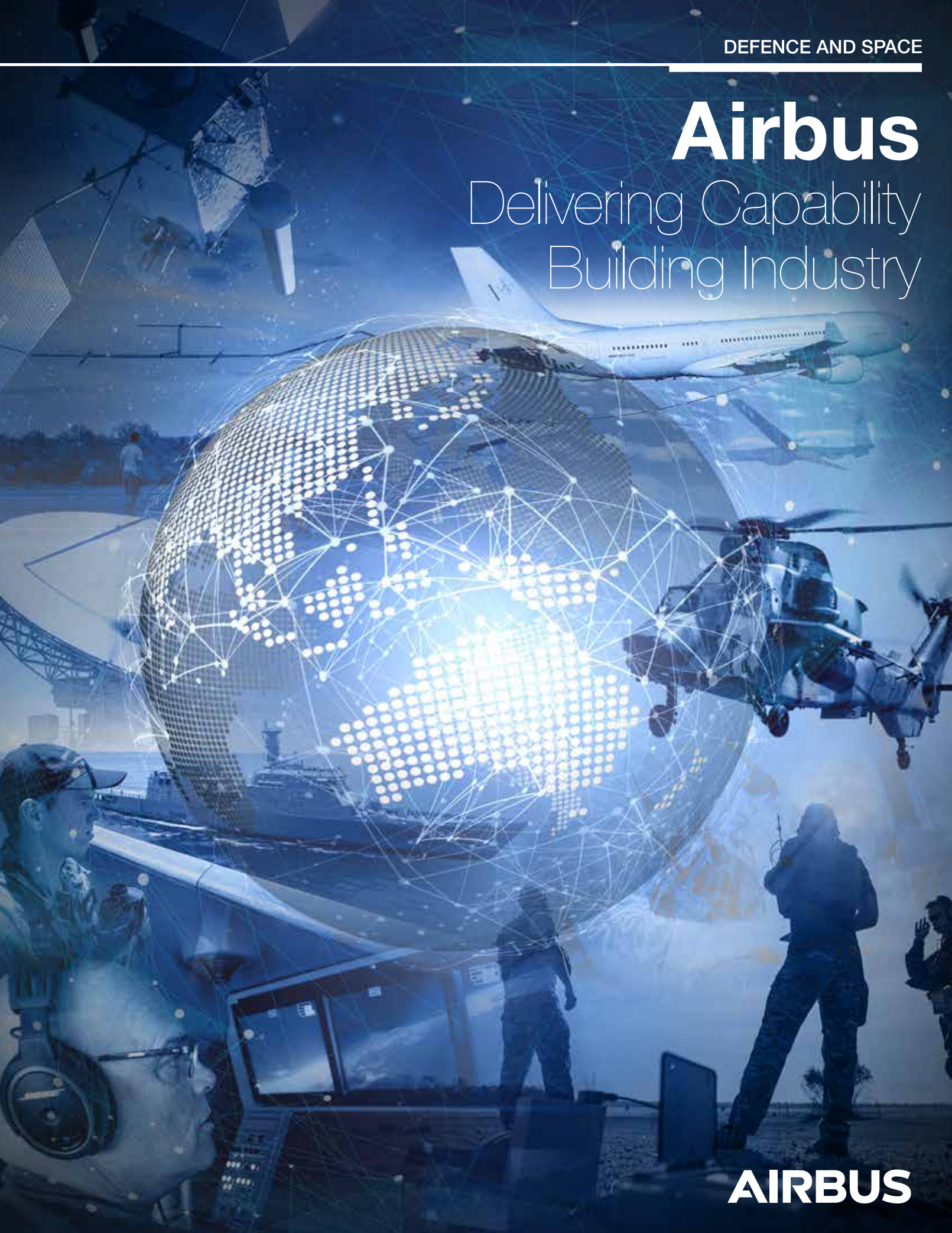
"Once you shut the engines down you are suddenly in this serene, tranquil and peaceful environment," says Thomas.

"I remember when I was on the Mir space station I thought I would be crossing off days on the calendar and waiting to get back to Earth, but I had this whole serenity about the experience.

"You can look out and see a profound and deep blackness and know you are looking towards infinity." ■

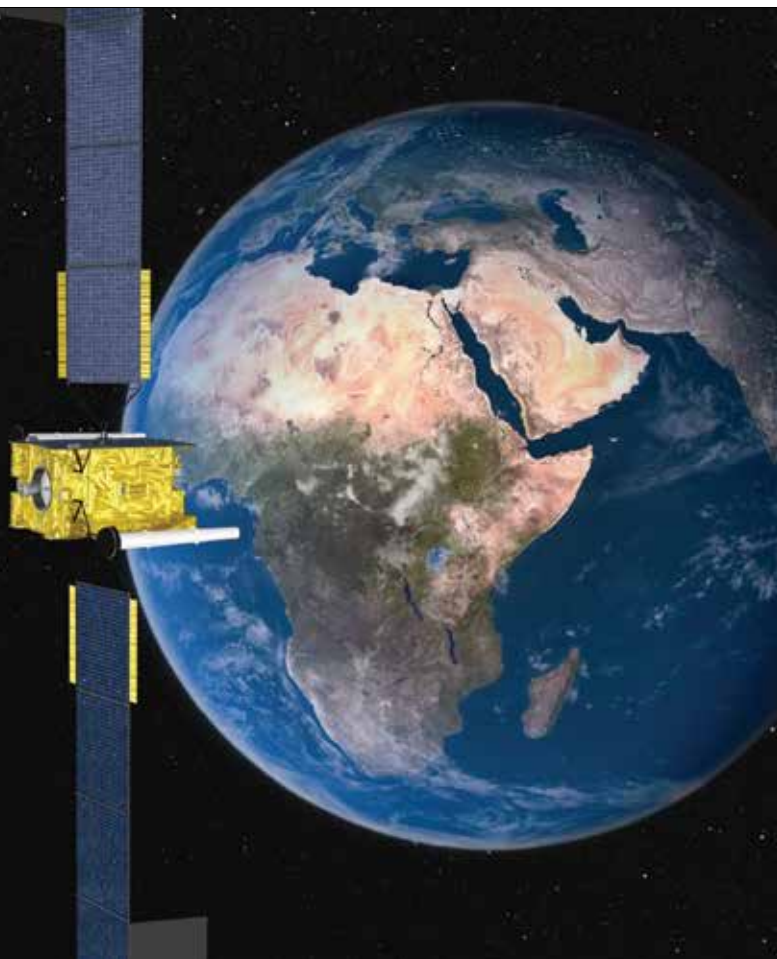
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AUSTRALIAN DEFENCE FORCE SPACE PROGRAMS



For the time being, Defence remains the biggest single customer of Australia's space sector. By **Gregor Ferguson**.

One of the truisms about Australia's space industry is that Defence is the major spender on space goods and services in this country. While that will change as the industry's civil sector growth spurt accelerates over the next few years, Defence (and especially the RAAF) will remain for a while the biggest single customer for Australia's space sector.

Defence has long recognised the

imperative of space mastery for both communications and intelligence, surveillance and reconnaissance (ISR). Since the mid-20th century it has invested heavily in global satellite communications (SATCOM) capability, notably with the purchase of dedicated Defence transponders on commercial satellites such as the Optus C1 and the agreement over 10 years ago to fund one of the US Air Force's 10 Wideband Global SATCOM (WGS) high-capacity X and Ka band communications satellites. Having provided the funding for one of these geostationary satellites gives Australia access, globally.

Now Defence is looking to modernise its SATCOM infrastructure and extend its space-based ISR capabilities through three major projects.

JP9102

Joint Project 9102 aims to roll together some of the ADF's existing narrowband and wideband SATCOM systems, along with new functionality, including new satellites and ground infrastructure, according to Luke Brown, Assistant Secretary Space and Communications in Defence's Joint Capabilities Group.

Secure, wideband communications make possible everything else that Defence plans to do across its area of interest, so the new Australian Defence SATCOM System (ASDSS) is a critical enabler, says Brown. First Pass approval from the Australian Government is expected later this year; a tender in late 2020 would see a contract signed in 2022 or 2023, and the ASDSS should start entering service from around 2027 or 2028, he



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"Defence's aim is to launch a constellation of approximately four Australian-owned geostationary satellites that cover Australia's entire area of interest and enable secure SATCOM in at least UHF, X-band and Ka-band – Australia's first sovereign satellite capability in this critical area."

tells *Australian Space OUTLOOK*.

The project is not yet approved by Government and Defence has not disclosed a budget for JP9102, but *Australian Space OUTLOOK* estimates put its worth at up to \$3 billion. Its planned footprint covers the Indian and Pacific Ocean regions. The ASDSS will not cover the entire area at once, but needs to be able to steer coverage to any part of this footprint when required, at very short notice.

Defence is planning JP9102 as an integrated program: where possible, it will gather up a lot of existing SATCOM infrastructure – both ground stations and satellite payloads delivered a decade and more ago under separate phases of JP2008 – in a holistic capability that will be delivered as an integrated program.

Defence's aim is to launch a constellation of approximately four Australian-owned geostationary satellites that cover Australia's entire

area of interest and enable secure SATCOM in at least UHF, X-band and Ka-band – Australia's first sovereign satellite capability in this critical area. JP9102 will also upgrade or replace existing ground stations, deliver a highly resilient SATCOM Management System that can grow and evolve with changing needs and new technologies, and deliver two new Satellite Operations (SATOPS) centres, a primary and a back-up.

"It is important that the selected solutions provider has the capability to build on the existing ground infrastructure, while ensuring the current systems are enhanced to complement the new satellites and keep pace with ADF's requirements into the next decade," says Airbus Defence & Space's head for Australasia, Thomas Pfister. The operational life of a satellite is typically 15 years, he adds, while the ground element of the system can

be significantly longer, with regular updates and technical upgrades. It can take three years to plan and deploy a military SATCOM system based on commercial ground and space assets, says Pfister, while a more complex, resilient and responsive system can take five years.

If approved, the new JP9102 satellites will be classic communications 'birds': fairly big, with a life of as much as 15 years, says Brown. Defence is not planning to use cheaper cubesats in low Earth orbit (LEO): LEO cubesats simply are not ready for this role yet.

Defence has been consulting and informing Australian and international industry since 2018 to ensure both customer and potential contractors understand the operational and technical challenges and potential solutions. *Australian Space OUTLOOK* believes that contenders may include Airbus and US firm ViaSat.

ViaSat could offer a system built around its Hybrid Adaptive Network (HAN) which would allow Defence access to both a Defence-owned SATCOM network and a commercial one, simultaneously. In addition, it is developing the third generation of a family of communications satellites



Luke Brown

which should be available for service in time for JP9102.

Airbus's offer could be based on its history of secure military SATCOM technology, including the UK's Skynet 5 and the Spanish SpainSAT NG1 and NG2 systems which deliver UHF, X- and military Ka-band communications. And its Australian footprint includes an

its operational life. It will draw upon Airbus's expertise with the Skynet 5 system, a highly secure end-to-end SATCOM system which it uses to deliver vital communication services to the UK MoD. The contract allows selected allies, including the Five Eyes community, to use the system also. Airbus is now looking at the next

"EO data is vital to modern defence forces, even though it demands high-end intelligence analysis. Therefore, priority access to EO data and the ability to analyse it efficiently is a key to autonomy and sovereignty."

Adelaide ground station exclusively for the Skynet 5A secure SATCOM satellite.

"Airbus has a solid track record in secure communications. We are able to offer proven security capabilities at the highest levels, while applying our first-hand knowledge of communications ecosystems," Pfister tells *Australian Space OUTLOOK*.

Airbus is one of the top three providers of secure communications, says Pfister, saying its solution will deliver a resilient and flexible capability for the ADF throughout

generation Skynet 6 system which is designed to ensure that the UK armed forces continue to have access to high bandwidth, secure and resilient communications during operations.

Airbus's SpainSat satellites for the Spanish Ministry of Defence have advanced anti-jam and anti-spoofing protection as well as being nuclear-hardened. They are based on Airbus's Eurostar Neo geostationary telecommunications satellites and feature advanced technologies such as electric propulsion, flexible payloads, software-defined antennas with in-orbit reconfiguration, and on-board digital processors for X and military Ka cross banding.

Airbus's SATCOM experience in Adelaide resulted in it becoming the first international prime contractor to sign a statement of intent with the Australian Space Agency, in 2018, to support space discovery, technology development, connectivity and STEM education in Australia, says Pfister. This will be the basis of its local industry engagement program.

One potential partner is Perth-based RF communications specialist Blacktree Technology. The company is a global leader in both narrowband and wideband SATCOM ground segment design and manufacture

and, equally important, in-service sustainment, says Director Joel Nevin. Blacktree is now Defence's narrowband SATCOM sustainment partner, servicing equipment at 13 sites across Australia from the company's specialist workshop in Perth.

Importantly, says Nevin, Blacktree offers an end-to-end capability, designing, manufacturing and sustaining everything from the tip of the antenna right back to the radio, including filters and amplifiers. The company is seeking to engage with potential JP9102 prime contractors as it offers both a genuine Australian industry capability (AIC) and demonstrated world-leading technology. "We've already articulated some good ideas as to how the planned network can be optimised to deliver better performance," she says.

DEF799

Project DEF799 is an acknowledgement that commercial space systems are also directly relevant to Defence. Its two phases are designed to provide Defence's Australian Geospatial-Intelligence Organisation (AGO) direct and more timely access to commercial imaging satellites to support ongoing Defence and national security activities.

The 2016 Defence Integrated Investment Program included \$3-4 billion for satellite imagery capability. About \$500 million was allocated to DEF799 and it has seen small bursts of intense activity in Phase 1 as Defence explores the scope of Australian space domain awareness industry capability. Defence is watching technology developments both domestically and by Australia's allies to determine cost-effective options for space-based imaging, including another new constellation of Australian-owned Earth observation (EO) satellites.



Thomas Pfister

"Airbus is ready to convert this plan into a successful operational capability," says Pfister. "A sovereign Earth observation capability is key to the development of national strategies."

Airbus is the prime for almost 120 satellites including optical, radar and other technologies, he tells *Australian Space OUTLOOK*. "Overall, we are totalling 680 years of EO in-orbit heritage, with zero instances of failure."

Airbus has developed a complete range of optical and radar sensors for 250, 450 and 850/950kg class satellites. These commercial off-the-shelf products may be customised to fit specific customer requirements, he adds.

EO data is vital to modern defence forces, even though it demands high-end intelligence analysis. Therefore, priority access to EO data and the ability to analyse it efficiently is a key to autonomy and sovereignty.

"Volume is not only critical in data analytics, AI or change detection analysis for defence applications," he tells *Australian Space OUTLOOK*. "It plays an equally important role in research. It helps start-ups and SMEs build the applications and services of tomorrow, helps war fighters perform their missions in better conditions, and at the same time, helps grow Australia's economy."

JP9350/51

Joint Projects 9350 and 9351 will provide Defence for the first time with its own Space Situational Awareness (SSA) Mission System and indigenous sensor suite, respectively. SSA is key to mapping satellites and space junk at a variety of orbital altitudes, from LEO to geostationary, in order to prevent inadvertent (and possibly deliberate) collisions. As David Ball, CEO of SERC explains on p.40, the

results of a couple of collisions in just one orbital place could be catastrophic, with clouds of debris denying that orbit to all users for decades.

The 2016 DIIP outlined a \$1-2 billion investment in SSA-related capabilities and Defence is using JP9350 and 9351 to examine options for ensuring that Australia's needs are met. JP9351 has seen significant activity over the past 18 months. In March 2019, the RAAF's Plan Jericho team conducted a SSA sensor capability demonstration and equipment trial at Woomera called SpaceFest. DST ran the trial and participants were EOS Space Systems, HEO Robotics, Inovor Technologies, Lockheed Martin Australia, Silentium Defence, Western Sydney University (WSU), Curtin University and DST itself.

Defence has also invested more than \$23 million in Defence Innovation Hub funding to increase the technical readiness of potentially useful space capabilities. It is also working with bodies such as the University of New South Wales, Canberra, which has received approximately \$10 million to develop with DST and the RAAF and launch a series of cube satellites to support Defence space education and help explore capability options.

While Defence has not yet issued detailed project plans for DEF799 and Joint Projects 9350 and 9351, it is staying abreast of technology developments and exploring how emerging technologies can satisfy its SATCOM, ISR and SSA needs. Thanks to initiatives like Plan Jericho it is also exploring innovative technical solutions with open growth paths that can accommodate new technologies as well as emergent needs – it does not intend to become a prisoner of either technology or acquisition orthodoxy. ■

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DEFENCE SHOOTING FOR THE STARS



By **David Lingard, Monique Hollick, Nick Stacy, Travis Bessell and Rod Smith, DST.**

The world has entered a new Space Age – colloquially known as ‘New Space’ – where commercial enterprise is rapidly driving innovation in small satellites, launch systems, and space-based services that offer opportunities in agile development, rapid deployment and intelligent systems. This significant global investment in space technology is resulting in a substantial reduction in the cost of developing and operating space capabilities. It provides Defence with new options and opportunities

for future investment in space through improved commercial access, allied partnering and sovereign development.

Defence has long recognised the importance of space for Australian Defence Force (ADF) operations. In 2016, the government released the Defence White Paper (DWP16) that outlined the challenge for Defence to maintain our capability edge and prepare for the more complex and high-tech conflicts of the future. DWP16 reaffirmed the criticality and reliance of the ADF on space-based systems, and noted the space-dependence of the future force for:

- Comprehensive situational awareness for superior decision-making
- Communications for a

networked force

- Accurate knowledge of position and time for precision effects

DEFENCE INNOVATION

Innovation drives the development of defence capability. In the DWP16, the government outlined a new approach to defence innovation, where Defence, Australian defence industry and our national research community would enhance collaboration and partnerships to deliver innovation to drive defence capability.

The Defence Innovation Hub (the Hub) was launched in December 2016 as part of Defence’s new approach to innovation. To date the Hub has invested over \$200 million in technologies with the potential to provide Defence with a capability edge. Over 80% of this investment has been with Australian small- and medium-sized businesses. Space is one of the highest capability priorities for the Hub, and over \$27 million has already been invested in advanced space-related technologies. One example is the Hub’s investment in a project worth over \$2.1 million led by Sydney-based company Saber Astronautics to enhance space traffic management by integrating multiple data sources.

Defence Science and Technology (DST) is now leading the development of The Defence Science and Technology Strategy 2020-30 (the Strategy) which introduces a whole-of-Defence approach to science, research and innovation. The Strategy articulates a 10-year vision and establishes a suite of initiatives to ensure that investment in science and technology (S&T) creates new capabilities for Defence. This includes S&T aimed at taking advantage of the “New Space”

technologies that lower the barriers to better, cheaper and more agile space capabilities for enhanced and resilient defence capability.

DST will lead the implementation of the Strategy on behalf of Defence, and is headlined by the introduction of a new concept – STaR Shots (Science, Technology and Research Shots). STaR Shots are aimed at inspiring and focusing the national S&T enterprise on large-scale programs of work that lead to specific leap-ahead capabilities for the ADF. They represent the most challenging, high impact capabilities that are best solved through S&T. Importantly, each STaR Shot will be established with a developed path for introduction into service.

SPACE STAR SHOT

The Resilient Multi-Mission Space STaR Shot has been established to focus strategic research and proactively develop new, leap-ahead Defence capabilities. This STaR Shot is aimed at exploring how the disruptions to the space industry can be leveraged for the benefit of Australian Defence in key mission areas to provide resilient global communications, position navigation and timing (PNT) and situational awareness capabilities direct to the ADF in future contested environments.

To deliver this STaR Shot, Defence will partner with Australian and international government, industry and academia space entities. A great example is the newly established SmartSat Cooperative Research Centre (CRC) where Defence is a core partner.

The SmartSat CRC is a consortium of universities and other research organisations, partnered with industry – with funding provided by the Australian Government – to develop know-how and technologies in advanced telecommunications

and Internet of Things (IoT) connectivity, intelligent satellite systems and Earth observation next-generation data services. Defence is an active participant in the CRC which comprises a \$245 million program over seven years with over 100 partners already involved.

THE BUCCANEER SMALL SATELLITE PROGRAM

To develop expertise and undertake innovative experimentation to explore the utility of cubesats – shoebox-sized satellites that have driven the recent revolution in the space industry – DST in partnership with the University of New South Wales Canberra developed and successfully launched the first of two planned Defence cubesat missions in late 2017.

The key objective of this dual-mission Buccaneer Small Satellite Program is to support Defence's high-frequency (HF) radar research program, including research to improve diagnostics and calibration of the multi-billion-dollar Defence asset, the Jindalee Operational Radar Network (JORN), by deploying an HF antenna and receiver into low Earth orbit.

Strengthening Defence's commitment to developing sovereign space capabilities, the recently established Adelaide-based satellite developer Inovor Technologies has been awarded the contract to provide the cubesat bus for the second Buccaneer mission. The Buccaneer Main Mission (BMM) satellite will be a '6U' cubesat, approximately 12kg in mass and twice the size of the first mission.

The primary BMM payload, a bespoke HF antenna and receiver, is being developed at DST and will include the same 3.2m-long HF antenna tested on the first mission, but will employ a more sophisticated

receiver capable of processing signals from the JORN system.

Another DST payload in development, an innovative deployable optics system called MANTIS (Maneuverable Antenna and Terrestrial Imaging System), will have a dual-surface, rotatable 3D-printed mirror and a focal length-variable liquid lens to take images of the satellite and the Earth.

BMM will also host an optical communications payload and a cubesat identification payload. Both of these payloads are being provided by international partners to enable demonstration of one-way optical communications and to provide a unique beacon for satellite identification to demonstrate Defence's commitment to being a responsible user of space.

The BMM cubesat is scheduled to launch via the United States Department of Defense Space Test Program in early 2022.

SPACE DOMAIN AWARENESS

As space becomes increasingly congested, space domain awareness (SDA) is fundamental to all space operations to ensure access to the space assets that we as a nation, but also our military, are so heavily reliant on. DST has an active area of research in SDA exploring novel sensors to perform surveillance of space as well as advanced algorithms in multi-sensor fusion and sensor scheduling, making the best possible use of data from limited sensor resources to provide accurate information for decision making. DST has also conducted two SpaceFest trials on behalf of the Royal Australian Air Force (RAAF) allowing Australian industry and academia to demonstrate their space surveillance capabilities to Defence, informing future capability decisions. ■

GOING FORWARD TO SPACE: AUSTRALIA'S FUTURE ON THE (CONTESTED) HIGH FRONTIER

As a new decade beckons, where does Australia head in space in the 2020s, and how do we manage a more contested space environment? By **Dr Malcolm Davis, Senior Analyst, Australian Strategic Policy Institute (ASPI)**.

The last three years have been remarkable for Australia's commercial space sector. Since the announcement of the establishment of the Australian Space Agency at IAC in Adelaide in October 2017, and its formal establishment on

1 July 2018, the growth of Australia's commercial space sector has been phenomenal. As a new decade beckons, where does Australia head in space in the 2020s, and how do we manage a more contested space environment?

The formal decision to locate the Agency's headquarters in Adelaide has coincided with the rapid growth of commercial space activity, not only in South Australia, but across the country. We are seeing the establishment of two, and potentially more, space launch sites – one in Northern Territory, near Nhulunbuy, and the other at Whalers Way, in South Australia. Australian companies are not only building satellites, but also developing launch vehicles to carry them into orbit. The future of a comprehensive and vibrant Australian space sector, which includes both an expanding ground and user

segment, as well as the ability to build and launch Australian satellites on Australian launch vehicles from Australian launch sites, is now within grasp.

That is a huge step forward from what existed even 10 years before. Then, the government's '2013 Satellite Utilisation Policy' was very conservative, stating "...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".

Luckily, we have moved on from that, yet challenges are still on the horizon. A key challenge in this decade is how Australia's defence and national security community sustains access to the space domain to ensure the ability of the ADF to undertake operations in a future conflict. Secondly, to what extent might this country's commercial space play a role in that vital task?

SPACE IS NOT A SANCTUARY

It is a myth that space is a peaceful sanctuary that sits serene and untouched by terrestrial geopolitical rivalries below.

There is now a common phrase used within the space policy community – that space is "contested, congested and competitive". This aptly describes the space domain in 2020. In military and national security terms, space is a vital 'centre of gravity' in modern information-based joint warfare, and its importance means it is becoming a warfighting domain. We have to be cognizant of that and plan defence capabilities with reality in mind.

Certainly, space has been a militarised environment since the dawn of the space age, with the superpowers deploying satellites for supporting their strategic nuclear forces. That military role, and the dependency of armed forces on space,

has grown dramatically over the decades.

Without access to space, the ADF's ability to undertake joint and integrated operations would quickly fall apart. Although space capabilities can be complemented by systems in other domains, such as high-altitude UAVs operating in 'near space', they cannot be completely replaced. The loss of GPS, space-based ISR and

There is now a common phrase used within the space policy community – that space is "contested, congested and competitive". This aptly describes the space domain in 2020.

satellite communications would see information-based armed forces revert back to a more industrialised and attritional use of force that would drive up cost in terms of lives lost, platforms destroyed and the potential risk of civilian casualties.

Our ability to undertake modern command and control of military forces, and to understand the battlespace with a high degree of

fidelity and detail, especially for expeditionary operations, would be severely degraded and we would be left deaf, dumb and blind, with little ability to sustain fast-moving operations in a complex and rapidly changing environment. As goes space, goes jointness as well as an ability to generate precision effect in space and time.

In particular, the positioning, navigation and timing (PNT) functions provided by global navigation and satellite systems (GNSS) like GPS are essential to enable joint and integrated command and control within network-centric warfare. Without space, command and control of war becomes more akin to the Vietnam era. Fog of war and friction become much worse, and the risk of military failure grows.

That is not to say that space capabilities always allow us to understand the operational and tactical picture perfectly or confer the tactical advantage. As recent US experience in Iraq and Afghanistan since 9-11 shows, poor strategy and inept political leadership, or a failure to understand the enemy, can waste a technology edge. And US Secretary





of Defense has noted that the “enemy always gets a vote”.

At the civilian level, key components of the globalised economy and information-based societies depend on assured access to space. These include the PNT functions of GNSS networks, and satellite communications for stock markets, national infrastructure and international trade. With the emergence of satellite ‘mega-constellations’ like SpaceX’s ‘Starlink’ currently being deployed which will provide high-speed broadband in the sky, pervasive Earth observation, and enable (along with terrestrial 5G/6G networks) the Internet of Things, that societal dependency on space for sustaining prosperity and stability is set to deepen dramatically.

People often talk about ‘a day without space’. The potential for disruption to space capabilities, whether through the result of the use

of ASAT capabilities by adversaries in wartime, the risks posed by growing congestion of space, or from severe solar storms such as another ‘Carrington Event’, would be devastating for modern military forces and for society. Efforts to prevent the use of space weapons through updated space law and regulation are certainly vital in this regard, and Australia is playing a leading role through the UN Office for Outer Space Affairs, and also with the Woomera Manual Project. But even the most determined efforts to promote space law and regulation and further space arms control may fall short if our peer adversaries fail to talk, or if proposed agreements cannot be effectively verified.

AUSTRALIA'S OPTIONS

In considering its next steps in space, Australia faces a decade rich in opportunity and growth of its

space sector, but the potential risks emerging in the coming decade cannot be ignored. The Australian Space Agency’s civil space strategy, released in April 2019, is a good basis for growing that sector in a manner consistent with the goals set by government. Defence too has a number of important space projects, notably acquiring space-based ISR through DEF-799 Phase 2 and the Australian Defence SATCOM System (ADSS) under JP-9102, as well as a growing role for the ADF in Space Domain Awareness. These projects are of key importance and were announced in the 2016 Defence White Paper and accompanying its Integrated Investment Program.

Yet in moving forward, we must be cognizant of the growing risks posed by the transition from the militarisation of space towards the ‘weaponisation of space’. Major power adversaries are moving steadily towards developing

and deploying counterspace capabilities, comprising a suite of 'hard-kill' and 'soft-kill' anti-satellite (ASAT) systems.

For the ADF, the overall objective should be to develop the means to reduce the risks posed by these adversary counterspace capability such that even if the space domain is operationally limited in future war as a result of use of ASATs, the ADF can fight through and prevail.

Firstly, we need to move away from continuing our traditional total dependency on the US to provide the entirety of space support to the ADF. By this, I am not implying we should sever our cooperation in space with the US. Instead we should deepen and broaden space cooperation by moving towards building sovereign capacity to burden share in orbit to a greater level. That sovereign space capability should directly contribute to the goal of strengthening space resilience and boosting space deterrence in the face of growing counterspace threats from China and Russia.

Our dependency on small numbers of large, complex and expensive satellites, such as the Wideband Global Satcom (WGS) constellation provided by the US, is a policy choice that needs review. The scenario commonly referred to is a 'space Pearl Harbor', that would see an adversary exploit direct-ascent and co-orbital ASATs, or ground-based counterspace systems, including cyber attack on satellites, to launch a surprise attack and generate catastrophic and rapid collapse of essential space capability.

To counter that scenario, there needs to be greater emphasis on building space resilience and deterrence. That can be achieved firstly through augmenting existing satellite constellations, in a manner that disaggregates space capability across larger numbers of small satellites and where possible,

fractionated and networked constellations of cubesats. That would complicate the task of any adversary that is seeking to attack our essential space capabilities. At the same time, having the ability to rapidly reconstitute lost space capabilities would prevent the catastrophic collapse of space support, if such an attack did occur.

If the costs and challenges confronting an adversary contemplating the use of ASATs exceeds the likely benefits gained in such an action, there is a greater

For the ADF, the overall objective should be to develop the means to reduce the risks posed by these adversary counterspace capability such that even if the space domain is operationally limited in future war as a result of use of ASATs, the ADF can fight through and prevail.

chance that state will be deterred from undertaking the use of counterspace capability in the first place. That could then open up prospects for greater cooperation of verifiable space arms control, reinforced by strengthened space law and regulatory structures, such as that proposed in the Woomera Manual.

Australia is well positioned to leverage its growing commercial space sector to contribute to this vital task. Given the falling cost of satellite design and development, and impact of reusable rockets driving down cost of space launch – what is commonly termed Space 2.0 – our commercial space sector will have growing opportunity for sovereign development of small satellite and cubesat technologies. Australia's commercial space sector should aim to capitalise on that trend as a means towards greater burden sharing in orbit with the US and other Five Eyes partners. There is no need for Australia's space capabilities to remain forever stuck on the ground.

Vital to achieving this goal is

developing responsive sovereign space launch. Once again, this is coming into place, with Australian commercial companies developing space launch capabilities – and space launch sites – to launch such satellites when needed, including for rapid reconstitution of essential satellite services during or after an adversary counterspace campaign. Having responsive space launch would grow our strategic capital with the US and with other Five Eyes partners, and represent the establishment of a mature space sector,

as it would mean we no longer have to depend on other actors to launch our satellites. We would have come of age in space.

The ability to develop and launch our own satellites allows us to not only support US and allied forces, but also boost independent ADF space capability. It acts as a force multiplier, even if the ADF is undertaking operations alone, as opposed to in a coalition. That would represent an entirely new type of capability for the ADF, and it takes Australia's use of space for defence and national security purposes to a new level.

In conclusion, the goal for Australia in the 2020s should be to grow our commercial space sector in a manner that allows Australian developed satellites to be launched on Australian launch vehicles from Australian launch sites on a regular basis. Having that ability to build a disaggregated and more resilient space capability to burden share in orbit with allies, and to directly enhance ADF operational capability, represents a logical step forward in an era of contested space. ■

FROM CYBER THREAT TO CYBER WARFARE



of sensitive data and malicious data attacks from malware. The industry also faces catastrophic cyber attacks designed to vandalise, take control of and cripple space-based critical national infrastructure such as satellite communications.

Today's bad actors' capabilities, combined with their motives, are game-changing – from cyber threats to cyber warfare!

OUR NEW FRONTIER OUT THERE

The risks of catastrophic cyber attacks reach from space organisations' business systems to launch control systems, and space-based communications and operations. The list of harmful impacts is as horrific as it is long.

Space industry infrastructure, space-based assets such as satellites, ground stations and data links at national, regional and international levels play a key role running a country's infrastructure – from telecommunications, transport (shipping, air and road), trade, financial and other business services. Weather forecasting and environmental monitoring and defence systems all depend on the space industry. Moreover, the space industry itself is a growing part of the nation's exports and international technology and security relationships.

CYBER WARFARE ON THREE FRONTS

The space industry faces three fronts on which to fight cyber threats: breaches where confidential data is stolen, network ingress where control systems are breached, and attacks where malicious content is deployed. These fronts are where business, R&D intellectual property and space operations are conducted.

Organisations' business activities – R&D, business conducted from multiple locations, business systems (cloud and SaaS), worker collaboration and file-sharing – are data network

By **Simon Galbally,**
CMO Senetas Corporation.

All high-tech and critical national infrastructure industry sectors are high-value targets for cyber criminals, rogue states, terrorists and other bad actors. These industries' IT systems provide numerous attack vectors where vulnerabilities are maliciously exploited. Whatever the intent – financial gain, theft of high-

tech intellectual property, business disruption or vandalism – high-tech and critical infrastructure organisations must understand that they are high-value cyber attack targets. Today's rapidly growing space industry is a stand-out example because it is both high-tech and part of our critical national infrastructure. All types of bad actors may have the space industry in their sights.

Significantly, space industry cyber threats should be seen more seriously than just risks of data breaches, theft

dependent. Here lie attack vectors and vulnerabilities.

Then there are space operations – launch and control systems, technical and other space-based operations, such as satellite communications. Here also lie attack vectors and vulnerabilities.

Using data networks to transmit sensitive data – from business and technical content to launch command and control codes, and space-based communications – provides high-value cyber-threat vectors. They are equally exposed to attacks that deploy malicious

to potentially catastrophic infiltration of undetected malware/ransomware and other malicious content attacks. All file types can be carriers of malicious content and once released little can be done – whether the malicious content is known, unknown or a zero-day attack. These attacks are often so effective that firewalls fail to detect and prevent the threat.

CYBER-THREAT TARGETS

The global technology market has seen strong growth. Forbes Global 2000 list

operations' control systems.

High-speed data networks may yield terabytes of data in a matter of minutes. By intercepting this data, cyber criminals improve their odds of stealing sensitive information or using it to gain systems access – including command and control systems used in space operations. Should this happen in the space industry, the stakes could not be higher.

Alongside the commercial damage, a successful attack could enable a bad actor to seize control of launch and command and control systems, and disrupt communications services impacting the lives of millions of people.

Moreover, such an event for any high-tech organisation puts the cornerstone of the business – its intellectual property – at significant risk. A breach of unencrypted data including intellectual property would harm all stakeholders – from employees and suppliers to shareholders.

"Space organisations are popular attack targets due to the rich rewards and/or serious harm bad actors can achieve with relative ease. Business-transforming technologies – cloud and SaaS – are dependent on public and private networks; but, they are not encrypted."

content to infiltrate targeted systems – from taking control to vandalising them.

Space organisations are popular attack targets due to the rich rewards and/or serious harm bad actors can achieve with relative ease. Business-transforming technologies – cloud and SaaS – are dependent on public and private networks; but, they are not encrypted. Hence, eavesdropping and other breaches of unencrypted data are not uncommon.

With the increased use of network-dependent technologies, space organisations face a diverse, evolving threat landscape, making cyber security increasingly important. In this case, the only answer is to ensure network data is encrypted using high-assurance and agile quantum-ready solutions. These are tried and proven – the first choice of defence and military organisations. There is no excuse for successful breaches of unencrypted data.

In day-to-day business activities such as file-sharing, work-group collaboration and use of email expose organisations

says the top 184 technology companies account for more than \$9 trillion in market value. These include the space organisations. What makes them valuable is what makes them cyber targets!

The cyber threats to high-tech and space organisations are wide-ranging – from network eavesdropping and intellectual property theft to malicious code infiltration and access to space

A NEW FRONTIER FOR THE AUSTRALIAN SPACE INDUSTRY

The global space industry, according to Goldman Sachs, (currently value at US\$360 billion) could be worth \$1 trillion by the 2040s.

Alongside significant government funding from the US, Europe, China, India and Russia, the market has seen large private investments. Satellite





"Few other industries have such direct roles in both economic and military functions. Because almost all military activities depend on space-based assets, any cyber-security vulnerabilities will undermine confidence in national security."

revenues have doubled in 10 years, with major players like Airbus, Boeing, Thales and Mitsubishi contributing to a commercial market value in excess of \$250 billion.

The Australian Government is also involved. The Australian Space Agency has announced that it is joining forces with NASA, spending \$150 million over five years that will see the collaboration support exploration missions to Mars and the Moon.

However, as these opportunities grow, the space industry is increasingly exposed to numerous attack vectors and vulnerabilities that threaten the security of everything from the intellectual property and launch control systems to the space-based satellite communications. There can be no

doubt that the industry's growth is also attracting the attention of a broadening mix of bad actors.

SPACE INDUSTRY: CRITICAL NATIONAL INFRASTRUCTURE

The space industry's crucial activities in commercial/civilian and military activities have national economic and security roles. It is an important part of the nation's critical national infrastructure. Few other industries have such direct roles in both economic and military functions. Because almost all military activities depend on space-based assets, any cyber-security vulnerabilities will undermine confidence in national security.

At a national level, the impact of a successful cyber attack could seriously

harm trade, financial services and even enable cyber terrorists taking over a country's strategic military weapons. Cyber attacks on satellites include communications signal jamming, malware and malicious content attacks on networks. The most serious would involve targeting command and control systems, attacks on ground infrastructure and even mission packages.

In US defence most aspects of national security, including the detection of threats, use of weapons, deployment of forces and re-supply, are dependent on the integrity of critical space-based infrastructure and capabilities. Those capabilities and systems are referred to as Command, Control, Communications, Computing, Intelligence, Surveillance and Reconnaissance (C4ISR) and logistics. Hence any successful cyber attack on space-based assets would be catastrophic.

Cyber attack-caused lost data, service disruptions, systems interference or the loss of satellite control or capabilities is unthinkable. A bad actor may take



control of a satellite via its command and control systems, alter or corrupt the data it provides, even redirect its orbit, thus transforming the asset into a weapon against other space infrastructure.

WHEN THE STATUS QUO JUST DOESN'T CUT IT

The daily evidence of successful malware/ransomware and other malicious content attacks highlights conventional anti-malware/firewall security solutions do not provide enough protection today. Such attacks are pervasive, reaching to all corners of IT infrastructure. All organisations must look to next-generation technologies for protection against malicious content for two reasons.

First, conventional anti-malware falls short of security standards required to protect modern infrastructure used by the space industry. The embedded malicious content is increasingly sophisticated. Second, email and other file-based attack vectors remain the primary point of ingress for successful malware attacks. Unknown and zero-day attacks are increasingly used.

The negative implications of malware attacks are extensive – from customer defection and loss of trust to business disruption, IT clean-up costs and even lost shareholder value.

The plethora of reported successful malware attacks show how today's reactive anti-virus and malware protection are not up to the job. Organisations must look to emerging technologies, such as Content Disarm and Reconstruction (CDR), for effective protection. Most malware protection rely upon external libraries of known threats to protect content. But what if the threat is unknown, or new? How do you protect

against zero-day attacks?

Next-gen solutions succeed because they apply new thinking to new threats. Votiro Disarmer, for example, leverages patented CDR technology to stop zero-day malicious content in milliseconds.

The Cybersecurity and Infrastructure Security Agency has commented that critical infrastructure has increasingly become the primary target of such attacks and that the targets are often inadequately protected against and prepared for these threats.

SOLUTIONS AND DATA SOVEREIGNTY

Space organisations' cyber-security issues are serious and complex. The optimal approach is to break the systems and operations down to their component parts, noting that all are linked by the data networks they use.

Solutions begin with long-term network data security, and data network protection from ingress of rogue data, using dedicated high-assurance authenticated encryption. Protection of all systems against the infiltration of malicious content requiring enterprise-wide CDR is a critical investment. It is essential to ensure that all work group file collaboration and file-sharing use an encrypted application with similar high-assurance features. Critically, a space organisation must see all data as sensitive, requiring maximum security.

What are the most common cyber risks that must be addressed? In order of statistical occurrence, the top five begin with: Denial-of-Service (DoS) attacks, Man-in-the-Middle (MitM) attacks, followed by Malware (all types), Drive-by Attack (malicious code injected into websites) and Phishing and Spear Phishing (email) attacks.

Recently, the issue of 'data sovereignty' has become so significant it is now treated as a cyber-security issue. It is often a deal-breaker when selecting a cloud-based solutions amongst organisations concerned about where their data is located, i.e. data sovereignty. Now many companies require data location control to ensure their data is only stored on their sovereign soil.

Because space industry organisations work with high-value intellectual property, data sovereignty should be a factor when considering cloud-based solutions.

WHERE TO NOW?

Whilst there are many attack vectors to be exploited by cyber criminals, the challenge is to identify the vulnerabilities – from networks carrying data, to everyday use of business systems and files. Easily said of course.

The common link among space organisations' day-to-day business activities, R&D, space-based assets and control systems is the data network infrastructure. All network transmitted data should be encrypted.

Like all high-tech organisations, systems-wide CDR anti-malware and encrypted file-sharing collaboration applications are essential protection.

In the face of an evolving threat landscape, security solutions must be agile and quantum-ready to ensure long-term data protection as quantum computing approaches. ■





Promoting our profession: enriching science teaching

The Australian Science Teachers Association (ASTA) is the national professional association for teachers of science. We are a federation of the eight individual member science teacher associations (one in each state and territory in Australia). As ASTA we work to promote the science teaching profession and enhance science teaching practice through meaningful collaborations with government, industry and business partners and draw on the strength of our federation, and the exceptional work and expertise of our member associations, to advocate and support teachers of science.

For as long as humans have been able to look up at the night sky, we have been curious about it; it drives us to wonder and to question, permeates our cultures and inspires us creatively from a young age. Space can be an exciting vehicle to engage future scientists and help them to develop their skills and discipline knowledge at all ages. Natural curiosity, when nurtured, can lead students on to more structured inquiry and open the door to studying the more challenging science and STEM subjects. The developing prominence of space, space science and associated STEM and industry career pathways across Australia also represents an exciting and critical component of Australia's future scientific, economic and educational landscape.

At ASTA we understand how fundamental the work of dedicated and committed teachers is in making all of this happen and how challenging it can be in the current educational landscape. We are committed to building the capacity and skills of science teachers. That is why we support teachers through opportunities such as CONASTA – the annual conference for teachers of science; SPECTRA – a national science award program for students in Year 1 – 10; SCIENCE ASSIST – a national online advisory service for science educators in schools; STEM X ACADEMY – a professional learning program for teachers; and TEACHING SCIENCE - a respected peer reviewed science education journal. All of these opportunities (and more) can be accessed through our state and territory associations.

We have also been involved in NATIONAL SCIENCE WEEK for nearly forty years, and in 2019, helped select the theme of 'Destination Moon: more missions more science' to celebrate the 50th anniversary of the moon landing and also explore the people, institutions, agencies and universities involved locally in advancing space science. The resource books for teachers, developed each year by ASTA, are still available through our website, even as you go to access information about National Science Week for 2020.

With so many exciting space science opportunities on the horizon (or above) in 2020 and beyond, we encourage you to get out there, get inspired and get connected with the cosmos on some level. You might even consider participating in our various workshops and events (a hub for lots of exciting space research).

Nathan Curnow
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SCIENCE TEACHERS AT THE FRONTLINE OF STEM

There is an inspirational and aspirational aspect to space which never fails to capture the attention of students, and science teachers are able to harness this interest as a way of motivating young people to study STEM subjects. By **Lachlan Colquhoun**.

When National Science Week coincided with the 50th anniversary of the Moon Landing in 2019, it was a great time to be a science teacher.

Around the country, school students

learned – at all levels – about the event and many were inspired by the epic story of human space flight and one of its most significant achievements.

For science teachers, space and astronomy are the easiest subjects in their efforts to get students to engage with science. There is an inspirational and aspirational aspect to space which never fails to capture the attention of students, young and old, and science teachers are able to harness this interest as a way of motivating young people to study STEM subjects.

As Professor Lisa Harvey-Smith, Australia's first Women in STEM Ambassador jokingly puts it: "Science communicators like myself joke that astronomy is the gateway drug to STEM."

"Kids love astronomy, and I have

presented astronomy at schools around the country for years and it's something that gets everyone engaged, no matter what cultural background or age they are. It really unifies people."

On the front line of science teaching in schools is the Australian Science Teachers Association (ASTA), a federated national body made up of state-based organisations representing thousands of science teachers around the country.

ASTA is the national voice of science teachers representing their interests at the highest levels, promoting the profession and enriching science teaching.

In 2019, ASTA produced the "Destination Moon. More missions, more science" resource for students, designed to introduce young people

to the importance of science and technology in solving problems, designing new solutions and predicting humanity's future expansion into space.

ONGOING STEM ENGAGEMENT

While significant anniversaries of events such as the Moon Landing are excellent opportunities for engagement, they are not permanent.

The role of the science teacher is an ongoing one, and teachers have the day-to-day challenge of inspiring the next generation to engage with STEM subjects, and for many of them to pursue STEM careers.

"Science teachers are catalysts through which many of these big changes happen," says Nathan Curnow, ASTA's President.

"If you think about all those initiatives that governments and those in education want to develop, science teachers are key drivers of change in the STEM space and they are there helping to ensure it comes to fruition."

One new constant in Australia's scientific landscape is the Australian Space Agency, and Nathan Curnow sees it as a "fantastic opportunity" for teachers to inspire students and capture their imagination.

Themes and imagery around space are common across the media and the arts, through music, film and poetry, so the excitement which this generates gives science teachers "a natural hook" to engage students.

"Drawing links between things that kids care about and are studying is what passionate teachers are looking for," says Curnow. "Every time you bring up topics related to space, kids are enraptured and while it's one of the few places they can't directly explore themselves, it is a place they could be exploring in the next generation."

"So in delivering the curriculum

and opportunities to work in with the national space agency are fantastic."

Space is also inspirational for students in that it contains many personal stories which students can identify with and can be motivated by.

"Kids are always looking for role models, and having a national space agency in our own backyard now gives them the opportunity to see that people like them can get involved," says Curnow.

"They might say 'I'm in a classroom in Adelaide, or in Mt Isa, but so was this guy and now he's launching rockets, or look at this woman from my town or city who is now conducting wild experiments on the international space station'."

"Every time you bring up topics related to space, kids are enraptured and while it's one of the few places they can't directly explore themselves, it is a place they could be exploring in the next generation."

In Canberra, Joseph Jennings teaches science and mathematics across years 7 to 10 at Caroline Chisholm High School, a profession he chose after initially studying engineering.

"Having the space agency is all part of building a sense of wonder and engagement with scientific material that is in front of the students," says Jennings.

"There are really beautiful things in maths which apply to the broader universe and space is a great way to link that all in."

Jennings says that having real life examples and practical challenges are often effective in engaging students with science and maths because they present opportunities for creative

problem solving.

"Often it's about giving students enough structure to find a coherent solution, but also giving them enough room to find multiple solutions to the problem," he says.

"Student self-direction is an important part of facilitating engagement, because not only does it let you give students multiple entry and exit points, but it enables you to work with the student to find the precise area that is engaging to them.

"So you make it a non-threatening challenge, because everyone loves being challenged and it helps get over the fear of failure which puts off many students."

Technology a force for change

ASTA President Curnow has been a science teacher for around 15 years, and says that while elements of the teaching challenge are the same, technology has been a force for change in many ways.

"Technology has changed what you can do in a classroom and changed how kids access their learning," he says. "It is changing our teaching approaches and what you can do with students."

Today's young people, says Curnow, are "prosumers" when it comes to technology: as a generation they are huge consumers of technology which they are also using to produce a diversity of things, from art to apps and more sophisticated scientific devices.

"Despite the proliferation of technology you have the narrative that the study of science is in decline, and that kids are choosing not to study difficult subjects," he says.

"But then you have students who do want to study these subjects, but their needs aren't always in alignment with some of the traditional structures we have had for a long time, and some of the things which have worked to build

career scientists in the past are not necessarily working for our students.

"This is one of the challenges teachers have, because they are still required to deliver the curriculum."

Science teaching, says Curnow, is about helping impart a framework which is a "scaffold" for learning and generating "those opportunities to do the big things kids dream of".

"Science is also about being creative and using it as a vehicle for problem solving," he says. "And of course as students' needs have changed, this has had implications for us in the classroom as teachers."

ASTA is involved in a career development program called the STEM X Academy, which takes around 70 primary and secondary educators through a five-day professional learning program with workshops to engage and empower education professionals to enhance their delivery of STEM learning.

The academy began in 2016 and is managed by ASTA with delivery partners Questacon and CSIRO.

Entry is competitive, with many more applicants than places, and participants are drawn from across Australia with some traveling from rural and remote schools.

To further spread the benefits of the STEM X Academy, a two-day regional program called STEM X Regional has been developed and has been held in regional centres.

"The STEM X Academy has grown into a community of practitioners across all jurisdictions and they are an active community which supports and links in with each other to implement STEM education in the classroom," says Nathan Curnow.

"This can be quantified, but it's also much richer than that. It is about practice change for teachers. When you combine this with all of the amazing work done by our state and territory associations who



are leading change, you can appreciate how important we are as agents of change."

Science teachers do not often receive national recognition, but the work done by Perth teacher and geoscientist Suzy Urbaniak was in the spotlight in January when she was announced as Western Australia's local hero in the Australian of the Year Awards.

Urbaniak was a pioneer in taking geoscience out of the classroom and into a hands-on experience in the field, with a focus on remote area schools in WA's Pilbara region.

Urbaniak previously received the 2016 Prime Minister's Prize for Excellence in Science Teaching in Secondary Schools for her work in establishing and fostering a teaching program known as the Centre of Resources Excellence (CoRE).

CoRE encourages students to be equipped with the right skills

and knowledge to take on a variety of career pathways in science and engineering so that the classroom is treated more as a workplace where students can focus on evolving as young scientists.

"School and university textbooks teach theory but hands-on experience enables a student to get a real sense of inquiry, investigation and solution outcomes by better connecting the classroom environment directly with what is happening in the real world," Urbaniak said when her award was announced.

"Critically, the future Australian science and engineering workforce is sitting in our classrooms today.

"As educators, it is up to us to build future skills, attitudes and attributes in our students focused on practical real-world learning and to embrace creativity and challenges to fixed learning methodologies." ■

AN OUT-OF-THIS-WORLD PROBLEM TO SOLVE

How would you like to be part of a team representing Australia in a robotics competition against teams from at least 11 other countries, with the finals being conducted in real time on the International Space Station (ISS)?

This is the latest in STEM outreach experiences being provided for Australia's student population to advance team development skills and embracing all areas of science, technology, engineering and mathematics (STEM). It is another giant leap in the extension of the skills needed for the 20,000 new jobs required by the space sector in Australia.

The Kibo Robot Programming Challenge (Kibo-RPC) is an educational program in which teams solve various problems by programming free-flying robots on the International Space Station (ISS). By providing students with the opportunity to work with professional scientists and engineers, they will be inspired to develop their own educational and professional goals to a high level. Team members will have the chance to learn cutting-edge methodologies and to hone their STEM skills through this amazing program.

The Kibo-RPC will also expand international exchange by encouraging students to interact with other participants from around the world. Globally, this program is hosted by the Japan Aerospace Exploration Agency (JAXA) in cooperation with the National Aeronautics and Space Administration (NASA).

In Australia this program is hosted by One Giant Leap Australia with support from the Australian Space Agency and

several Australian universities, with Sydney University being the first.

Engineering teaches us that a simulation can only approximate the real world. Thus, participants are expected to learn techniques for creating simulation programs that perform well in the real world despite uncertainties and within margins of error. Students will learn the necessity of controlling and correcting positions and orientation of a free-flying robot in micro-gravity and how to perform assigned tasks in the onboard environment through simulation trials.

The Astrobee, NASA's new free-flying robotic system that was only deployed to the ISS in 2020, consists of three cubed-shaped robots, software and a docking station used for recharging. The robots use electric fans as a propulsion system that allows them to fly freely through the microgravity environment of the station. Cameras and sensors help them to 'see' and navigate their surroundings.

Astrobee will help astronauts reduce the time they spend on routine duties, leaving them to focus more on the things that only humans can do. Working autonomously or via remote control by astronauts, flight controllers or researchers on the ground, the robots can perform tasks such as taking inventory, documenting experiments, or moving small items or cargo throughout the station.

Astrobee builds on the legacy and lessons learned from the SPHERES robots – short for Synchronized Position Hold, Engage, Reorient, Experimental Satellite – which have been aboard the station for over a decade. Once the Astrobee system has been fully

commissioned, it will take over from SPHERES as the space station's robotic test facility, helping us to learn new capabilities in our journey to explore space.

Guest scientists, in this case our student teams, will be able to use Astrobee to carry out investigations that will help to develop technology – both hardware and software – for future missions. Since the robots are modular and can be upgraded, the system gives researchers and scientists diverse capabilities for performing a wide range of experiments inside the station.

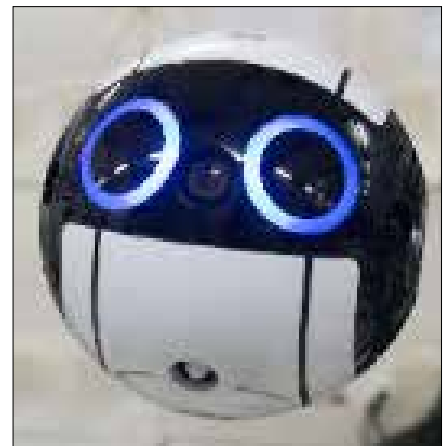
Robots will play a significant part in the agency's mission to return to the Moon as well as other deep space missions. Robots such as Astrobee have the capacity to become caretakers for future spacecraft, working to monitor and keep systems operating smoothly while crew are away.

FAST FACTS:

The three Astrobee robots are named Honey, Queen and Bumble.

The robots are shaped like cubes, 31.75cm wide.

When needed, the robots can return



to their docking station and recharge their battery power.

Each robot also carries a perching arm that allows it to grasp station handrails in order to conserve energy or to grab and hold items and assist astronauts.

Int-Ball is a free-flying camera robot aiming to reduce crew time ultimately to zero for routine video-shooting tasks by crew in the ISS/Kibo. Similar to current consumer-grade cameras, Int-Ball works closely with onboard crew to provide flexible views for ground operators. Int-Ball is perhaps the first human-friendly camera robot in space.

The Int-Ball was manufactured entirely by 3D printing and it uses existing drone technology. It is essentially a floating ball with luminous blue eyes that looks like something straight from Pixar. The drone can be controlled from Earth by the JAXA Tsukuba Space Center.

JAXA says the robot drone can move anywhere at any time through autonomous flight and can record images from any angle. The Int-Ball weighs 1kg, has a diameter of 15cm and has 12 propellers, according to The Japan Times.

The Int-Ball also enables flight controllers and researchers on the ground to check the ISS team from the same viewpoint as the crew, which will help to maximise results of experiments. It has also cut the amount of work done by Japanese astronauts on the ISS by about 10%, photographing work and equipment for evaluation that otherwise would have to be done manually.

In the future, says JAXA, the Int-Ball will be able to check supplies and even help with onboard problems – though the details of how that will be accomplished by a limbless orb of cuteness are not yet known.

The competition scenario for 2020 is:



“A meteor has crashed into the international Space Station and the air is leaking. Operate the Astrobee and stop the air leakage. JAXA needs your help!

“Emergency alert is activated! Save the International Space Station with robots.”

The mission is to create a program to operate Astrobee and stop the leakage, saving the astronauts and the International Space Station.

HOW CAN YOU PARTICIPATE?

All teams must be linked to a partner university, either by enrolment or as an outreach activity. A team is comprised of three or more members. Students cannot join more than one team.

Team leader:

- Each team must have a leader who is responsible for team management.
- A student in a team can be the leader.
- The team leader has the following responsibilities:
 - Manage the progress of the team
 - Submit applications and programs
 - Communicate and share information with the point of contact (POC) in its country.

Other conditions:

The following skills and knowledge are recommended but not mandatory:

- Android programming and image processing
- College-level knowledge of physics or mathematics

Preliminary round: All entrants will have a preliminary competition by simulator in the country of application to select the team that will represent that country.

Qualification round: Six countries will proceed to the final round. If there are more than six participating countries, all teams will compete in an elimination round until six finalists are left.

Final round: The final round will be held in ISS/Kibo module. The six teams from the preliminary or qualification round will compete for the grand prize.

The final round will be held connecting the ISS and Tsukuba Space Center (TKSC) in Japan, so in principle, the finalist teams are expected to come to TKSC in Japan.

Remote venue: Teams who cannot come to Japan can attend from remote venues. The coordination of logistic and settings in remote venues must be done by the POC of each country.

This program is intended to continue developing STEM outreach after 2020. If you are interested in future programs, contact the Australian Co-ordinator, One Giant Leap Australia through www.onegiantleapaustralia.com or email kibo@onegiantleapaustralia.com





THE SOUTHERN HEMISPHERE SPACE STUDIES PROGRAM: 10 YEARS OF WORLD-LEADING SPACE EDUCATION

With the goal of meeting the sector's growing educational needs, the International Space University and the University of South Australia formed a consortium in 2010 to launch a space education program focused on the southern hemisphere.

The space world has changed significantly in recent years. New applications and technologies have developed, and the costs and benefits of space access have changed markedly. Many smaller nations are now placing increasing emphasis on the practical benefits of space and are creating new space programs, cooperative initiatives and new agencies. All space-faring nations are looking for space education opportunities that match their level of development and capability, are cost effective and compatible with their academic schedules. They are seeking quality educational programs that will assist them in developing their national space-related capabilities, giving them

context in their regional and global space frameworks.

With the goal of meeting this growing educational need, the International Space University (ISU) and the University of South Australia (UniSA) formed a consortium in 2010 to launch a new space education program focused on the southern hemisphere. The Southern Hemisphere Space Studies Program (SHSSP) is an intensive, five-week, live-in experience held in January and February each year, incorporating the international, intercultural and interdisciplinary educational philosophy for which ISU is renowned. The program is open to participants from all disciplines, ages and nations.

The SHSSP's interdisciplinary program is designed to meet the needs of:

- Professionals seeking greater knowledge of and contacts in the international space sector
- Graduate researchers in all fields seeking a broader knowledge of international space activities and the disciplines involved
- Undergraduates who have completed two years of a university degree, who wish to be exposed to a range of space studies disciplines in order to direct their remaining undergraduate programs, or to investigate professional and research opportunities in the space sector after graduation

PROGRAM RATIONALE

ISU has been conducting international space education since 1988, with an expanding set of program offerings. It all started with the two-month Space Studies Program (SSP), which is held in different locations around the world in the northern hemisphere summer months of July and August, including in

Adelaide in 2004. In 1995 the 11-month Master of Space Studies program was launched at the new ISU central campus in Strasbourg, France. Today the ISU program offerings include the annual Space Studies Program, the one-year or two-year Master of Space Studies, and a range of short professional development courses, including the Executive Space Course held in Canberra in November 2019. To date, the ISU network comprises 5,000 international alumni and demand for its programs continues to grow.

The University of South Australia has more than 30,000 students, with campuses in Adelaide and regional South Australia. It has a long-standing collaborative relationship with ISU dating back to the early 1990s. Its Institute of Telecommunications Research (ITR) is internationally recognised as a leader in satellite telecommunications research. UniSA was also a founding member of the SmartSat Cooperative Research Centre, Australia's largest space-related research and development organisation, established in 2019.

UNISA'S MAWSON LAKES CAMPUS

The SHSSP is held annually at the Mawson Lakes campus of the University of South Australia in Adelaide. In addition to UniSA's contribution to the planning and the curriculum, on-site logistical, organisational and IT support is provided by UniSA staff. Program participants are registered as UniSA students and have full access to campus library, athletic and computing resources. Accommodation is provided for faculty, staff and participants in modern, well-equipped air-conditioned apartments located in Mawson Lakes, a mere 10-minute walk from the campus. Dedicated catering of all meals at facilities on campus and immediately adjacent, social events and public engagements are also provided.

PROFILE OF PARTICIPANTS

A total of 371 participants completed the program between 2011 and 2020. The most recent program, launched in January 2020, had a record 53 participants from 14 countries. In this program, 15% had PhD qualifications, 55% had masters' degrees and 28% had bachelors' degrees. 17 participants were resident in Australia and 18 were from China. Twelve other European, North American, Middle Eastern, Asian and African countries were also represented.

Some participants are self-funded. Other participants are supported by employers from the international space sector or with scholarship support from space agencies, governments (including the Government of South Australia) and other benefactors. A diversity of nationality, gender, professional background and level of experience in the composition of the class is strongly encouraged.

EDUCATIONAL CONTENT

The core lectures, delivered by ISU and UniSA faculty and invited space experts from around the world, cover all of the space disciplines. The lectures are presented in a manner clearly understandable to participants from a wide range of backgrounds and provide a broad understanding of the role of space, the current status of our capacity to use it, as well as future directions, opportunities and challenges for the developing nation space sector.

The workshops are often linked with lectures, with hands-on activities using local remote sensing data, satellite telecommunications, GPS field exercises, life sciences, satellite data acquisition, space policy, law and commercial workshops, professional skills development and other topics. Specific topics have included: team building activities, planetarium visits to study the southern sky, STK workshops (orbital mechanics), crisis communication, space

tourism, GIS and remote sensing, and GPS computer labs, as well as field trips, commercial and regulatory issues in space launches, space human factors, satellite communications and ground stations, space public outreach, space entrepreneurship, commercial satellites, writing and presentation skills, and presenting space history and heritage.

Highlights of recent programs included a stratospheric satellite launch and a model rocket competition. The satellite, designed and built by the participants, carries a number of sensors and a camera transmitting live images to the ground. It reaches an altitude of about 36km during its three-hour flight. The model rockets are designed, built and then launched by small teams of participants in a competitive environment, receiving marks for design, altitude reached and the successful landing of a payload.

In 10 years, the Southern Hemisphere Space Studies Program has established a reputation for excellence in international interdisciplinary space education and is making a positive contribution to the space capability of many countries. It enjoys strong support from the international space community and is a good example of the benefits of international collaboration between universities. ■

For more information go to ISU website: <https://www.isunet.edu/shssp/> or the UniSA website: <https://www.unisa.edu.au/spaceprogram>



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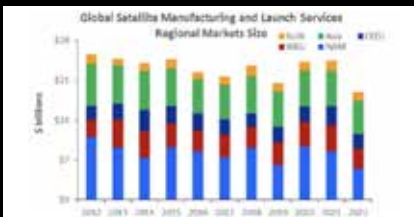
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Are you an Australian Satellite/Spacecraft Manufacturer?

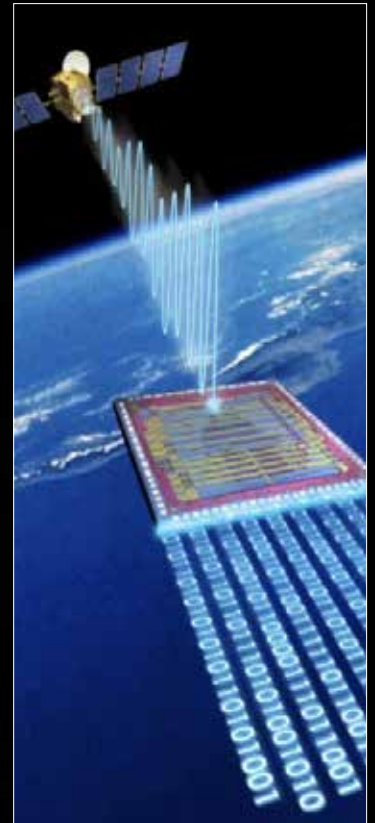
Spacechips supports clients by providing advice on component selection, how to design, test, assemble and manufacture space electronics. We also develop and deliver bespoke satellite/spacecraft avionics.

Spacechips' Training Services has taught Space Electronics to over 600 professionals in 12 countries, including 37 companies and 6 agencies. Our courses help countries develop local capability and expertise, preventing them over-engineering, delivering late and spending too much. We also teach attendees how to make informed component selections and will be teaching in Australia in 2020.

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Spacechips' Business-Intelligence Services help you understand future technical and commercial trends for the global space industry. We provides answers to the following questions: what technologies will satellites require in the future, why will these be needed, where and how will they be used, by whom and when. These insights allow you to define a go-to-market strategy, identify target clients, market size and establish product roadmaps to guarantee ROI.

Spacechips' Technical-Marketing Services position you as the go-to-provider as well as increasing market share, global sales and securing design-ins on future missions.



SOUTH AUSTRALIAN SPACE SCHOOL



By **Olivia Samardzic,**
Department of Defence.

The first South Australian Space School (SASS) was held in 1997, led by a team of three South Australian science teachers and a Defence Science and Technology (DST) scientist, with the aim of providing a stimulating and rewarding educational experience for secondary school students to focus them on a career in science, technology, engineering, mathematics and medicine (STEMM) by using space as an exciting application.

SASS is held during school holidays and is targeted at Year 10 students from public and private, rural and city schools, and has been sponsored from

its inception by DST and, since 2001, the Sir Ross and Sir Keith Smith (SRSKS) Fund. Whilst the SRSKS Fund is now the largest sponsor, DST is the founding and longest sponsor, without which SASS would not exist.

The school is run residentially over three days. The activities give students contextual information about space sciences, but also provide enough examples and career information to highlight the benefits of choosing a STEMM career.

Students are selected to attend Space School based on a written application and a recommendation from their school. The educators on the space school are volunteers who often use their leave to run the school.

Space School activities include:

- A European Space Agency (ESA) or

NASA astronaut who visits for the duration of the program, providing opportunities for personal interaction with the students

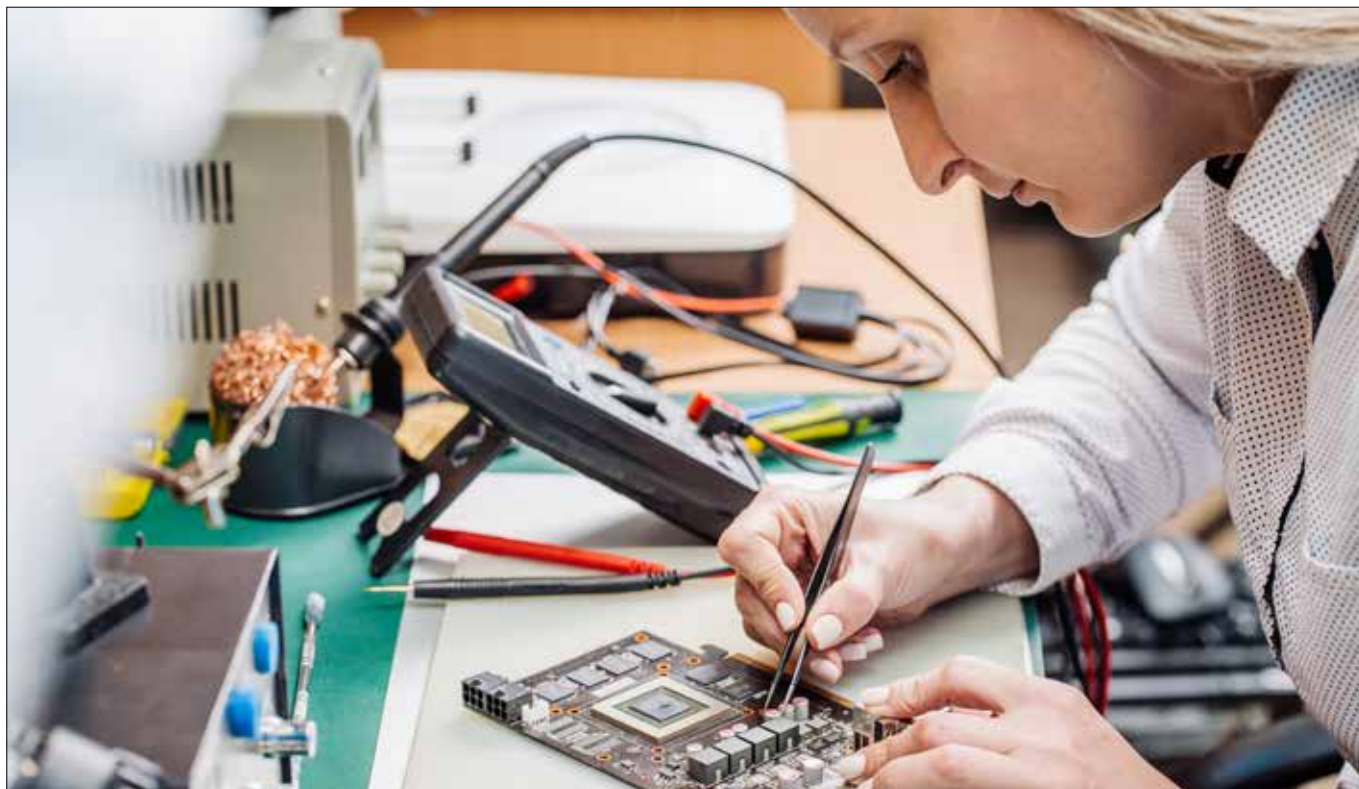
- Guest lectures by space professionals to demonstrate the exciting range of real-world activities and careers related to space, particularly in Australia but also internationally
- Hands-on activities such as physics experiments, building and launching model rockets, and contextual science exercises
- Site visits including government research facilities, military bases, university laboratories and the Planetarium
- Information talks about relevant university courses and STEMM careers

In addition to the Year 10 SASS program there is a National Space Camp (NSC) that is run at a Year 11 level for a group of graduates from SASS. This program can include a trip Woomera to participate in a rocket launch by the Australian Space Research Institute (ASRI), to Victoria to take part in the Mission to Mars and to work on Human Biosciences (humans in space) at the Victorian Space Science Education Centre (VSSEC), or to Canberra to visit a number of space science related organisations such as Tidbinbilla, Mount Stromlo and the Australian National University.

In 2017, SASS staff ran a 20-year longitudinal study of past SASS and NSC students to ascertain the impact of these programs on students' career choices. The results were overwhelming with over 75% steering towards STEMM careers.

One past student is working at the ESA Astronaut Training Centre in Cologne, Germany and is the voice to the International Space Station. Other past Space School students have gone on to join the Royal Australian Air Force, work at DST and complete PhDs in physics and degrees in space sciences and engineering. ■

CUAVA: TOWARDS SPACE 2.0



CUAVA brings together academia, government and industry with a mission to develop Australia's expertise in next-generation satellite and UAV technologies. By **Lachlan Colquhoun.**

A few years ago, Iver Cairns was feeling a little frustrated with the level of official support for developing the Australian space industry.

Professor Cairns, the Professor in Space Physics at the University of Sydney, then took matters into his own hands, forging an alliance with the University of NSW and the Australian National University which resulted in the

construction of a cubesat, one of the new class of small satellites.

That satellite was launched in May 2017 out of the International Space Station. It was one of the first Australian cubesats and, so far, one of only around half a dozen Australian satellites ever launched since WRESAT went skywards from Woomera in 1967.

The cubesat was also only the second satellite to pass testing as part of the international QB50 project to launch 50 new cubesats into space.

Since that launch, quite a lot has happened in the Australian space industry, which has new momentum culminating in the creation of the Australian Space Agency.

The Space Agency is not the only new initiative, however, and Professor Cairns now heads up the recently formed CUAVA – the ARC Training Centre for CubeSats, Uncrewed Aerial Vehicles

(UAVs) and their Applications.

With five-year funding from the Australian Research Council (ARC) which began in late 2017, CUAVA brings together academia, government and industry with a mission to develop Australia's expertise in next-generation satellite and UAV technologies.

CUAVA's academic partners are Macquarie University, University of NSW, the University of Sydney along with US institutions the Rochester University of Technology and Texas A&M University.

From the government sector, partners are the Bureau of Meteorology, Defence Science and Technology, and the NSW Office for Science and Medical Research.

Industry partners comprise Air@Wave Communications, ArborCarbon, HyVista and Saber Astronautics.

"Our role is to try and help create an Australian space industry, and specifically develop the human capital

to develop cubesats and UAVs," says Professor Cairns. "So that means training people in terms of research but also for industry, with a commercial focus and that means developing new applications for the satellites.

"These can be things like looking at thermal plasma so we can improve our knowledge of space weather, to reflecting GPS signals off the sea so that we can understand wind speeds which are critical for predicting weather and sea state."

The satellite industry, says Professor Cairns, is developing rapidly beyond the large and expensive satellites which take years to build and launch.

Lower orbiting cubesats, weighing less than 5kg, are faster to develop and launch and are much cheaper to deploy.

"If you are doing something in a business sense, how many business cycles is a big satellite which can take years?" he says.

"The idea now is that not only are cubesats cheaper, but you can get them into orbit quickly and you can do it in a three- to four-year timescale and do something interesting and exciting with them."

The 2017 cubesat, for example, was simply sent up to the International Space Station on the autonomous Cygnus spacecraft, which regularly services the station as a cargo vehicle, and then deployed from a pod. No separate launch was required.

The second focus for CUAVA is the UAV industry, which is also set for takeoff as a major new market, and offers high resolution applications at low cost.

UAVs are even faster to deploy and less expensive than cubesats, and have shorter observation periods.

"The big picture is that a much higher percentage of our GDP will be associated with the collection and processing of space data collected from cubesats and UAVs," says Professor Cairns. "We are going to have much

more imaging data, and that can be used for commercial purposes such as assessing the health of crops and searching for minerals, or for better weather forecasting and for pure research.

"Space is vital to our future and we really need to engage with it and we have an opportunity now and an approach which can really see us play a part in the so-called Space 2.0."

Developing cubesat expertise, he says, could also see Australia develop other, slightly larger satellites – "the size of a slab of beer" – which can pack more technology.

"If you can build a cubesat you can build a larger one if you need to," says Professor Cairns.

CUAVA is currently building its first satellite – CUAVA 1 – which is set for launch from the International Space Station later this year.

The goal is then for CUAVA to launch a new satellite every year, rolling out new and faster communications technologies and with different applications developed by its partners.

Each satellite will be launched at an altitude of around 450km above the Earth and orbit for a year and a half before breaking up on re-entry.

CUAVA's UAV program has also already conducted its first flight, a project launched at Jervis Bay in NSW.

"That was a whale-watching project," says Professor Cairns. "One of our students was interested in behavioural studies of whales and identifying them based on imagery.

"That can be extended to technologies which enable the autonomous identification of objects, and this can be useful in remotely identifying anything from a tree to a tank."

With its ARC funding, Professor Cairns estimates CUAVA will be able to put around 30 postgraduate students through its program, and there are currently around five students working at the Centre.



"Looking at our current PhD students, a very small percentage of them are likely to go into academia," he says.

"The American experience is that around 60% of PhD students go into industry and that is where we should be expecting ours to go too."

These students, says Professor Cairns, are likely – as he did himself – to spend some of their careers overseas learning more, but it was important to create an industry in Australia they could come back and work in.

"We just don't want everyone to go overseas and not come back," he says.

"We can't have that as a country, and the goal of CUAVA is to help develop a new domestic space industry which has momentum and critical mass and can make a real contribution." ■



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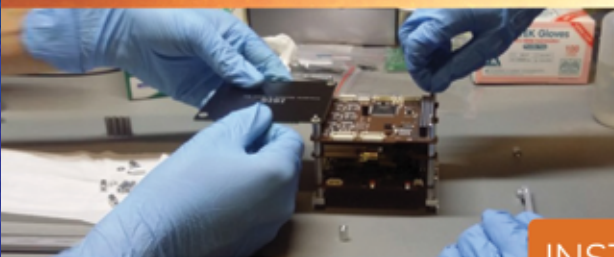
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ROMAR INVESTS IN ROCKET CAPABILITY

Modern rocket engines comprise a multitude of intricately made and specialised components, and in the near future some of these components are likely to be made by Sydney-based Romar Engineering. By **Lachlan Colquhoun**.

With half a century of engineering heritage behind it, Romar Engineering has recently invested significantly in both high-tech equipment and also in the human capital required to get the best out of the new technology.

The result is that the company, which began as a manufacturer for the automotive supply chain

before moving into health devices, could soon be a significant – and highly specialised – manufacturer of components for the space and aerospace industries.

Alan Lipman, Romar's chief executive, explains that the company recently invested in a precision 3D printer which is the latest in additive manufacturing, and the only one of its kind in the southern hemisphere.

The German-made Lasertec 65 machine is hybrid technology which combines additive manufacturing, 5-axis machining and in-process inspection.

It gives Romar new capabilities in compression and injection moulding and silicon biomedical assembly which have applications not only in the space industry, but in areas such as defence and mining.

"These machines are among the most sophisticated pieces of manufacturing equipment in the world, but they are not 'plug and play'," explains Lipman. "To get the best out of this machine requires a deep understanding of everything that goes with it, and that is a deep knowledge of materials and the stresses and the speed of manufacturing individual components.

"Anyone buying that machine would take years to get it right without the right person operating it, and that is why we also invested significantly in human capital."

Romar's new hire in 2020 is American Steve Milanoski, a veteran of Elon Musk's SpaceX and an earlier career on US Navy nuclear submarines as a navigational electronics expert, where he clocked up around 17,000 nautical miles navigating the Los Angeles class attack sub.

At SpaceX, Milanoski pioneered the 3D printing of some of the largest parts installed on the company's latest generation Raptor Engines and he has similar plans for his role at Romar.



Image: Romar Engineering

"The machine shop at SpaceX is where theory met practicality," says Milanoski.

"I started there as part of the propulsion team building components for the earlier Merlin rockets, and had eight great years at the company."

Milanoski also had a key role in creating the first 3D-printed components for rocket engines, building parts which have been certified by NASA that have paved the way for next-generating manufacturing processes.

"We flew the world's first 3D rocket engines, and that has led to the rocket engines we see now," he says.

"There are so many components in rockets, and at Romar we have the capability to supply some of the most critical parts, such as seals and parts made of highly specialised metals."

Milanoski says Australia has a long heritage of participation in space, going back to the Apollo program, and says that local industry can "absolutely" participate in the next chapter of space flight and it was "common sense" to create the Australian Space Agency.

"Australia has great cutting-edge research and applications, but they tend to be in areas such as software and artificial intelligence," he says. "While it might not do so much on manufacturing side, that is where we are looking to dovetail and make a contribution."

As Lipman explains it, Romar is at the beginning of a transformation journey which could see it play a major role not just as a collaborator in the Australian space industry, but internationally as well.

Today, around 65% of the company's business is in building components for medical devices, with the balance in industrial products.



"I see that moving to around 50:50 over time, and we build up the high-tech manufacturing for space and aerospace," he says.

"Having someone like Steve here who completely understands the machine, and where the envelope can be pushed in terms of the technology, is a massive advantage for us.

"We know that we not only have the machine, but one of the only people in the southern hemisphere who can get the best out of it, so we are definitely looking to leapfrog into the space sector and we have an opportunity to be a leader in our field."

Lipman says that today's space industry is a collaborative effort, with companies focusing on being the absolute best in specialised areas.

"We are good at what we do here at Romar, and we can combine with others who have the same outlook but in other areas," he says.

"There are so many components in making a rocket work, and if we can supply some of these critical parts we only need to make around

20 of them a year to make a contribution to space, and achieve our own goals."

To this end, Romar is aiming to achieve the updated AS9100D standards certification for the aerospace industry from the Society of Automotive Engineers and the European Association of Aerospace Industries.

The widely adopted quality management accreditation will open up more opportunities for Romar as it ramps up its capability.

From the medical device side of the business, Romar already has a component on the International Space Station through its expertise in silicon moulding, and the hope is that rocket componentry will be the next of the company's products in space.

"Here we are, a little company in Sefton in Sydney manufacturing a part which is on the International Space Station," says Lipman.

"That is because we punch way above our weight in the moulding of silicon, and I think we can do the same thing in regard to supplying 3D components for rockets." ■



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ADVANCED MANUFACTURING TO THE FORE

Advanced manufacturing techniques with next-generation composite materials are a key part of building a modern space industry. By **Lachlan Colquhoun**.

Australia has a number of growing companies participating in the advanced manufacturing area, leveraging research from universities with advances in 3D printing and additive manufacturing to create a rapidly growing sector of innovation.

Many of these companies are already servicing the aerospace and defence industry supply chains in addition to the health industry, and

space offers a new market for these advanced techniques.

Some – such as Romar Engineering in Sydney – began as suppliers to the automotive industry and are developing and investing heavily in new expertise which positions them to participate not only in Australia's space industry, but internationally.

AMAERO INTERNATIONAL

At Amaero International in

Melbourne, chief executive Barrie Finnin makes the point that Australia has had a capability in high technology to supply the space sector for many years, through organisations such as the CSIRO and Defence Science and Technology, and the local operations of companies such as BAE Systems.

Finnin welcomes the new focus on the sector, and the creation of the Australian Space Agency, as a way to develop a strategic “Team Australia” focus which has been lacking but which can now help foster a bigger industry and create more jobs.

“We lost the engineering capability which was part of the automotive vehicle industry, and while the defence sector has stepped up the space industry can also be a new dimension,” he says.

“I see the space industry as part commercial and part government, be that an organisation like the Bureau of Meteorology or Defence, and it makes sense for there to be a significant locally manufactured component.

“Having the space agency now doesn’t assure that, but at least it ensures that there is a capability here

for it when it is needed.”

While it already has customers in defence and commercial aerospace, and has a capability in the area of medical devices, Finnin sees Australia’s developing space industry as another potential market for his company.

“We have already produced components for satellites and done rocket motors,” he says.

“One of our largest customers is a significant player in the space market, so the potential is there for us.”

AMIGA ENGINEERING

While Amaero is a young company, beginning life as a spin-off from Monash University in 2013, other players in the advanced manufacturing sector have been around for much longer.

Melbourne-based Amiga Engineering, for example, was founded in 1988 by two brothers – Michael and Dale Bourchier.

Originally, the company was an outlet for machining pipe flanges, fittings and special components and then grew to become a supplier to the oil & gas, petrochemical, marine, medicine and defence industries.

Amiga has invested in a 3D metal printing capability, acquiring two industrial-grade printers and also investing in post-processing equipment for heat treating and machinery polishing.

This gives Amiga the ability to not only create new designs, but also the capability to develop parts overnight, as opposed to over days or weeks. This ultra-fast design process allows designers and engineers to test and develop parts much faster.

TITOMIC

Titomic is a younger company than Amiga, but is also based in Melbourne.

The company was created in



2014 and has the exclusive rights to commercialise the CSIRO's patented process for the application of cold-gas dynamic spraying of titanium or titanium alloy particles onto a scaffold to produce a load-bearing structure.

In 2019, Titomic unveiled what was to that point the world's largest 3D-printed titanium rocket.

The 5.5-metre rocket, which was built in less than 28 hours, was displayed at FormNext, the world's biggest 3D printing fair, held in Frankfurt, and was a scaled-down version of a real-size spaceship.

The company says it has the capability to build a full-scale space rocket in 165 hours, while a rocket of that size and material would normally take years to build.

In 2020, Titomic announced a partnership agreement with US-based Ascent Aerospace, for the execution of commercial opportunities to deliver the unique capabilities of Titomic's Kinetic Fusion (TKF) for Ascent's associated aerospace customer base.

Ascent is the leading provider of aerospace tooling systems, assembly automation and factory integration for the aerospace, defence and space industries globally.

SUCCESS IN ROCKETRY

Titomic is not the only young Australian company with a successful track record in the area of rocketry.

In 2017, a team of Monash engineering PhD students successfully designed and test fired a rocket engine manufactured by Amaero Engineering in Melbourne.

This engine was built to a unique design called 'aerospike' using a super-alloy called Hastelloy X, and was among the first to be constructed using the almost limitless geometric complexity of additive manufacturing (AM).

Amaero, a company which originated out of the research and



Some companies – such as Romar Engineering in Sydney – began as suppliers to the automotive industry and are developing and investing heavily in new expertise which positions them to participate not only in Australia's space industry, but internationally.

development laboratories at Monash University, had already built a jet engine through AM, and then challenged the engineering students to design a rocket engine which would be built through the same process.

"We were able to focus on the features that boost the engine's performance, including the nozzle geometry and the embedded cooling network," says the project lead, Graham Bell.

"These are normally balanced against the need to consider how on earth someone is going to manufacture such a complex piece of equipment. Not so with additive manufacturing."

The unique aerospike design offers some unique advantages over its more conventional counterparts.

"Traditional bell-shaped rockets, as seen on the space shuttle, work at peak efficiency at ground level," says Amaero engineer Marten Jurg. "As they climb the flame spreads out reducing thrust. The aerospike design maintains its efficiency but is very hard to build using traditional technology.

"Using additive manufacturing we can create complex designs, print them, test them, tweak them and reprint them in days instead of months."

The rocket project was an effective demonstration of Amaero's

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capabilities, and also led to the creation of a start-up called NextAero, which aims to take these concepts to the global aerospace industry.

The commercial opportunity the company sees is in developing rocket engines which are more fuel efficient, and can maximise launch revenue.

While retaining involvement in NextAero, the rocket project showcased only a very small part of what Amaero does.

From its origins at Monash University, Amaero was formed in 2013 and was listed on the Australian Securities Exchange in 2019 to further commercialise its world-leading AD capabilities.

Also known as 3D printing, additive manufacturing builds a three-dimensional object from a computer-aided design model, usually by successively adding material layer by layer.

This is unlike conventional machining, casting and forging processes, where material is removed from a stock item or poured into a mould and shaped by means of dies, presses and hammers.

Although "still basically a start-up", according to chief executive Finnin, the company already has a significant manufacturing capability in three continents and is supplying customers in Europe, the US and Australia with bespoke metal components created by 3D printers. Clients include defence primes such as Thales, Raytheon and Boeing.

Finnin says Amaero's competitive advantage is that it was an early adopter of this technology, and the quality of its products has already been certified for use in the aerospace industry.

"There are a lot of people out there selling 3D printers and metal powders, and there are people out there trying to make the grade

with products for flight critical applications," he says.

"The work that Monash University did was in optimising the chemistry, the powder morphology and also the machine parameters and post-processing.

"So while there are a lot of people who claim to be able to do work similar to ours, we have been through the qualification process and that takes about five years, so we are ahead thanks to the investment by Monash and are now well positioned for manufacturing, not just prototyping."

While a commercial spin-off from Monash University, Amaero is still located in close proximity to the researchers and maintains contact and research links.

Amaero is continuing its collaboration with Monash, where each party provides services to the other such as access to 3D printers and related equipment, access to specialised personnel and licences to intellectual property.

"Right next door to us we have the Monash Centre for Additive Manufacturing, and the university has over 50 full-time dedicated researchers working in this area," says Finnin.

"The CSIRO's Lab 22, its centre for additive manufacturing, is right across the road, so we are still in a research cluster and can draw on that as a flexible labour force."

AMAERO'S COMMERCIAL FOCUSES

Commercially, Amaero has two focus areas. "One of these is the defence and aero sector, and that is dominated by defence primes, and then there is the commercial aerospace sector which is also dominated by a handful of big companies," says Finnin.

The second area is tooling, and Amaero has the capability to 3D print for this market, delivering the advantage of faster turnaround times.

"The tooling market is probably worth around US\$90 billion globally," says Finnin.

"We'd be pretty happy with 1% of that, and then to see that grow to around 10% in 10 years.

"We are not going to reach potential scale for a few years yet, but if we get some of the opportunities we are going to get it would make sense for us to get a much larger footprint in the US."

In February of this year, Amaero International expanded to the United States, opening a facility at El Segundo, Los Angeles, California.

The facility will produce tooling and parts for existing customers such as Boeing, Raytheon and Northrop Grumman which are located nearby.

In Europe, Amaero has a manufacturing facility in the southern French city of Toulouse to service a strategic partnership with Safran Power.

For Safran, Amaero will provide its EOS SLM 3D printing capability and additive manufacturing expertise.

This partnership comes after a successful demonstration of Amaero's manufacturing capabilities where together with several partners they reproduced a Safran Power Units gas turbine jet engine from a Falcon 20 executive jet using metal 3D printing.

In Australia, the original manufacturing facility in Melbourne was joined by a facility in Adelaide, officially opened in March 2020.

This came after Amaero signed a strategic partnership agreement with the University of Adelaide to develop an additive manufacturing capability in South Australia.

MATRIX COMPOSITES & ENGINEERING

Another company with a significant history in manufacturing is Matrix Composites & Engineering, which specialises in the design, engineering and manufacture of composite and advanced material technology solutions for the civil and infrastructure, resources, oil and gas, defence and transportation industries.

Matrix has gained a reputation as an industry leader and has become a major exporter of Australian goods and services with customers located all over the world.

Founded as Begley International in 1980, Western Australia-based Matrix listed on the Australian Securities Exchange in 2009 and established a US facility in 2012.

The company has been a long-standing supplier to the defence industry supply chain, producing engineered products, functional additives and advanced materials for a variety of defence applications.

Last year, Matrix partnered with UK company Qinetiq and local universities and received a \$1.5 million grant to develop stealth materials to make submarines more difficult to detect.

The grant was from the federal government's Next Generation Technologies Fund established in 2016, which will allocate \$730 million over a decade on innovation in areas such as quantum science and autonomous systems.

In 2019, Matrix opened an upgrade to its Henderson facility in WA, featuring a new large composite workshop and a newly installed roto moulding machine.

The facility also includes Matrix's hydrostatic testing area, which is used to simulate deepwater environments down to 5,300 metres and has growing applications in the defence sector. ■

AMAERO

ADDITIVE MANUFACTURING

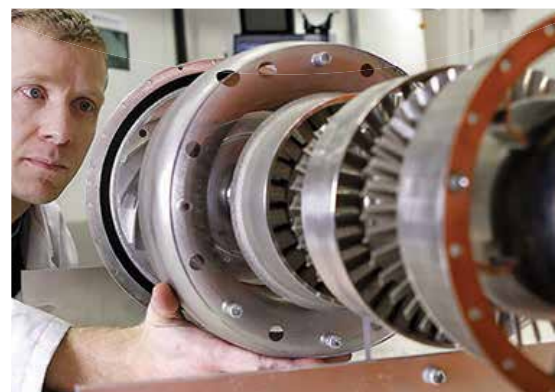


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However, it is how well the interconnections are made from one printed circuit to the next layer in the stack that will define the integrity of the system. HRPC like Micro-D and Nano-Ds or Hi-Rel 2mm or 1.25mm pitch Datamate connectors allow for higher density, while still supporting current levels needed to run up and down the stack.

Here the old adversaries, Finance and Engineering, meet at the project budget and ask the question is the high-cost component better than the low-cost component? Naturally there are many options and answers. Part of the cost of components involves the level of screening/testing levels (see table below) and number of failures to reach the standard required for that part. To build 100 parts you may need to make 112 to have 100 at the end of the process, so the cost of 112 gets distributed over the resulting 100, which increases the unit cost. The failures are due to variations in the raw materials used in the production process.

How many times have you had a coffee from your favourite coffee place and it is different from the last one? It can be due to who made it, milk temperature or how the batch of beans were roasted; it is the same principle.

Then consider the component assembly process: if it is a simple

By **Glenn Clarke,**
Managing Director, Clarke
& Severn Electronics.

The LEO or GEO space environment is harsh with temperature variations of hot and cold extremes, the effect of shocks and vibrations on components, radiation and outgassing as component materials experience a change of state. The quality of the connectors selected will affect the success or failure of your mission, so Hi-Reliability Precision Connectors (HRPC) should be a major consideration in the design process, as well as how far and how long you expect your sat to go or be in space. The experience of space agencies like ESA, NASA, CSA and others have helped by defining material standards for connector construction used in HRPC.

With improved packaging, smaller cables and smaller connectors, designers can, indeed, cram more electronics into smaller and lighter-weight boxes. Selective digital chips are also offering significantly higher digital processing capabilities as well as dramatically increasing circuit speeds.

Cable and connector interconnections focused on 'small and light-weight' must also exceed reliability assurances for extended use in deeper space. NASA-approved low outgassing materials, construction methods and connector reliability certifications are required in design and construction. Additional attention is also needed on long-term shock and vibration effects, as well as for extended thermal cycling

Screening level	Special screening	Outgassing
Level 1. Mission critical	SPT 1	Less than 1% TML
Level 2. High reliability	SPT 2	Less than 1% TML
Level 3. Standard reliability	Standard reliability	Less than 1% TML

part then the assembly process can be automated and made by and inspected by machine, but if it is a complex part involving more manual assembly, then the cost goes up. Same with inspection and testing – more or less automation affects the cost.

Finance and Engineering can work together by changing the question from high or low cost to what is fit for purpose and value for money in terms of the budget. Use components that will do the job, the simple design parts will suit most interconnection requirements. But if you need a lot of connections, with limited board real estate then it may be that complex design part that saves you from a costly redesign. Along with the length and type of mission planned in are all factors that should be considered when selecting components, as an incorrect choice can be very costly if

the mission fails to meet its goals.

Some examples of HRPC parts are Harwin's M80 Datamate, 2.0mm M300 or 1.25mm G125 series which are high-quality, low cost because they are of a simple component design which lends itself to highly automated assembly, along with the screening level. They are suitable for space applications and have been used in QB50, Waterloo Rocketry and Warrick Satellite Programs.

Omnetic's Micro-D, Nano-D, Series are high-quality with a higher cost because they are complex in design, have a higher pin density per part and assembly is semi-automated not fully automated with more manual processes, along with the screening levels. They are suitable for space applications and have been used in Virgin Orbit Launcher One, Hubble,

Curiosity Rover, TanDEM-X and TeraSAR-X.

Many miniaturised connectors achieve high reliability in satellite connectors using a specialised design that employs a Flex Pin/Spring Pin/Socket System (used by Omnetics) or Solid Pin/Socket Clip system utilising 4 Finger Clip (used by Harwin) with proven reliability over wide ranges of shock, vibration and thermal changes. Made of BeCu (beryllium copper) with high tensile strength, they are designed to withstand the rigors of use and physical abuse experienced in lift-off and space flight.

The HRPC options for sat systems are many, but more importantly, because they have access to HRPC components, designers at all levels from students to engineers can now accomplish design tasks at comparatively lower cost. ■

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SPACE LAW IN AUSTRALIA: WHAT IS IT AND WHAT DOES IT MEAN?



Effective and predictable legal regulation is a necessary precondition for every business sector and space is no different. By **Joel Lisk, PhD candidate, Adelaide Law School, University of Adelaide; Lawyer, Cowell Clarke.**

Just like the financial services, banking, mining and construction industries, the Australian space industry is subject to a specialist legal regime. Within Australia, and across the world, there are laws dedicated to the licensing and regulation of launch activities, regulation of electromagnetic spectrum,

telecommunications, and the import and export of space technology. These laws play an essential role in the ongoing operation of the space sector – they are intended to provide certainty for operators, protect Australian national interests and allow industry participants to work within a defined framework of rules.

In the last year, an essential part of this framework came into force – the Space (Launches and Returns) Act 2018 is an updated and modernised law that marks a firm transition from the envisioned large launch, single payload space industry and laws of the late-1990s, to the nimble and innovative Australian space sector of today.

THE SPACE-ADJACENT INDUSTRIES

The introduction of the Space (Launches and Returns) Act 2018 does more than amend the existing legislation to ensure Australian laws are flexible and well adapted to the modern space industry – the legislation has solidified the ongoing

importance of the space industry and those sectors of the economy that sit alongside the launch and satellite sectors.

The space industry requires input from more than the engineers and scientists on the ground and in the lab. Companies seeking to operate space assets inevitably require lawyers to assist them in navigating legislation like the Space (Launches and Returns) Act 2018 in Australia and similar laws overseas, structure companies in a way that protects assets and allows for financing from third parties, and to assist with the day-to-day operations of a business that requires navigation of contracts, corporations laws and numerous other obligations that can appear along the way to successfully operating space assets. Furthermore, the content of applications for launching under the Space (Launches and Returns) Act 2018 and rules beneath it solidify the importance of other experts: environment consultants and planners for launch sites and other developments, physical and cyber security experts to ensure that space assets and launch facilities are secure, and financial planners and economists to assist businesses in complying with their financial obligations at law and are capable of funding research and development. This is in addition to downstream industries and individuals that benefit from Australian participation in outer space. The Space (Launches and Returns) Act 2018 symbolises the reality that orbit and outer space are viable domains for commercial activity, allowing for businesses to invest and rely on the sector.

THE 1998 LAW

In 1998, Australia became the sixth nation to introduce laws focused on regulating space activities, following nations including the United States and United Kingdom. The Space

Activities Act 1998 sought to regulate the launching activities of Australians and companies operating into Australia and was implemented to directly respond to three separate proposals from private industry to establish commercial space launch facilities, namely at Christmas Island, Woomera and Cape York. The legislation also focused heavily on insurance and liability issues, amidst a concern about taxpayer responsibility for any space-related disasters.

At the time it was submitted to the Federal Parliament, that legislation intended to attract commercial investment while ensuring that Australia complied with its international obligations

"The Space (Launches and Returns) Act 2018 symbolises the reality that orbit and outer space are viable domains for commercial activity, allowing for businesses to invest and rely on the sector."

and protected its national interests. Australia is party to the five United Nations space treaties (the Outer Space Treaty, Rescue Agreement, Liability Convention, Registration Convention and Moon Agreement) and is internationally obligated to authorise and supervise the activities of non-governmental entities. Furthermore, one of the more unique aspects of the international legal regime applicable to space activities is that Australia is financially liable for the activities of Australian nationals, or those activities that have been conducted from Australian territories. The Space Activities Act 1998 went to addressing these obligations and the inherent sovereign risks that may arise as a consequence of private space activities.

Some elements of Australia's approach to regulation were unique, focusing on the type of activity a company intended to undertake rather than granting a general authority to launch rockets and conduct activities in outer space. Australia also introduced a unique approach in defining outer space, for regulatory purposes, to start at 100km above mean sea level, a measure that has only been followed by Denmark and Kazakhstan since its introduction into the Space Activities Act 1998 in 2002. This demarcation of outer space set the general applicability of the Space Activities Act 1998 – if an operator did not intend on reaching 100km above sea level, they did not need a launch licence. This diverges significantly from the approaches of other nations which either refrain from providing a clear definition of outer space or use technical measures such as orbital trajectories. In many respects, the definition of outer space provides a clarity of applicability that cannot be found in other domestic laws

On the other hand, the Space Activities Act 1998 adopted a traditional approach to regulating by prohibiting certain space-related activities without a licence and introducing a range of compliance obligations for those who did have a licence. The legislation created five licences and authorisations, each with a different focus based on the activity an operator sought to undertake: space licences, launch licences, overseas launch certificates, return authorisations and exemption certificates. The legislation introduced a range of application requirements, and compulsory and discretionary licence conditions. A notable requirement was that licence holders were required to hold \$750 million of insurance to cover any potential damage that may occur as a result of a permitted activity.



Despite government enthusiasm and the implementation of what was considered to be an innovative legislative framework, an Australian space launch sector never eventuated. The legislation, which had been drafted with a specific vision of Australian commercial space operations in mind, neither reflected the space industry of the day nor adapted to an evolving 21st century space industry.

REFORM

After nearly 17 years in force and much technical innovation in the space sector, Christopher Pyne, Minister for Industry, Innovation and Science at the time, announced a review of the Space Activities Act 1998 with the aim of ensuring that legislative framework “keeps pace with international change and technological development without adding unnecessary impediments to private investments”.

The review unearthed significant malcontent directed at the Space Activities Act 1998 by industry.

Submissions highlighted the barriers the legislation imposed on innovation, a lack of balance, and that its conditions were too restrictive. One submission went so far as to call the Space Activities Act 1998 “draconian”.

SPACE (LAUNCHES AND RETURNS) ACT 2018

The review prompted the development of Space (Launches and Returns) Act 2018 – an amendment (both in substance and name) to the Space Activities Act 1998 that aimed to clarify, simplify and modernise the law. These amendments passed the Federal Parliament on 23 August 2018 following further consultation periods and entered into force, replacing the Space Activities Act 1998, on 31 August 2019.

The changes saw a mix of wholesale and finer adjustments to key provisions in an attempt to sufficiently modify the existing legislation sufficiently to suit rapidly evolving needs. Following the legislation’s introduction into the Federal House of Representatives,

Minister Dan Tehan emphasised that the amendments were focused on “accommodat[ing] technological advancements” while not “unnecessarily inhibit[ing] innovation in Australia’s space capabilities”.

In terms of changes, the first and most obvious is the change to the title of the Space Activities Act 1998. The new short title recognises that the Space Activities Act 1998 did not regulate all space activities, just the launch and return of objects conducted in Australia or by Australian nationals.

The object and purpose of the legislation – a statement of what the legislation seeks to achieve – also changed to reflect the evolution in the international space industry. A core focus in 1998 was the establishment of a system for payment of “adequate compensation for damage”. This gave way to a focus on removing barriers to participation in space activities, encouragement of innovation and entrepreneurship, and seeking a balance between commercial activities

and the safety of space activities and risk of damage to persons or property. This theme continues throughout the Space (Launches and Returns) Act 2018.

The licences and authorisations under the legislation are still delineated based on activity, with amendments to streamline and simplify the licences required by operators. These licences are:

- Launch facility licence to authorise the construction and operation of launch facilities within Australia and its airspace
- Australian launch permits to allow for the launch of rockets from Australia
- Overseas launch certificates cover activities by Australians using launch services overseas
- Return authorisations continue from the Space Activities Act and regulate the return of certain objects from space to Australia
- Authorisations certificates to provide for exemptions in the case of emergencies or for activities that do not fit into the other categories

A significant new inclusion is a dedicated licensing regime focused on the use of high-powered rockets. The definition of these rockets remains highly technical, with a focus on the rocket's engine power and intended altitude less than 100km above sea level. The inclusion of high-powered rockets is described as a measure to ensure that Australian legislation "recognises the evolving nature of space technologies and provides a regulatory framework for the safe launching and return of these rockets". The incorporation of this new class of regulated activities is likely a response to the emerging 'sub-orbital' industry sector.

The Space (Launches and Returns) Act 2018 also recognises more innovative approaches to launching,

notably launching from aircraft in flight, a mechanism used by companies including Virgin Galactic, Virgin Orbit and Stratolaunch.

Most notably for operators, the Space (Launches and Returns) Act 2018 sees the reduction in one of the largest barriers to participation for small and medium companies in Australia: the previous insurance requirement was reduced from the maximum figure of \$750 million to \$100 million. This is further reduced to \$0 for overseas payload permits and specific classes of return authorisation, representing a recognition of the low

"Most notably for operators, the 2018 Act sees the reduction in one of the largest barriers to participation for small and medium companies in Australia: the previous insurance requirement was reduced from the maximum figure of \$750 million to \$100 million."

risks associated with many overseas launches, cross-waivers, insurance and indemnity provisions in launch contracts, and a reduction in regulatory burdens for smaller operators.

The Space (Launches and Returns) Act 2018 itself is not the only regulatory instrument that has been amended. The Space Activities Act 1998 allowed the production of the Space Activities Regulations 2001, a document that provided more detail to the overall regulatory regime, detailing the information required for applications, the fees payable for each class of licence, conditions on licences and other administrative matters. The Australian Space Agency has taken responsibility as the licensing body for the Space (Launches and Returns) Act 2018 and produced three sets of 'rules' that provide more detail for

those seeking a licence to conduct a space activity:

- Space (Launches and Returns) (General) Rules which covers the information and requirements applicants for licences must comply with
- Space (Launches and Returns) (Insurance) Rules which details more information about the insurance an applicant for a licence must hold
- Space (Launches and Returns) (High Power Rocket) Rules which relates to the licensing and operation of high-powered rockets

The general rules rectify one of the most significant issues with the previous legal regime by detailing the requirements that must be met with increased specificity, making it easier for industry to meet the standards required by the Australian Space Agency when assessing applications. The existence of an Australian Space Agency also reflects a growing maturity of the space industry.

Amendments to the domestic space law of Australia have benefits beyond increased support and certainty to the Australian space industry. They also provide certainty to the international space industry and demonstrate that Australia is a real and viable participant in the international space sector. This is further bolstered, for example, by the Federal Government's commitments to the United States' Artemis program.

The Space (Launches and Returns) Act 2018 represents a shift in governmental priorities for the regulation of space activities, one that recognises the capabilities of industry and changes in technology. The space industry is experiencing constant change and this revised regulatory regime has gone part of the way to encouraging and facilitating Australia's contribution to the global space economy. ■

USING SATELLITE TECHNOLOGY TO FEED A GROWING, HUNGRY WORLD

With the global population increasing and food production needing to step up to meet demand, remote sensing using Earth-observation satellites can provide growers with an aerial view to make quicker and more accurate assessments of their crops. By **Dr Rajan Bedi**.

Global population is predicted to increase to almost 10 billion people by 2050, requiring food production to increase by 70%. At the same time, the amount of land available to grow crops is declining rapidly, with 95% of the world's fare grown in soil. It is, therefore, incumbent that fields are used as efficiently as possible to guarantee security of food supply and long-term sustainability.

Farmers assessing their fields only get a limited view when visually checking for damage, weeds or pests. Remote sensing using Earth-observation satellites provides growers an aerial view to make quicker and more accurate assessments of their crops. Hyperspectral optical and synthetic aperture radar imagers measure the sunlight reflected by plants (greenness), fluorescence (productivity/growth rate of each plant) as well as soil quality to optimise yields. These observations are complemented by IoT sensors on the ground which determine soil moisture, pH and leaf wetness, providing farmers near-real-time status of the cultivation of their fields. If data suggests they need to spray their plants with water, fertiliser or pesticides, growers can combine the results with GPS data to instruct tractors how much treatment to apply at which rate at every point in the field enabling true-precision farming.

Earth-observation satellites are increasingly using passive hyperspectral

sensors to measure the reflected sunlight in the visible and infrared wavelengths from objects within its field of view (swath). Hundreds of bands of information for every pixel are collected and signatures are generated that are uniquely characteristic of plant physiology, crop health and plant speciation.

As the satellite orbits Earth, hyperspectral sensors capture individual slices of the incoming view through a physical slit and breaks this into discrete wavelength components onto a focal plane array. The system then separates the light in each spatial pixel into the different colours. Each time the camera

takes a picture through the slit, it gets a full frame of spectral data for each pixel. Stacking up each image as the spacecraft moves over the scene builds a cube of hyperspectral data. High-throughput payloads exploiting ultra-deep submicron FPGAs are being used to process this information. The ability to distinguish certain wavelengths is called spectral resolution and different materials have unique signatures. Spatial resolution is the measure of the observable detail in an image, from sub-metre to tens of kilometres, and is a function of the area/footprint viewed by the satellite known as the swath.

To allow real-time, high-resolution monitoring when there is cloud cover, inclement weather or during the night, an active sensor is used such as a synthetic aperture radar (SAR). Radio waves are transmitted to 'illuminate' the target scene and the echo of each pulse is received, digitised and processed to reconstruct 2D, 3D and 4D (space and time) imaged views. The amplitude

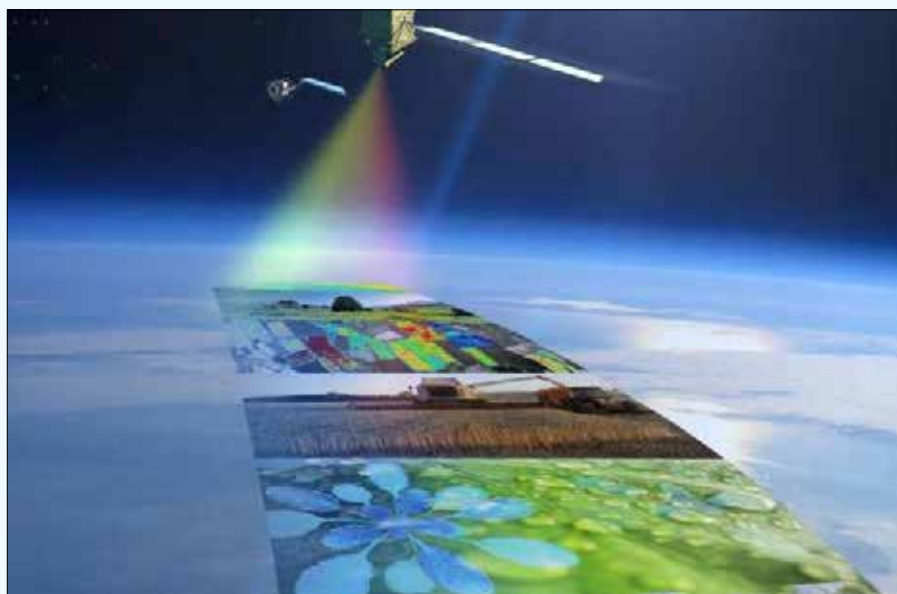
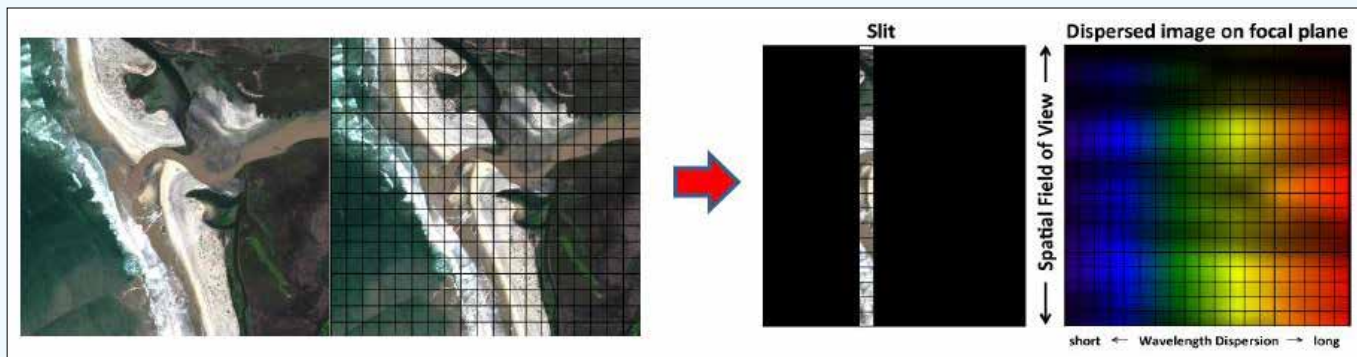


Illustration of ESA's Fluorescence Explorer mission to quantify photosynthesis.



Hyperspectral image capture and generation of resulting spectral data.

and phase of the backscattered signal depends on the physical (geometry and roughness) and electrical (permittivity) properties of the reflected scene. In the case of spaceborne SAR, as a satellite moves, transmission and reception occur at different positions within its orbit, allowing the construction of a virtual aperture that is much longer than the physical antenna length.

Global warming compounds guaranteeing security of food supply and long-term sustainability: most human activity has some impact on the environment or on specific ecosystems and this situation will only get worse as population increases. The need for continued economic development relies on activities which traditionally damage the environment and NASA's Global Climate Change website displays key vital signs, some of which are alarming to say the least. Satellites provide a global view of land and sea temperatures and ESA has created the Climate Change

Initiative which integrates datasets from different missions to produce comprehensive, long-term records.

A combination of depleting groundwater resources, climate change and extreme natural disasters are resulting in poor yields and crop loss in certain parts of India. Each year, the delays caused by institutional apathy are causing 12,000 farmers living below the poverty line to take their own lives. To address this tragic situation, satellite data complemented by information from IoT sensors is now being used to provide insurers accurate estimates of plant growth in real time, allowing farmers to receive compensation speedily.

To guarantee security of food supply and long-term sustainability, the situation at sea is equally dim: it is estimated that up to 20% of all fish caught is done so illegally, depleting the world's oceans of their precious marine stocks. Today, over one billion people in developing countries rely on fish as their primary

source of protein.

Managing sustainability at sea-level is almost impossible due to the sheer number of vessels spread across the Earth's seas and oceans. Furthermore, boats engaging in unregulated and unreported fishing can simply turn off their navigational, positional tracking and avoidance system (AIS). Satellites allow real-time monitoring of vessels, fishing methods and suspicious behaviour using optical, infrared and SAR sensors in all weather conditions and also at night. ■

Dr Rajan Bedi is the CEO and founder of Spacechips, which provides ultra high-throughput, on-board processing and transponder products for telecommunication, Earth-Observation, satellite-based internet and M2M/IoT satellites. The company also offers design consultancy, technical-marketing, business-intelligence and training services (www.spacechips.co.uk).

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SAR-based Earth observation in cloudy conditions.

TESTING HIGH-THROUGHPUT SATELLITES: FROM PROTOTYPING TO IN-ORBIT VERIFICATION

To deliver the next generation of satellite applications, operators are exploiting the on-board processing advantages of digital, wideband high-throughput payloads at higher frequencies. By **Dr Rajan Bedi**.

By moving to Ku, K, Ka, O and V bands, larger bandwidths are available to deliver services such as real-time, ultra-high-definition Earth observation and low-latency internet.

When developing satellite electronics, testing occurs throughout all stages of spacecraft development: from characterising the performance of analog parts, digital logic, SpaceWire/ SpaceFibre interfaces, RF circuits and antennas during the initial system architecture, to verifying the functionality of hardware demonstrators and validating proof-of-concepts at the prototyping (EM) phase. This is followed by measuring the performance of complete payload sub-systems and then entire spacecraft validation in a representative environment using thermal-vacuum chambers during the qualification (EQM) stage. Prior to lift-off, final integration checks are typically performed at the launch site and throughout operation, regular in-orbit checks of the transmission links are made to monitor and confirm quality of service (QoS).

A single channel of a digital, wideband high-throughput transponder is illustrated below and the key challenge for today's manufacturers of high-throughput satellites is how to test

payloads processing GHz bandwidths using M-QAM, M-PSK or M-APSK RF carriers. The ADCs and DACs are directly sampling IF/RF carriers at GSPS speeds handling Gbps of data.

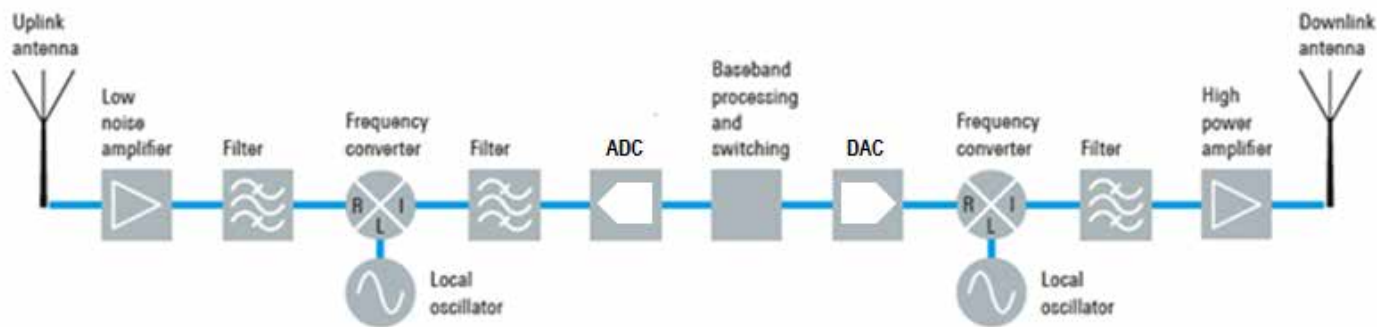
Starting at the receiver, phased-array antennas and digital beamforming techniques are increasingly being used by satellites of all sizes, orbits and frequencies to maximise the radiation pattern for reception and transmission. Determining the direction of arrival of incoming signals improves the received signal strength, reduces fading, interference and side-lobe levels, increasing the capacity of high-throughput payloads. Higher spatial diversity, better frequency reuse and more precise user positioning are also achieved.

Continuing with the high-throughput signal chain but moving to RF frequency conversion in the receiver and transmitter, a key challenge for satellite manufacturers is how to measure relative or absolute group delay (phase linearity) with unknown or unstable local oscillators. Frequency and phase changes due to drift and noise limit the accuracy of current testing methods. Furthermore, increasing integration and miniaturisation has meant that OEMs no longer have access to the local oscillator or a common reference signal.

This article will focus on mixed-signal and payload testing. As the resolution and speed of broadband ADCs/ DACs continue to increase, satellite manufacturers are struggling to verify if their mixed-signal sub-systems can reliably meet the needs of operators. Traditional signal generators do not help as their harmonics, intermodulation distortion and phase-noise levels pollute measurements, leaving many OEMs unsure if their ADC/DAC designs are compliant and/or whether their test equipment is fit-for-purpose.



SMW200A Vector Signal Generator.



Wideband, high-throughput satellite transponder.

For ADCs and DACs, the first tests are a series of single-tone measurements at different frequencies to understand in-band SNR, harmonic and spurious performance. CW characterisation allows OEMs to simultaneously differentiate between device-level artefacts and system issues, for example an ADC interleaving spur versus noise coupling from the routing of the sampling clock, power supply or poor grounding.

ADC/DAC sampling multiplies the input with the clock in the time domain which is equivalent to convolving the signal spectrum with that of the clock. It is, therefore, paramount that satellite manufacturers understand the bandwidth and frequency content of both.

For single-tone testing, the SMW200A offers spacecraft OEMs good spectral purity with a specified single-sideband phase noise of -139 dBc (typical) at 1 GHz (20 kHz offset), and non-harmonic and harmonically related spurs of < -90dBc and < -55 dBc respectively. Its output power ranges from -120 to +18 dBm, sufficient to exercise the full scale of an ADC's analog front-end.

Once the single-tone performance of the mixed-signal hardware has been understood, its linearity and wideband operation can be characterised using more representative stimuli such as multi-tone or noise-power ratio carriers to provide a measure of intermodulation distortion.

Following CW, multi-tone and wideband measurements, the

complete payload is then tested using representative stimuli such as modulated carriers to verify operational performance. The SMW200A can be used to generate any arbitrary waveform capable of synthesising 2 GHz of I/Q signal bandwidth up to 40 GHz.

For modulated carriers, the SMW200A offers a measured frequency response of < 0.4 dB over the 2 GHz of bandwidth. There is an option of a second RF 2 GHz I/Q channel up to 20 GHz, and for beamforming satellites, precise, stable, phase-coherent outputs are available to measure active antenna systems. Proprietary waveform standards can also be generated.

Once a modulated carrier format is selected and input to the payload processor, for example M-QAM, M-PSK or M-APSK, its performance needs to be measured. For digital RF communication, error vector magnitude (EVM) and bit-error rate (BER) are the major metrics used to measure the quality of transmission.

EVM is a measure of multi-level, multi-phase digital modulation quality and error performance used by satellite communication, quantifying the difference between the expected complex voltage of a demodulated symbol and the received value. EVM considers all of the potential phase and amplitude channel distortions as well as noise, providing a single, comprehensive measurement figure for determining quality.

BER is the number of errors divided

by the total number of bits transmitted measured during a given time interval and usually expressed as a percentage.

The FSW signal and spectrum analysers can directly measure the resulting EVM and BER modulation quality, as well as traditional metrics such as group delay, noise figure, spurious, NPR, ACLR, phase noise, compression and frequency response up to 500 GHz. Pre-defined satellite standards such as DVB-S2(X) are supported.

The FSW signal and spectrum analysers offer up to 5 GHz of analysis bandwidth for high-throughput satellites. The specified phase noise is -140 dBc at 1 GHz (1 kHz offset), the real-time bandwidth is 800 MHz, SFDR > 100 dBc, a minimum displayed average noise level (DANL) of -169 dBm and a measurement uncertainty of < 0.4 dB. DANL refers to the level of the instrument noise floor given a particular bandwidth and represents the best-case sensitivity of an analyser when measuring small signals. An input below this level cannot be detected.

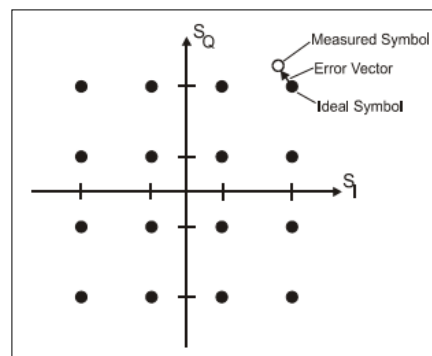


Illustration of EVM for 16-QAMw.

Once a high-throughput payload has been tested and proven in ambient conditions, its operation must be characterised and qualified in a representative environment. Vacuum chambers replicate the thermal and atmospheric conditions of outer space; however, standard test equipment is not designed to work within TVAC, remaining outside and interfacing to the DUT inside the chamber using long cables. A key concern for manufacturers is that leads, adapters and switches in the setup drift as the temperature changes within TVAC and regular calibration is necessary to ensure accurate measurements.

Previously, system error correction for network-analyser measurements used to be a tedious task as the calibration units in the setup had to be continually connected and disconnected. This was a time-consuming and error-prone process! An in-line calibration module is available to track up and downlink errors due to cabling and temperature changes from -30 to +80C. The ZN-Z33 has low insertion loss, from 1.5 dB at 1 GHz to 5 dB at 40 GHz, and high directivity from 10 MHz to 40 GHz.

Once the performance of the payload hardware has been successfully verified and qualified, testing of the flight-grade (FM) production electronics can be automated to allow OEMs to meet time-to-market needs, while at the same



Thermal-vacuum chamber at NASA's Johnson Space Centre.

time, providing a fast and repeatable test solution. All of the equipment discussed can be controlled remotely using industry-standard interfaces such as GPIB IEEE 488.2, LAN, USB and RS-232, supporting many scripting languages including Matlab, Python and CVI. The Standard Commands for Programmable Instruments (SCPI) command for every operation can be displayed and a really useful feature is a SCPI macro recorder which captures the manual testing steps developed during the verification of the initial prototype and generates code for automated measurements during production. This pre-programmed sequence of computerised testing can also be replayed if components have to be de-risked for space during radiation testing at a cyclotron and throughout the qualification phase in TVAC.

After launch, signal and spectrum analysers can be used by operators for in-orbit verification to measure the quality of downlink carriers from satellites, the received uplink or the regenerated signal inside the

transponder by comparing with known references.

For post-launch verification of satellite links and ground stations, the key challenges are to ensure that carriers arrive with sufficient power to maintain QoS and that frequency components experience the same delay to preserve their relative phases. Atmospheric conditions affect a satellite's signal power received at a ground station which in turn impact EVM and BER; for example, fog, clouds and precipitation attenuate the downlink carrier and increase noise especially at higher communication frequencies such as Ku and Ka bands.

A concern for operators is unintentional or deliberate interference which degrades the QoS of a satellite link or in the worst case, puts it out of operation. Ground stations can direct an uplink to the wrong satellite saturating a transponder. The cost to perform tests is also a major concern, i.e. the time a channel is out-of-service for post-launch maintenance rather than generating revenue. ■

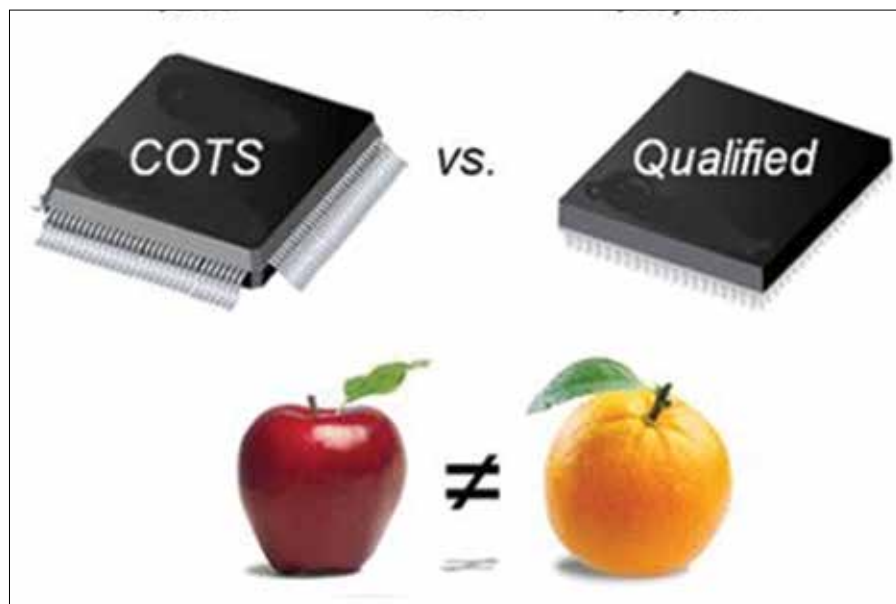
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FSW Signal/Spectrum Analyser.

HOW TO SELECT AND USE COTS COMPONENTS FOR SPACE APPLICATIONS



For some spacecraft manufacturers, the use of commercial off-the-shelf parts is the only option to meet the performance and cost needs of a mission.

By **Dr Rajan Bedi**.

For many satellite original equipment manufacturers (OEMs), the price and long lead-times of fully qualified components is simply unaffordable. Today, many commercial off-the-shelf (COTS) devices are operating successfully in-orbit and this article discusses their use and selection for space applications.

CMOS scaling, epitaxial fabrication, the use of shallow trench isolation, TMR HDL coding, SEU fault injection and sensitivity classification of the

configuration bitstream have allowed some ultra-deep-submicron, SRAM-based COTS FPGAs to be used for three- to five-year LEO missions. During system development, single and multi-bit errors can be randomly or strategically introduced to characterise potential SEFI behaviour, allowing you to understand the impact of changes to device configuration, plan a system-recovery response and improve the soft-error rate.

Today, several COTS flash-based FPGAs are operating successfully on-board satellites with users adding EDAC and TMR to increase overall reliability. Their configuration memory is SEU immune and devices can be re-programmed in-orbit.

The successful use of COTS components must be an integrated part of your complete design process: from initial parts selection, the assessment of their suitability for use in space, how devices are handled and stored once they arrive

in goods-in, worst-case and reliability analysis, testing and an approach to hardware design which reflects system reliability, e.g. prototyping early in the development cycle and burn-in to 'weed out' infant mortality failures allowing the use of more reliable components in their normal operating phase.

To achieve mission reliability, the location of COTS parts and sub-systems within the overall build is important and spacecraft modelling software such as FASTRAD can help identify areas of the satellite structure that can offer improved levels of shielding from radiation and OMERE can be freely downloaded to predict the space environment for your mission. When using COTS components, it is not devices which are being qualified, but an assurance of your total engineering philosophy!

The selection of a COTS part is as much about how a component is used as the individual device itself. For example, I am currently using very successfully a fully qualified, un-hardened DAC for 15-year missions which was never intended for satellite applications. The fabrication technology is BiCMOS, in fact, SiGe bipolar and SOI CMOS. From a semiconductor process radiation hardness perspective, that is a good start! The supplier told me that he suspected the section of the micro-architecture which synchronises the incoming digital data was soft and I recently de-risked the DAC avoiding this timing path and using another. The outcome is that the maximum sampling speed for space applications is less than that available for commercial users,

but still high enough to satisfy all of my satellite customers to date. As part of component selection and risk assessment, using a COTS in this way is acceptable.

Similarly, I was recently asked to evaluate a COTS BiCMOS ADC which has a fully bipolar digitiser and bulk-CMOS configuration logic. As part of the risk assessment, I was concerned at the potential softness of the unhardened configuration circuitry. Radiation testing confirmed that this logic continuously resets (multiple SEFIs) making the device unusable.

Today, the commercial versions of some space-grade components contain the same die as fully qualified parts, or have slightly different silicon, but are still fabricated on the same hardened process. This information is not always publically shared by suppliers and Spacechips keeps a database of such parts to help satellite OEMs select low-cost COTS devices. The number of requests received has quadrupled in the last 18 months, especially from manufacturers of New Space LEO constellations.

Most COTS parts have a plastic package which can outgas volatile materials that condense onto sensors, radiators and solar cells. Offgassing is exacerbated in the vacuum of outer space and this risk needs to be assessed on an individual mission basis. Placing the parts in a sealed (hermetic) box is one solution to limit outgassing.

Some silicon vendors offer an enhanced plastic option which are parts assured over an extended temperature range, e.g. from -55 to +125°C, where testing and characterisation accounts for glass transition effects and thermal expansion coefficients. Components can also be batch managed and typically assembled using a controlled baseline, i.e. no variation between foundries, lots and wafers, all of which

can potentially modify the hardness of parts.

The above safeguards and improved traceability are very good for the space industry as changes to the fabrication technology and/or die shrink have been known to alter the radiation hardness of COTS parts. The enhanced plastic option differs between silicon vendors and it is important that you check with your supplier as to what assurances are being offered. Many manufacturers will not guarantee the use of their COTS components for space applications nor accept any liability.

Another option to consider is that some suppliers can up-screen COTS parts to a higher level of reliability and offer QCOTS or COTS+ components. Additional tests are carried out to address known failure mechanisms for plastic parts to identify and eliminate rejects. Recent discussions with some traditional semiconductor vendors suggest they will consider requests on a case-by-case basis and there may be some MOQ requirements. Likewise for users, there are costs associated with each assessment and a typical up-screening flow can include DPA, temperature cycling as well as tests for humidity, burn-in, electrical functionality, ESD, outgassing and C-SAM to check for delamination. Formal standards such as Mil-Std 883, JESD-22/26 and MIL-PRF 55365 exist for these, and some are carried out on the complete lot whereas destructive tests such as radiation testing are performed on a small sample.

Compared to fully qualified parts, using and selecting COTS components requires careful risk assessment and their operation and/or specification may have to be modified or de-rated to meet your mission's reliability needs. When using COTS components, it is not devices which are being qualified, but an

assurance of your total engineering approach. Analyses increase reliability, mission success and give confidence that the design will deliver the required performance up to end-of-life, e.g. worst-case and parts FMEA, FMECA and MTBF. Functional, EMC and environmental testing complements analyses. When using an approach to hardware design which reflects system reliability, it is possible to successfully deliver space electronics at significantly lower cost with shorter lead times. Circuit failures are one of the largest causes of mission failure with nearly 50% of insurance claims related to the electrical power system. Design assurance typically represents less than 5% of the total spacecraft cost, whereas insurance premiums can account for up to 33%. Formal standards exist for analyses and testing, e.g. TOR, ECSS and Mil-Std. ■

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