WHAT WENT WRONG WITH AUSTRALIA'S VACCINE, AND WHY IT COULD SAVE THE WORLD

COSMOS

THE SCIENCE OF EVERYTHING

Issue 90

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118 species in a scoop

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AUSTRALIA ENTERS THE SPACE AGE – AND SHOOTS FOR THE MOON

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A shot at the Moon

The lessons we've learned through coping as Australians – such as living, working and surviving in remote locations, and communicating over great distances – are the things that give us a place at the table of future space exploration. **TORY SHEPHERD** reports.

THE DOZEN APOLLO ASTRONAUTS WHO WALKED on the Moon between July 1969 and December 1972 left more than 100 objects behind after their missions. Some were United States flags, of course. They also left four defecation collection devices, three golf balls, some tongs, and a decent array of footprints.

Then there were the sentimental items – the "we came in peace" plaque, a replica of an olive branch, and medals to commemorate two dead cosmonauts. These human artefacts are still sprinkled across what Buzz Aldrin (who reportedly dislikes being referred to as the "second man on the Moon") called "magnificent desolation".

Aldrin told *National Geographic* in 2019 that when he stepped out of the landing module he thought about the magnificence of human achievement, as well as "the most desolate sight imaginable".

"No oxygen, no life, just the lunar surface that hasn't changed for thousands of years – and the blackness of the sky. It was the most desolate thing I could ever think of. And that's why I said those words: the magnificence of the achievement and the desolation of where we were," he said.

On the first Moon walk, Aldrin also left something that could have enormous consequences for the next Moon missions, in NASA's Artemis program. During Apollo 11's time on the lunar surface Aldrin set up the Passive Seismic Experiment Package (PSEP): four solar-powered seismometers intended to detect moonquakes and sent the data to Earth.

That data gave scientists their first look at the internal structure of the Moon. Along with other seismometers left by subsequent Apollo missions, the data from moonquakes and meteorite strikes showed that, like the Earth, the Moon has a crust, a mantle and a core. Studying the moonquakes showed the crust was about 50km deep, and gave some inkling about what minerals were present.

The first seismometer ran for just three weeks (NASA says it probably overheated in the midday Sun) but its effects are still reverberating. Just over 50 years later, Flavia Tata Nardini, CEO of Fleet Space Technologies – a startup nanosatellite company – started thinking about the PSEP.

Fleet describes itself as "agile". The South Australian company's mission is "to connect

SAMANTHA CARRIROLO / GETTY IMAGES

everything using cutting-edge communications and space technologies to enable the next giant leap in human civilisation". It's part of the Seven Sisters consortium, a group of private companies and universities that is pitching to play a serious role in the Artemis program, and beyond. And they'll use seismic monitors on the Moon to do it.

What excited Tata Nardini, and the rest of Australia's space industry, was the idea of Australia having its very own moonshot moment.

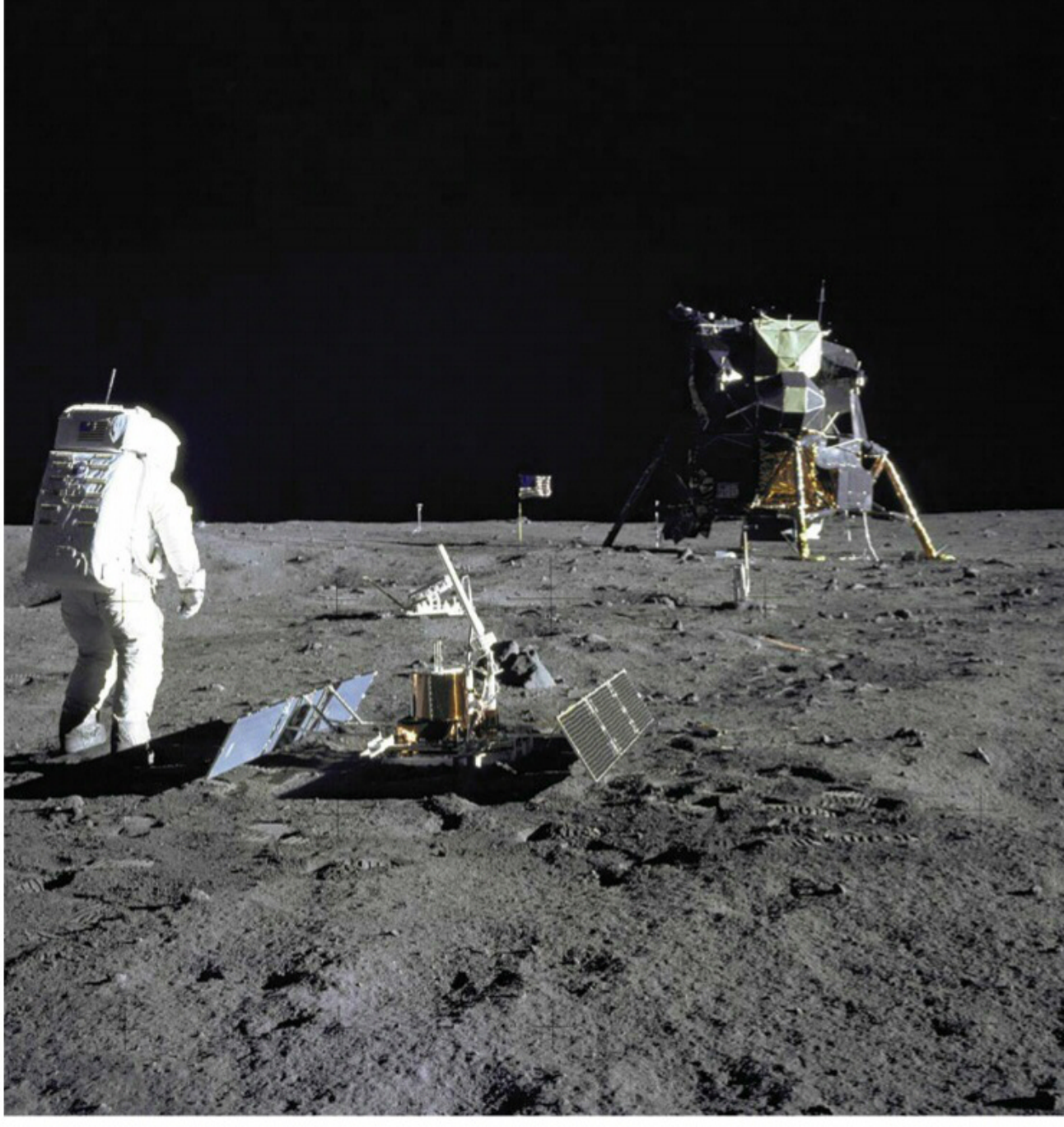
THE IDEA OF SHOOTING FOR THE MOON started with US President John F. Kennedy, as NASA grew, the Cold War got chillier and the Apollo missions beckoned.

"We choose to go to the Moon," JFK said in Houston, Texas, in 1962. "We choose to go to the moon in this decade and do the other things, not because they are easy, but because they are hard, because that goal will serve to organise and measure the best of our energies and skills, because that challenge is one that we are willing to accept, one we are unwilling to postpone, and one which we intend to win..."

Australia played a critical (if bit) role in the 1969 Moon landing, and had its own space success around that time through satellite launches from Woomera, South Australia. Now, it has a chance at its own moonshot. Bolstered by the recent creation of the Australian Space Agency, private industry and academic prowess are carving out a niche in the Artemis program, which aims to put the first woman and the next man on the Moon in 2024.

Australians are making gourmet space food and space ibuprofen, helping space clocks synchronise, and working out how to sustainably mine the Moon and Mars and set up human colonies.

The Federal Government has committed $41 million for the Agency, another $260 million for space infrastructure – particularly satellites – and



The Passive Seismic Experiment Package is deployed by Buzz Aldrin on the Moon on 20 July 1969.

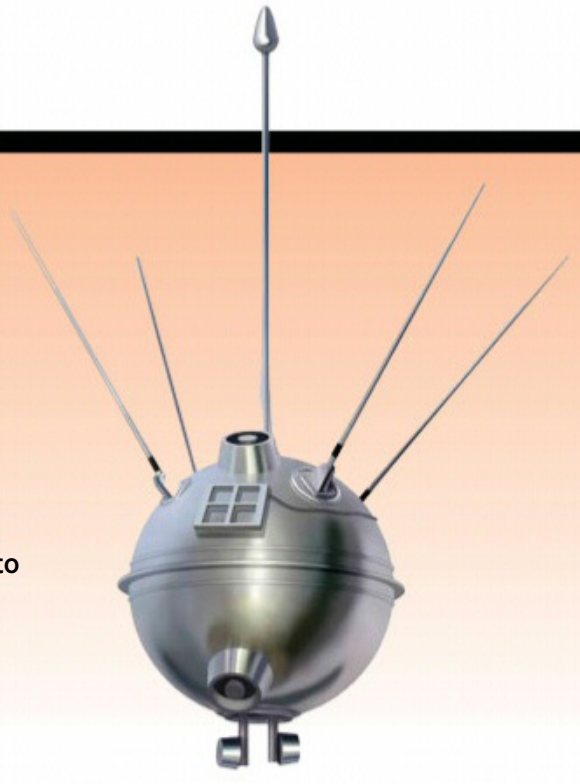
more for the Space Discovery Centre. And there's billions more for the Australian Defence Force, because space is the new frontier for national security.

The new head of the Agency, Enrico Palermo, says while the entity is young, Australia has a long and proud history. "With the rapid transformation of the sector and continued growth in unique capabilities like remote assessment management, robotics and automation, and advanced communications, Australia is well placed to offer significant value to the global space economy and be a trusted partner in future space exploration," he says.

NASA has budgeted more than $23 billion for

ABOVE: HERITAGE IMAGES / GETTY IMAGES

4 Jan 1959



Soviet probe Luna 1 is the first artificial object to fly past the Moon. It flies on to be the first human-made object to reach an orbit around the Sun.

7 Oct 1959

The USSR's Luna 3 takes the first photograph of the far side of the Moon.

LEFT TO RIGHT: QAI PUBLISHING, SOVFOTO / GETTY IMAGES

There's an increasing focus on the human side of space. And the human side is what Australians have experience in, through desert and Antarctica.

this year alone, an amount that dwarfs Australia's taxpayer expenditure. But that discrepancy doesn't reflect the significance of Australia's role.

Australia signed the Artemis Accords with NASA in 2019. The deal promises "support for NASA's plans to return to the Moon and onto Mars in areas of mutual agreement, such as robotics, automation, asset management, space life sciences, human health, and remote medicine".

There's also plenty of talk about "leapfrog research and development": the way Australia can be nimble and swift in the ways it takes established space technologies and surges ahead using already established knowledge in earthly domains. The Agency points out that Australia "punches above its weight in technology", with 0.3 per cent of the world's population but more than 4 per cent of its scientific publications.

A moment is beckoning, and some pretty clever people say we'd be crazy to let it slip by.

Rowena Christiansen, qualified space doctor, founder, ad astra vita project, a portal for space medicine

THE AUSTRALIAN SPACE AGENCY'S trailing momentum has swept up a swag of locals finding their way into space.

Rowena Christiansen – a qualified space doctor and founder of the ad astra vita project, a portal for space medicine – remembers looking through her grandfather's telescope and seeing Jupiter and Saturn. She remembers the Moon landing, and building and painting her own Apollo model. She was fascinated with Dr Spock – Star Trek's resident Vulcan – and his problem-solving abilities.

She decided to be an astronaut. It was only when she finished school that she found out women weren't even allowed to join the Royal Australian Air Force, the first step to becoming a space pilot. Eventually Christiansen got into medicine, and became interested in Australia's extreme environments: isolated communities, the desert, Antarctica. "I saw them as an analogue to space," she says.

She started working towards becoming a space physician. A conversation with her is peppered with talk about rural and remote medicine, about endeavours like the Royal Flying Doctor Service, retrieval medical support for isolated people. About Antarctica, where isolation and confinement are serious issues, and the psychological and behavioural issues that come with that: sleeping, eating well.

Her catchphrase is that she wants people in space to "thrive, not just survive".

While there has been plenty of coverage and conversation about the technical side of space travel, there is an increasing focus on the human side. And the human side is what Australians have experience in, through the desert and through Antarctica. "The human side is a lot more complicated," she says. "Australians have done the hard yards."

She points to sleep research done on Australian bases in Antarctica, where the extreme and remote environment, and absence of "regular" light patterns, can help researchers understand what astronauts need. (Naps help.)

As an aside, Christiansen says there might also be opportunities for Australian physicians in space tourism – Richard Branson has talked publicly

12 Sept 1962

In a speech in Texas, US President John F Kennedy says of the American space effort: "We choose to go to the moon in this decade."

31 July 1964

Probe Ranger 7 captures a US spacecraft's first picture of the Moon – 17 minutes before crashing into the lunar surface.

LEFT TO RIGHT: AFP/NASA / GETTY IMAGES. NASA/JPL

(and controversially) about Woomera as a base for commercial space jaunts. Take people up for a day in low Earth orbit; look at Uluru, the Great Barrier Reef. "They'll need doctors to do spaceflight medicals, to work out if they're fit to fly," Christiansen says.

"You need to look at people's ability to tolerate those G-forces, make sure their cardiovascular systems can cope. [And] things like space motion sickness. When people get up to space and start floating around, [vomiting] is a particular issue. All of a sudden to have vomit floating around the cabin…"

Then there are respiratory conditions, and the possibility of panic attacks. Spaceflight has a far bigger checklist than that confronting you when you sit in the exit row on a domestic Qantas flight.

There are also locals working on making better food for long missions. Volker Hessel, the research director at the University of Adelaide's Andy Thomas Centre for Space Resources, talks not only about the importance of nutrition on space flights, but also flavour. Good food is critical for morale.

"Ask people who stay for months in Antarctica or two weeks in a COVID-19 hotel," he says. "Food can be the only thing that makes you happy."

Hessel is experimenting with ways to make space food tastier to begin with, and less susceptible to cosmic-ray-related flavour loss. He says smell is a critical part of taste, but normally 99% of smell is bound up in the protein of the food. So if you can break the chemical bonds to free up just one per cent more, the flavour can be almost doubled.

A pharmaceutical engineer, Hessel is also working on how you might make medicine from elements found on the Moon or Mars, so humans won't have to pack painkillers. He's testing medicine on the International Space Station (ISS) and also analysing what materials might be able to make new medicines, on the Moon or Mars.

UWA's rooftop observatory telescope dome containing one of the self-guiding optical terminals which can be used for more stable and high-speed optical communications.

Among other things, Hessel used moon rocks brought back by the Apollo missions to concoct his recipe.

The first batch is inside the station, sheltered from some of the space radiation. The second lot will be mounted outside, in the Materials International Space Station Experiment.

He will study how radiation and microgravity affect the mix of ibuprofen, vitamin C and molecules found on the Moon including silica, magnesium silicate (talcum) and calcium phosphate.

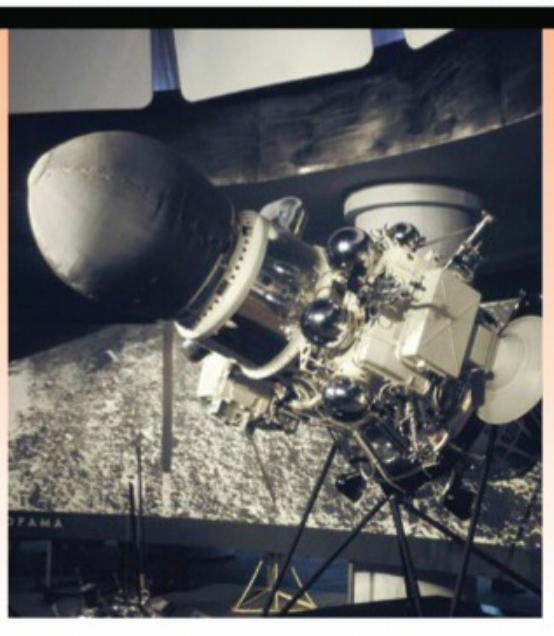
AUSTRALIA'S SPRAWLING DEPTH AND WIDTH has also ensured that we've built considerable expertise in long-range communications.

ABOVE: ICRAR X2

24 Mar 1965

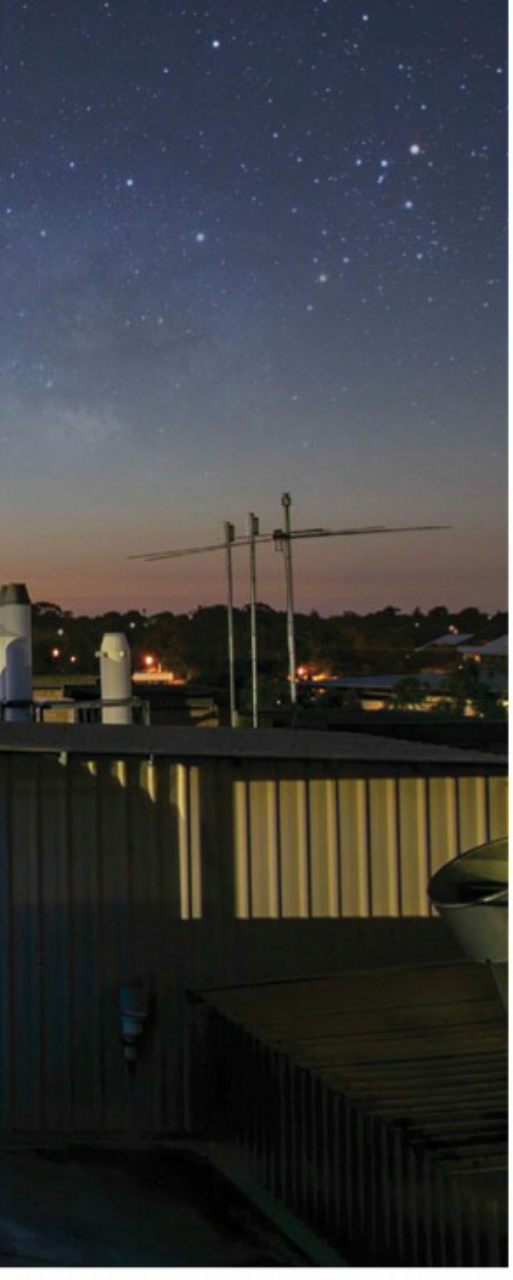
The first televised pictures of the Moon's surface beamed live to Earth from Ranger 9 are watched by millions (including space-crazy kid Jay Bodnar).

3 Feb 1966



The USSR's Luna 9 (right) makes the first "soft" landing on the Moon. It and sister craft Luna 13, later that year, both take pictures of the lunar surface.

LEFT TO RIGHT: BETTMANN, SOVFOTO / GETTY IMAGES



Danail Obreschkow (above) aboard an ESA parabolic flight to demonstrate a satellite deployment system.

Danail Obreschkow is the head of the recently launched University of Western Australia (UWA) International Space Centre. He highlights the role Australia played in the Apollo missions. NASA needed us both for our expertise and because we – and it – are on the other side of the planet. As the Earth turned, Australia could maintain contact with the astronauts.

That very Australian film *The Dish* may not have been entirely scientifically accurate, but Australia's location was critical. For project Apollo, the communications technology was radio waves. The UWA centre is working with optical communications.

Instead of the classic radio receptor that people saw in *The Dish*, in the Artemis age optical communications – lasers – will transfer about a thousand times more data per second. It will mean instead of those grainy Apollo images, we'll watch the next Moon landing in hi-res. Lasers are faster, but they're also more precise and resistant to atmospheric turbulence.

"It will be critical to have something that can receive those laser communications in Australia," Obreschkow says. "It is now about time to get the downlinks in place. That's what we are in the game for. And they don't just use the lasers for video and voice communications – they use it to synchronise clocks all over space. Clocks in space... the entire GPS system relies on ultra-precise timing."

Then there's mining, which is a large part of Australian industry involvement in interplanetary missions. There's huge value in any resources space missions can collect and use, rather than carry. Water and other resources will be critical to allow humans to stay on the Moon, to set up a waystation to Mars, and eventually to establish a human colony there.

Mining is Australia's most talked-about niche expertise, combining knowledge about autonomous vehicles (because in space no one can hear you tell them to turn left), robotics, artificial intelligence and machine learning. Robots are needed to do dirty, repetitive and dangerous work. Lessons learned remote mining in the Pilbara or on offshore oil rigs will be required.

And future Mars rovers might not only learn how to better navigate the Red Planet, they will also learn how to reproduce themselves. "Autonomy is the clue," Obreschkow says. "One might even envision machines that can produce their own smart machines. They don't just cut a piece of brick but manufacture some sort of other machine, or it recreates itself."

Then there's the Seven Sisters, inspired by Buzz Aldrin's seismometers.

24 Dec 1968

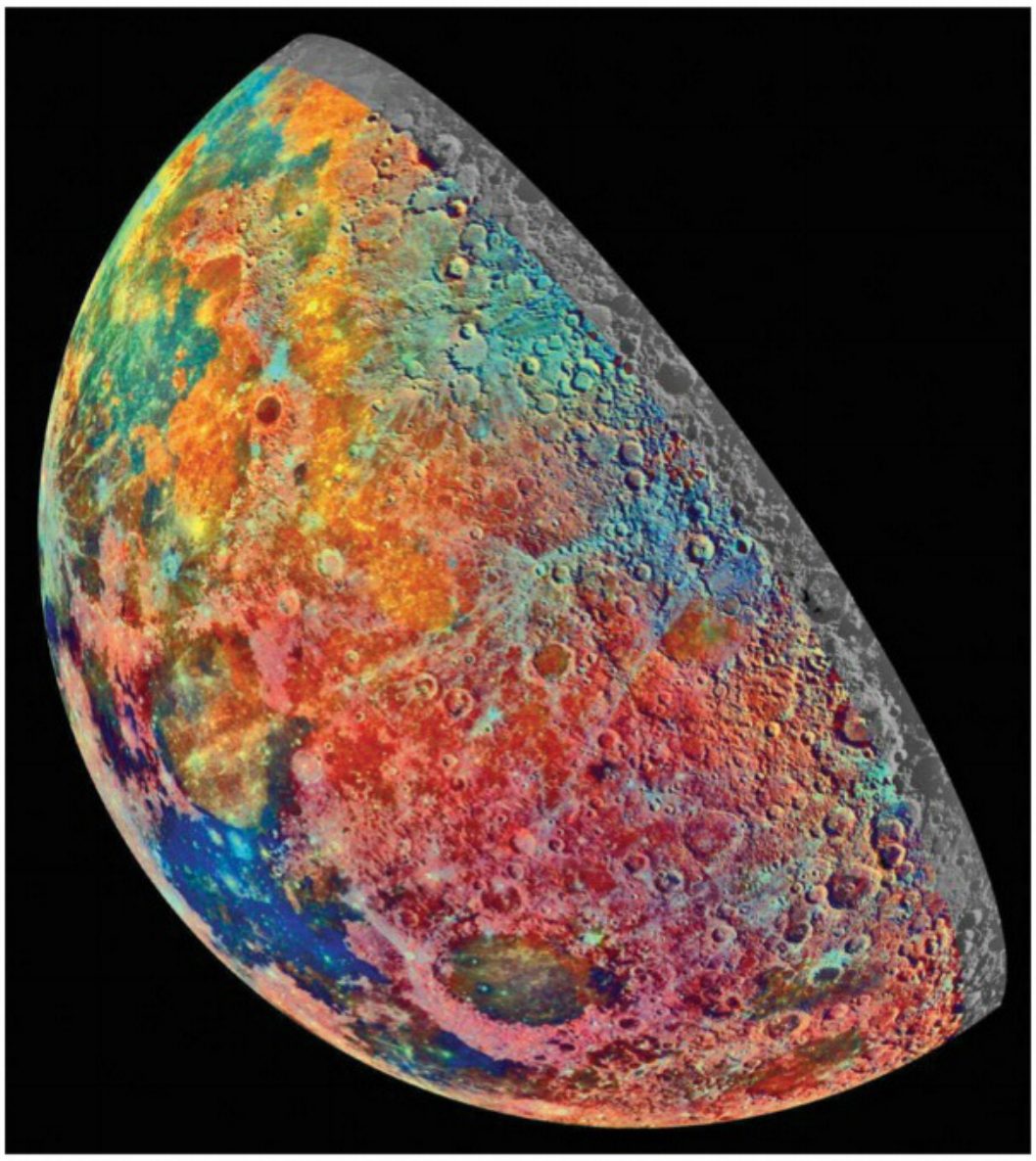
Apollo 8 crewmen (l–r) James Lovell, William Anders and Frank Borman are the first humans to enter lunar orbit and see the far side of the Moon in person.

24 Dec 1968

Anders takes "Earthrise", the first colour image of Earth seen from the moon. Nature photographer Galen Rowell calls it "the most influential environmental photograph ever taken".

LEFT TO RIGHT: INTERIM ARCHIVES / GETTY IMAGES.

ELEMENTAL, MY DEAR WATSON



This false-colour image of the Moon's surface composition is a mosaic of 53 frames taken through spectral filters as the probe Galileo flew over the Moon on in December 1992. Pinkish areas indicate highlands materials, mainly igneous rocks, such as those around the Crisium impact basin near bottom centre. Blue to orange shades mark volcanic lava flows. To Crisium's left, dark blue Mare Tranquillitatis – Apollo 11's landing site – is richer in titanium than light blue areas, which point to thin, mineral-rich soils associated with recent impacts.

Tata Nardini says Fleet Space has been working for years with mining companies to help them find new resources using sensors, nanosatellites and data.

"We realised that Buzz Aldrin had put seismic sensors in the ground [on the Moon] but they were very expensive…then with machine learning we realised there was so much movement on the Moon. So we worked on that concept on Earth with [Adelaide-based mining company] OzMinerals and others," she says.

"If you think about what's going to happen on the Moon and Mars, they want to understand how people can live there.

"You need the basics, you need water. There is a willingness to understand what is under the surface. Where are the resources? They don't know, so they drill a lot. It's expensive and invasive."

But with tiny sensors that can gather data and beam it back to Earth, telling explorers what they can expect to find and where, the cost and the impact shrinks.

So Seven Sisters was born in a collaboration that includes the University of Adelaide, University of New South Wales, OzMinerals and Dutch geo-data specialists Fugro.

The symbolism of the name is neat. Aboriginal people were Australia's first astronomers. The Seven Sisters songline – a tradition in several language groups including the Martu, the Ngaanyatjarra and the Anangu Pitjantjatjara Yankunytjatjara – traces more than half the continent, telling the story of sisters fleeing a sorcerer who chases them across the night sky. The tale comes from the Pleiades constellation, which in Greek mythology represents the companions of Artemis – sister to Apollo.

"We really wanted to build something that's relevant to Australia and where we can contribute to the Artemis mission with the things we are best at," Tata Nardini says. She's working on a concept based

20 July 1969

The Apollo 11 mission sees Neil Armstrong and Buzz Aldrin make the first human footprints on the Moon's surface.

17 Apr 1970

Apollo 13 mission controllers erupt upon hearing astronauts Jim Lovell, Jack Swigert and Fred Haise are safely back on Earth. "Houston, we've had a problem here," Swigert said three days earlier, when an explosion crippled their spacecraft.

LEFT TO RIGHT: NASA/GETTY IMAGES. NASA

Volker Hessel, research director, Andy Thomas Centre for Space Resources

around a rover that deploys small, non-invasive sensors. "You gather data," she says. "With machine learning you understand everything. This is the Internet of Things."

And that, she hopes, is where Australian know-how will translate into extra-terrestrial know-how. "We've done it in the middle of nowhere," she says of the Pilbara. "You look at it. It's basically Mars. You can do everything remotely, without human intervention, connected to satellites.

"We [Australia] are the best on automated technology and IoT. We are the only ones in the world that can actually do this."

Tata Nardini points to Mars rovers, which have failed at planned substrate investigations because their creators didn't know enough about what was beneath the surface. For example, a heat probe on NASA's InSight lander had to be retired earlier this year because it couldn't penetrate the Martian soil and burrow in to take the planet's internal

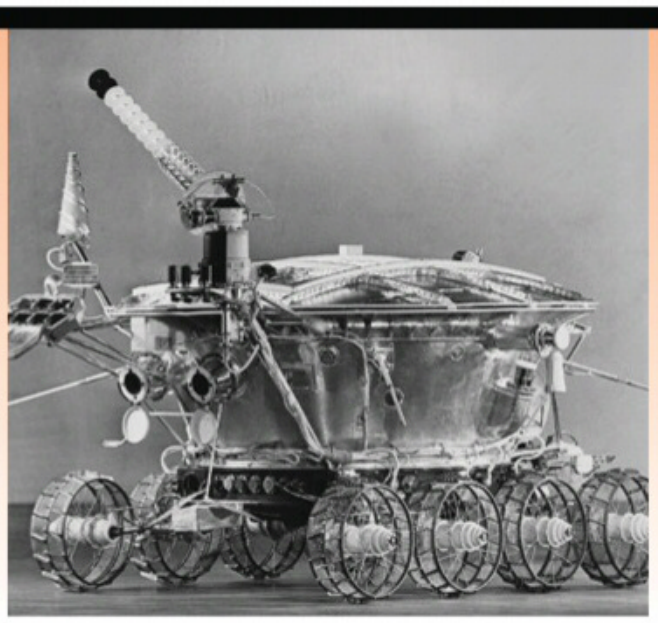
The Antarctic-based EDEN ISS greenhouse (above) is used to conduct research into food production in hostile conditions such as those on the International Space Station (right), which has experimented growing lettuce in light of the wavelength thought to promote photosynthesis. Also being tested are medicines (right, top) fabricated from elements found on the Moon.

temperature. "We're going to deploy a thousand [sensors]," Tata Nardini says. If the plan works it would remove the need for destructive drilling. She says there's no way we'll just "tread anywhere" on the Moon. "Humankind is trying to do Moon to Mars in a really sustainable way," she says.

Like others who talk about Australia's moonshot, she's passionate, but not a Pollyanna. Part of the plan

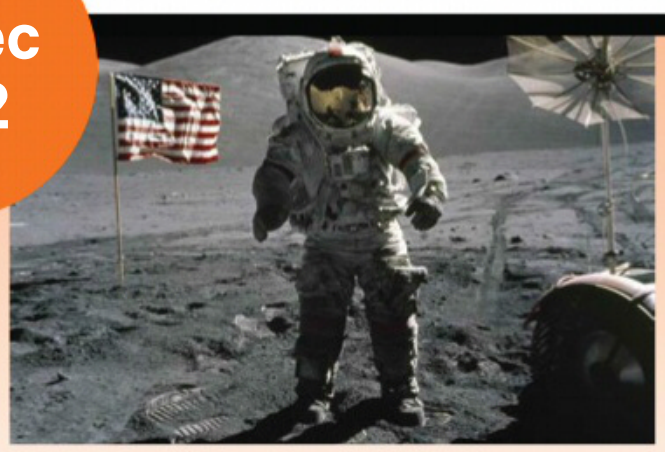
(EDEN ISS) NASA. (PILLS) COURTESY OF VOLKER HESSEL. (LETTUCE) NASA

17 Nov 1970



The Soviet's Lunokhod 1 is the first robot rover to land on the Moon. Over 11 lunar days (321 Earth days), it takes more than 20,000 images and 206 high-resolution panoramas, and performs 25 lunar soil analyses.

13 Dec 1972



Apollo 17 commander Gene Cernan is the last human to stand on the Moon, completing a lunar excursion of more than seven hours.

LEFT TO RIGHT: KEYSTONE-FRANCE, DONALDSON COLLECTION/GETTY IMAGES

is to put smallsats into Moon orbit, which hasn't been done before. It's a different proposition to Earth orbits. There are radiation differences. It's a long journey. So Tata Nardini talks about demonstrating and proving one bit of technology at a time – first on Earth and in Earth's orbit, then off-Earth.

The moonshot, she says, is all about pushing boundaries: "Can we get there? Can we communicate? Can we gather data? Can we analyse it?"

THERE'S A PLEASING CIRCULARITY TO AUSTRALIA'S moonshot. People get better at autonomous vehicles, at mining, at communications, at remote health, and then bring all that expertise into play down here on Earth to the benefit of space exploration. The bonus side effect is getting young people – particularly women – inspired in the same way that Apollo 11 inspired a generation, and generations that came after.

Fred Menk is chair of the Australian Academy of Science's National Committee for Space and Radio Science. After extensive consultation with the space community, the Academy has a draft paper – "Australia in Space: a draft decadal plan for Australian space science" – on what Australia can do and where the gaps are.

He emphasises the role of private enterprise, rather than government, describing Australia's moonshot as a challenge to industry. "Come up with the goods," he says. Australia has a chance to be part of the bigger picture, to go to the Moon and on to Mars – and the critical thing is how that will in turn improve life on Earth.

"We have a lot of experience in remote and hostile environments… and we have the opportunity to help the whole ecosystem grow," Menk says. "Think about astronauts in a long-duration space mission. How will you handle the medical challenges from radiation impact? How do you make sure they have a healthy diet? How do you deal with physiological changes due to zero G? And if there's a medical emergency how do you handle it in space?"

The same technology that will help astronauts cope with the rigours of microgravity could also help bedridden, Earth-ridden patients

Flavia Tata Nardini, CEO, Fleet Space

Menk says if you can ride the momentum of space research and work out how to help astronauts – isolated, struggling for fresh food, dealing with sleep issues and with no big spaces to run around – live a healthier life, you can use that for older people. Sedentary people. Isolated people.

Think about RMIT's Centre for Materials Innovation and Future Fashion creating Australian-designed space suits, he says. The same technology that will help astronauts cope with the rigours of microgravity could also help bedridden, Earth-ridden patients with bed sores, burns, or osteoporosis.

And while billions of dollars will be spent on space missions, it is estimated that the return on investment could be in the $7–$40 range for every dollar spent. NASA lists spinoffs including technology to quake-proof buildings that was developed from Apollo-era shock absorbers, the digital flight controls that have been adapted for airplanes and cars, food safety principles, as well as "spillovers" – where technology and innovations spread into unrelated industries, such as the development of rechargeable hearing aids.

Australia's moonshot might turn out to be a

18 Aug 1976

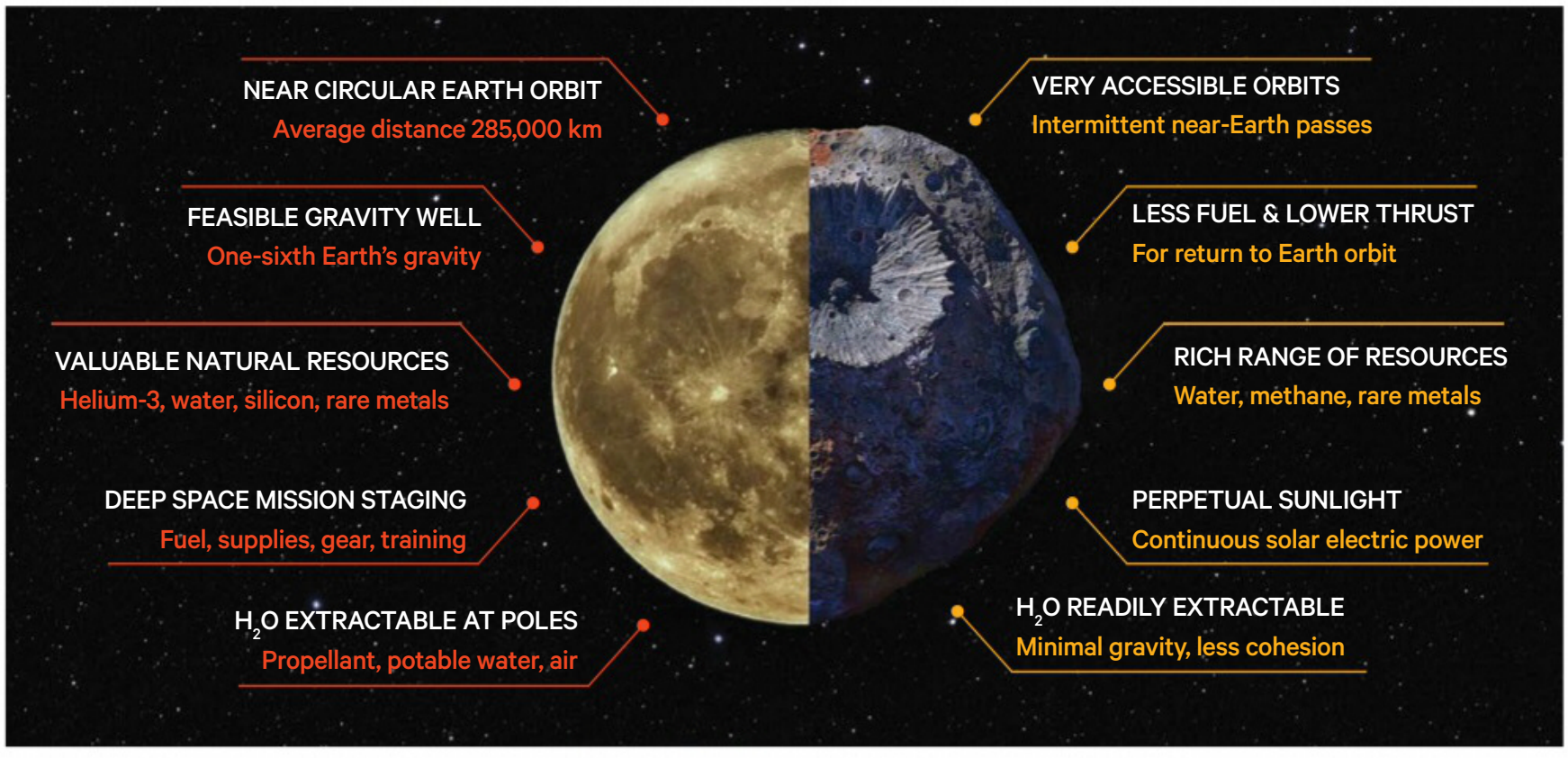
Luna 24 (replica, right) is the USSR's last lunar spacecraft and the last to make a soft Moon landing until China's Chang'e 3 touches down on 14 Dec 2013.

6 Jan 1998

NASA's Lunar Prospector is launched, and goes on to map the Moon's surface composition, measure magnetic and gravity fields, and detect hydrogen at both lunar poles, which scientists theorise to be in the form of water ice.

LEFT TO RIGHT: MOSCOW MUSEUM OF COSMONAUTICS; NASA

BATTLE OF THE ROCK STARS: MOON vs ASTEROID



ABOVE: NASA

blue-sky dream. But it seems like our time has come.

Imagine the idea of everyone excitedly watching hi-resolution footage of the first woman walking on the lunar surface. Imagine crocodile lines of school kids trooping through Adelaide's Mission Control Centre to watch it live, to watch Australians direct the action.

Imagine kids looking up at the night sky and knowing that we had the audacity to go there. And not just there, but to Mars.

Equipment developed for Apollo missions brought about technological and industrial innovations and products now in everyday use. Space missions are not just about planting that flag. They're about everything they leave behind – the spinoffs, the spillovers, the enduring awe and inspiration, the improvements to life on Earth.

Tata Nardini says that's the point of Australia's moonshot: the journey's returns.

"We've done it here, in the middle of nowhere. Space is where you push yourself to the limit. Then you bring that learning back."

TORY SHEPHERD has worked as a journalist for 15 years. Based in Adelaide, she has covered Space 2.0 extensively. This is her first feature for *Cosmos*.

22 Oct 2008

India launches the uncrewed lunar probe Chandrayaan-1, and becomes the fourth country to reach the lunar surface.

16 Dec 2020

Chang'e 5 returns from the Moon with 1.731kg of Moon material, making China the third country (after the US and USSR) to retrieve lunar samples.

LEFT TO RIGHT: ISRO, CNSR