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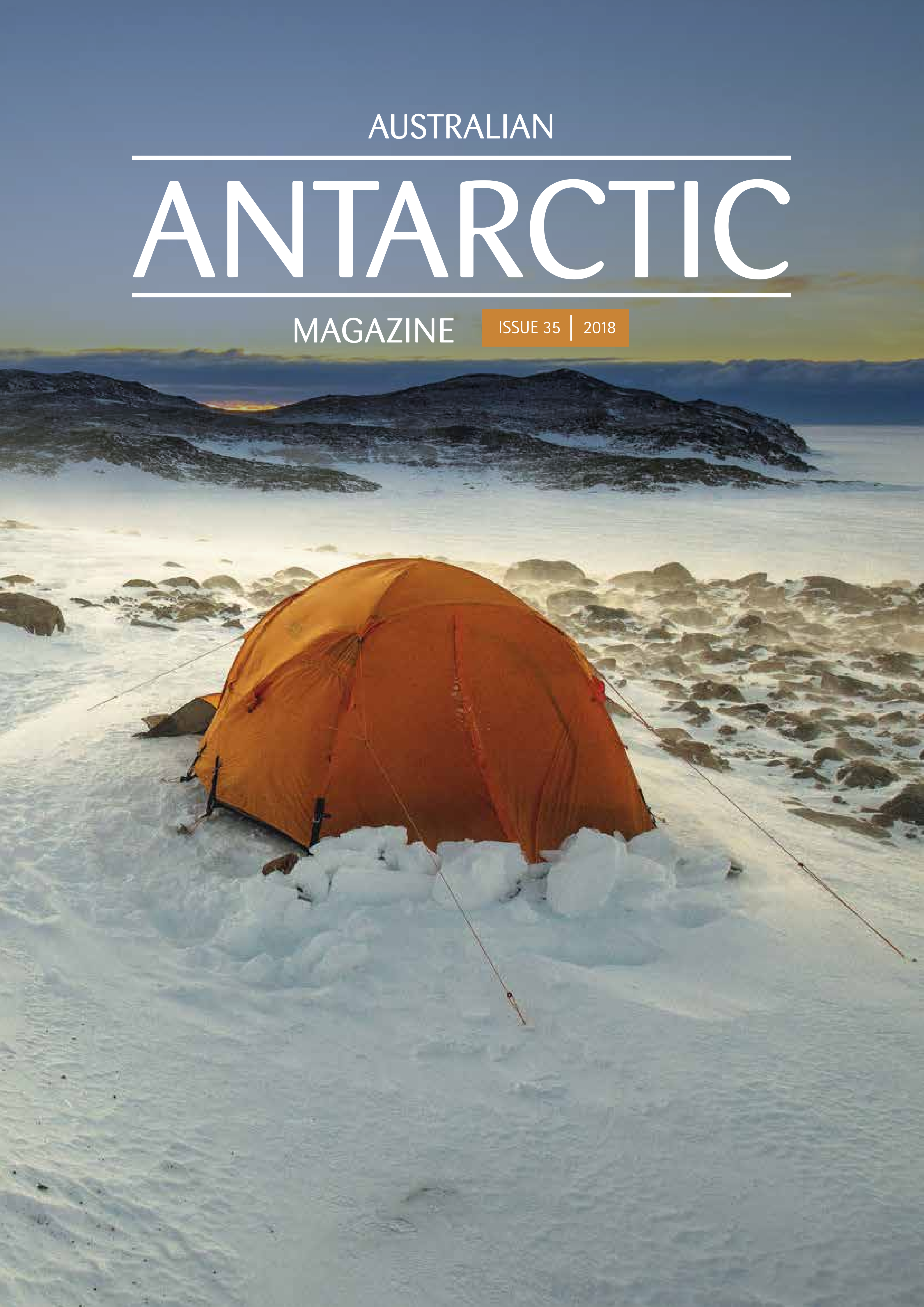


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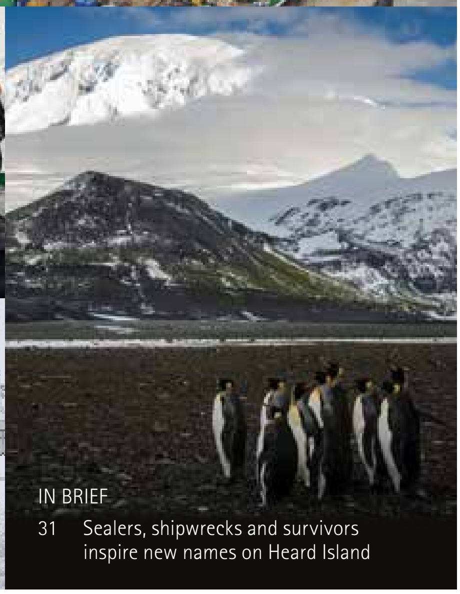
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ABOUT THE COVER

Casey Station Leader, Rebecca Jeffcoat, took this photo of a late-winter campsite near Robbo's Hut, overlooking Odbert Island, during a visit to the island to undertake maintenance of seabird nesting cameras. She used a Canon 6D EOS Mk II (ISO 400, f10, 1/160 sec). Rebecca is on secondment from the Royal Australian Navy. She previously visited Antarctica on a resupply voyage and a Station Leader familiarisation trip.

The Australian Antarctic Division, a Division of the Department of the Environment and Energy, leads Australia's Antarctic program and seeks to advance Australia's Antarctic interests in pursuit of its vision of having 'Antarctica valued, protected and understood'. It does this by managing Australian government activity in Antarctica, providing transport and logistic support to Australia's Antarctic research program, maintaining four permanent Australian research stations, and conducting scientific research programs both on land and in the Southern Ocean.

Australia's Antarctic national interests are to:

- Preserve our sovereignty over the Australian Antarctic Territory, including our sovereign rights over the adjacent offshore areas.
- Take advantage of the special opportunities Antarctica offers for scientific research.
- Protect the Antarctic environment, having regard to its special qualities and effects on our region.
- Maintain Antarctica's freedom from strategic and/or political confrontation.
- Be informed about and able to influence developments in a region geographically proximate to Australia.
- Derive any reasonable economic benefits from living and non-living resources of the Antarctic (excluding deriving such benefits from mining and oil drilling).

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From the Director

Photo: Adam Roberts

As you flick through the pages of this latest edition of the *Australian Antarctic Magazine* I will be embarking on a new and exciting chapter of my life, and a new Director will be taking the helm of Australia's Antarctic Program.

I leave at a time of great change and opportunity and I feel deeply privileged to have played a small role in guiding the Antarctic Program to its current state.

The Australian Antarctic Division and the broader Antarctic Program are defined by, and proud of, our rich history and those who built our Antarctic legacy. We are indebted to the Australian National Antarctic Research Expeditions (ANARE) Club who remind us that we are part of a long tradition of shared endeavour in Antarctica. We all bring passion and commitment to our jobs, with expeditioners returning time and again to our Antarctic and sub-Antarctic stations, and Kingston staff remaining a part of this community for much of, or all, their careers.

It is this sense of purpose and pride in our work that make being part of the Australian Antarctic Division, or heading south as part of our Antarctic Program, such a wonderful experience. It is these same strengths that we now need to harness to enable us to respond to the rapidly changing environmental and political arenas in Antarctica.

The changes in Antarctica are profound. When I started my Antarctic career in 1985 as a (very) young biologist on Heard Island, and then a winter at Davis research station, our research was largely unknown in Australia, and the Antarctic Treaty had changed very little over its 25 year history. Australians knew a little about Antarctica's heroic era, but saw little relevance to their daily lives in our work or how the continent was governed.

Communicating the importance of our Antarctic research and governance, and the significance of Antarctica to the planet, is a challenge to which we must continue to rise.

We now know that Antarctica and the Southern Ocean drive much of our global climate and weather. We also know that the science we do is fundamental to our understanding of just how vulnerable Antarctica is to human influence, and to informing our ability to mitigate and adapt to the massive challenges we face with climate change. There is a very clear and direct line between the science we do, the policy it informs and the wellbeing and resilience of Australians and Australian society in the future.

At the same time that we recognise how important Antarctica is, the central tenants of the Antarctic Treaty system of peace, science and environmental protection are being challenged.

> *Our great strengths that are built from our past, need to be focused on a future that embraces change.*

One of the things I am most proud of contributing to, in my role as Chief Scientist and then Director of the Australian Antarctic Division, has been the 2016 *Australian Antarctic Strategy and 20 Year Action Plan*. This strategy strengthens Australia's leadership role in Antarctica by setting in place major science and support commitments, including transport (our new Antarctic icebreaker RSV *Nuyina*, a proposed new aerodrome near Davis, and deep-field traverse capability), station infrastructure (the new Macquarie Island research station and upgrades at other stations), and mechanisms to support greater and more sustained funding for science.

These investments will drive a fundamental change in the scale and nature of the way the Australian Antarctic Division and the Antarctic Program functions, and will set us up to deliver on the promise of continued and urgently needed leadership and influence in the Treaty.

Our great strengths that are built from our past, need to be focused on a future that embraces the necessary change, to remain relevant and influential in a rapidly changing and increasingly threatened Antarctica.

I'm immensely grateful for the support and encouragement I have received from so many of you over my years here, and I hope you provide that same level of support to my successor. The Antarctic and Hobart communities are small enough to ensure that my path will cross with many of you in the future, and I look forward to that.

Fair winds and following seas to you all.

Dr NICK GALES
Australian Antarctic Division

Antarctic icebreaker afloat

Australia's new Antarctic icebreaker, RSV *Nuyina*, is now floating, after 50 Olympic swimming pools of water were pumped into the docks where the ship is being built, in September.

It took two days to pump enough water from the nearby river into the dry dock, raising the water level six metres above the dock floor and floating the 10,751 tonne ship about 30 centimetres off the ground.

Australian Antarctic Division Icebreaker Project Manager, Mr Nick Browne, said it was a precision operation to then manoeuvre the ship about 250 metres into the adjacent wet dock.

"We had 34 buoyancy bags tethered in strategic places around the ship to ensure the bow and stern were level for floating out," Mr Browne said.

"Then we used a series of controlled lines to pull the ship into position in the wet dock. The ship is 25.6 metres wide and the dry dock is 35 metres wide, so we had less than five metres either side.

"There's about 10 metres of water in the wet dock, which will be enough to support the 16,000 tonne weight of the ship when it's completed."

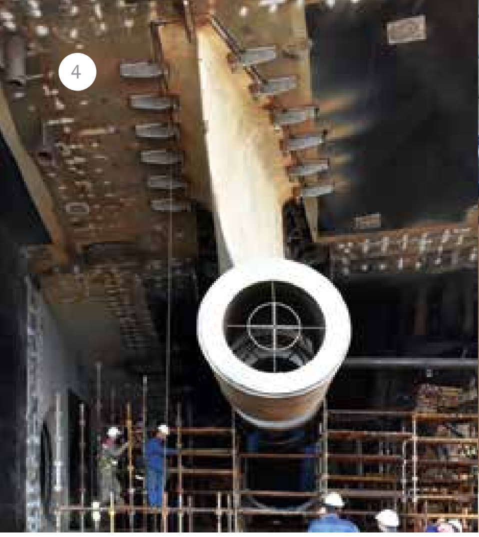
At the time of the floating, construction on the ship had reached deck level four (the science deck), and the engines, generators, shaft lines, propellers and rudders were all in place (see next story).

When complete, the ship will rise to 10 decks at navigation bridge level, measuring 50.2 metres from the keel to the top of the weather radar on the main mast.

"After six years of planning and more than two years of construction, it was a thrill to see the ship finally floating in the water," Mr Browne said.

"We'll see the *Nuyina* rapidly taking shape over the next few months; it won't be long now before she'll be sailing into Hobart in 2020."

1. *Buoyancy bags were attached in strategic places around the ship to ensure it remained level while floating. (Photo: Michiel Jordaan)*
2. *The* Nuyina *prior to the removal of the gate between the dry and wet docks. (Photo: Michiel Jordaan)*
3. *The dry dock filling with water to float the 10,751 tonne ship. (Photo: Damen)*
4. *One of two gondolas that will hold the ship's propeller shafts. The length of steel above the propeller shaft tunnel will help deflect sea ice broken up by ice knives at the rear of the ship. The cross at the front of the tunnel is for a laser sighting, to ensure the propeller shaft is correctly aligned with the ship's engine. (Photo: Michiel Jordaan)*



Nuyina's construction propels ahead

In preparation for the RSV *Nuyina*'s floating in September (see previous story) a number of critical components of the ship's propulsion system were installed.

First were the ship's two 'gondolas' – each made of 80 tonnes of steel – which hold the ship's propeller shafts (see photos).

Australian Antarctic Division Icebreaker Project Manager, Mr Nick Browne, said the complex and precise nature of the gondolas required a specialist team of 27 welders to install them.

"Each gondola was pre-heated to 150°C before welding could commence, as welding cold steel can cause it to expand and contract unevenly, affecting alignment and possibly causing the steel to fracture," Mr Browne said.

"Each welder spent one hour on the job before another took over, and they had to wear wooden-soled shoes to cope with the heat."

With the gondolas complete, the propeller shafts could be aligned. The 50 metres-long shafts connect the main engines at the centre of the ship to the 40 tonne propellers (and hubs) at the stern. The shafts each sit inside a 'stern tube', which allows them to pass through the hull without water leaking into the ship.

"The propeller shafts were aligned by sending a laser beam through the stern tubes," Mr Browne said.

"Perfect alignment of the shafts is critical to prevent propeller wobble and structural failure of the shafts, and will contribute to the silent operation of the ship during scientific surveys."

In open water the main noise on the ship is from the propulsion system – the engines, gear boxes and propellers. This interferes with scientific acoustic instruments and can affect the behaviour of fish and other marine organisms that the scientists want to study (see *Australian Antarctic Magazine* 34: 2-3, 2018).

With the propeller shafts in place, the propeller hubs, on which the blades are bolted, could be attached. The propeller hubs are made of nickel, aluminium and bronze and are 1.94 metres in diameter and weigh almost 21 tonnes. During operation the hubs are filled with oil to actuate the variable pitch of the propeller.

"Each propeller has four blades made out of stainless steel and weighing about 4.5 tonnes each. The total diameter of the complete propeller is 5.65 metres," Mr Browne said.

The gondolas and propellers are protected by ice knives at the stern of the ship. These help to split and distribute ice under the vessel after it has been broken up by the weight of the bow. Rudders, each weighing 33.5 tonnes are installed beneath the ice knives.

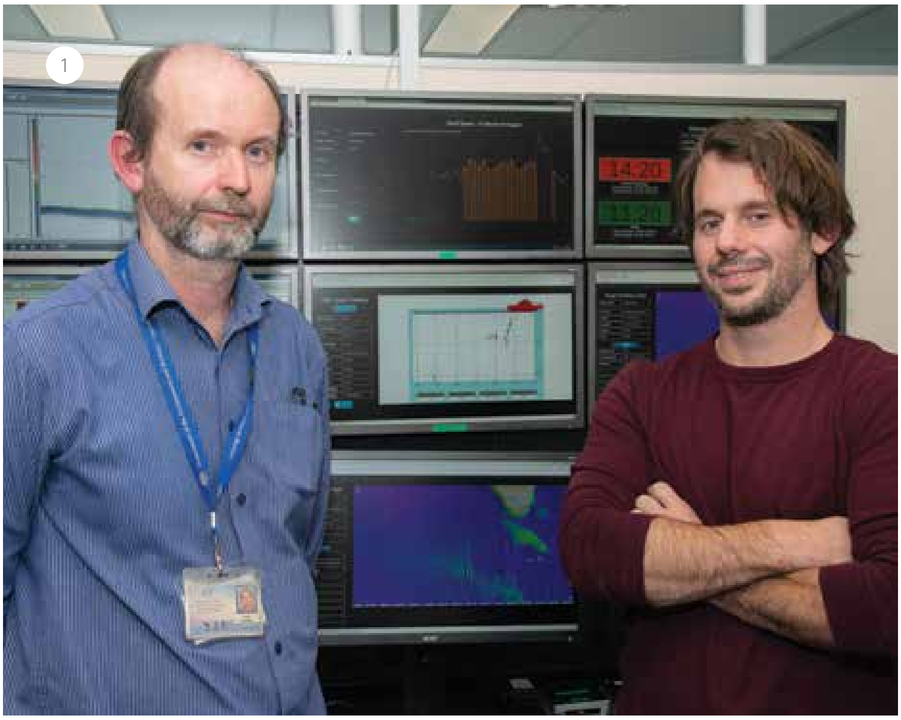
Finally, six tunnel thrusters help the ship spin on a dime and hold a set position (dynamic positioning) with ±20 m accuracy. Three thrusters at the bow and three at the stern each require 1300 kW of electrical power for maximum thrust. The thrusters will hold the ship in place during deployment of scientific equipment in a range of sea states, as well as during small boat deployment and cargo operations.

WENDY PYPER
Australian Antarctic Division

5. *This 12.7 metre-long stern tube will enclose a propeller shaft. The stern tube enables the rotating propeller shaft to pass through the hull without water leaking into the ship. (Photo: Michiel Jordaan)*
6. *The final blade of a propeller being craned into place. Each blade weighs 4.5 tonnes. (Photo: Michiel Jordaan)*
7. *The ship's propeller blades are bolted to this propeller hub, which weighs almost 21 tonnes. Once the four blades are added the structure will weigh almost 40 tonnes. (Photo: Michiel Jordaan)*

Data to the bunk

1



Expeditioners and crew onboard the *Aurora Australis* can now get the 'DIRT' on what's happening on the ship, from the comfort of their own bunks.

'Data In Real Time' is a new web service developed by the Australian Antarctic Division's Science Technical Support Team, allowing scientists, voyage managers, crew and expeditioners to receive data from scientific instruments via their mobile phones or laptops, anywhere on the ship.

They can also get the latest information on the ship's position, the air and water temperatures, and wind speeds.

Technical Services Manager, Lloyd Symonds, said the new service means scientists don't need to stay glued to a single computer screen during long deployments of oceanographic equipment, such as trawl nets and conductivity, temperature and depth (CTD) probes.

"DIRT is an aggregator of data – so it takes complex information from our scientific displays, as well as the ship's underway data, and distils the essential information into something more accessible," Mr Symonds said.

"No matter where people are on the ship, they can now see, for example, how long a deployment has to run, so that they can continue doing other things, whether that be other work or watching a movie on their bunk.

"Then, when the deployment needs attention, the relevant personnel can go to the science control room and complete the job."

Once in the control room, scientists can view DIRT and information from other scientific equipment across eight computer screens.

For krill scientists, the technology allows them to view acoustic echosounder data – which bounces off krill swarms beneath the ship and appears as bright blobs on the computer screen.

They can then make decisions about when to deploy a net, as well as when to open and close it to get the maximum amount of krill.

The technology can also store data to replay later, for training purposes. Mr Symonds and his colleague, electronics engineer Michael Santarossa, have developed software to allow scientists to practice complex oceanographic deployments using this stored data.

"Often the first time people see the computer screen on the ship is when they need to deploy a krill net or CTD, and they don't know which button to push," Mr Santarossa said.

"With this technology we can bring them into our office at Kingston and show them how it all works. For example, we can use echosounder data from a voyage to help them line up a virtual krill net on a virtual ship to catch the krill in real time.

"While it's not exactly the same, it gives people a greater chance of getting it right on the day."

The challenge now is to adapt the software for the new ship, RSV *Nuyina*, which is expected to begin Antarctic operations in late 2020.

"The *Nuyina* will have 18 screens in the science control room, rather than eight, so we'll have the capacity to display a diversity of data that we can't display on the *Aurora Australis*," Mr Symonds said.

"We can develop new screens fairly rapidly and we've come up with a system where people can design their own screens.

"But our biggest challenge is to understand each of the instruments on the new ship and develop the on board displays, as well as the simulation software for training."

They will also have to contend with a larger volume of data being collected.

"The *Aurora Australis* tells us the GPS position of the ship once per second, but the *Nuyina* will tell us our position between 10 and 100 times per second," Mr Symonds said.

The pair are working with a team from the Marine National Facility RV *Investigator*, which has some of the same instrumentation as *Nuyina*, allowing them to access example data and software.

It's a big job, but no one ever said getting the latest DIRT would be easy.

WENDY PYPER
Australian Antarctic Division

1. *Lloyd Symonds (left) and Michael Santarossa in front of computer screens set up to mimic the* Aurora Australis *science control room and deliver 'data in real time' (DIRT). (Photo: Glenn Jacobson)*

Tractor traverse to support deep field research

A new fleet of heavy tracked vehicles will be harnessed to support Australia's deep field operations, including the search for a million year ice core.

Australian Antarctic Division Traverse Systems Lead Project Officer, Anthony Hull, said the traverse fleet will have five heavy tractors and two snow groomers that will tow sled trains carrying food supplies, accommodation, communal areas, scientific facilities, power generation and up to 160,000 litres of fuel.

"This is a step-change in our ability to rapidly move large quantities of cargo and equipment deep inland in all weather conditions, and into areas that we can't traditionally access by aircraft," Mr Hull said

"It will allow us to deploy scientists and support teams to some of the most remote and extreme parts of the Antarctic ice sheet for extended periods of time."

The traverse will be managed by a team of eight expeditioners and will be able to travel up to 1500 kilometres inland.

The first expedition is planned to depart Australia's Casey research station in early 2021 and set up a mobile research station 1200 kilometres inland at a location known as Dome C.

The station will be able to support 16 people flying in to undertake scientific research for up to three months.

Australian Antarctic Division glaciologist, Dr Tas van Ommen, said the new capability will open up the Antarctic interior to ambitious science projects, including the search for the Earth's longest continuous ice core climate record (*Australian Antarctic Magazine* 33: 6, 2017).

"The million year ice core will be a window into a time when a major shift in the Earth's climate system took place, and when the regular pacing of ice ages gradually slowed," Dr van Ommen said.

"We are working closely with our international collaborators to understand what caused this shift, because we believe it can help us better understand present day climate change."

Scientists and engineers at the Australian Antarctic Division have also begun work on a new drill design for the project that is capable of extracting ice cores 3000 metres deep.

"Many of the components we need are specialist designs that have to be constructed and built in-house, and we have the right team to do that here in Hobart," Dr van Ommen said.

"We are incorporating the latest technology that will allow us to recover the best quality core, to drill most efficiently, and hopefully get to the bottom of the ice sheet over a three-to-four year drilling period."

The Australian Government committed $45 million in 2016 to re-establish an overland traverse capability and drill for the million year ice core as part of the *Australian Antarctic Strategy and 20 Year Action Plan.*

The tender process for the heavy tracked vehicles is currently underway and procurement of other traverse components will occur over the next 18 months.

The new traverse system will meet Australia's scientific and operational needs for the next 20 years.

DAVID REILLY
Australian Antarctic Division

1. *Australia will re-establish a traverse system to travel 1200 kilometres inland from Casey research station. In 2016–17 Australia travelled with both British and French traverse teams to gather information on traverse technologies and methodologies to assist with the design of a new Australian capability (*Australian Antarctic Magazine *33: 4–6.2017). (Photo: Todor Iolovski)*

Grand sub-Antarctic designs

How do you design a group of buildings that can withstand the wild Southern Ocean weather and three-tonne elephant seals on the doorstep, while accommodating the needs of a diverse, self-sufficient community, living and working far from home and conducting globally significant science?

This is the challenge facing the Australian Antarctic Division's Macquarie Island Modernisation Project team, as they embark on the design of a new Macquarie Island research station.

The project is part of the government's *Australian Antarctic Strategy and 20 Year Action Plan*, and includes the renewal of the island's network of field huts and decommissioning of the existing 70 year-old station.

While the four-person project team is well qualified for the job – with experience in engineering, architecture and trades – they're not doing it alone.

As well as Australian Antarctic Division staff, key personnel at the Australian Bureau of Meteorology, Geoscience Australia, the Australian Radiation Protection and Nuclear Safety Agency, and the Tasmanian Parks and Wildlife Service, have also fed their requirements into a 'functional design brief'.

Station Infrastructure project officers, Travis Thom and Alison McKenzie, said the brief considers all the design requirements and constraints, such as legislation, building codes, maintenance, the function of each building, current and future scientific and operational needs, and the station's environmental impact.

"The functional design brief is a guide to what we want to achieve from an end-user perspective, and sets out the requirements and constraints that could have design implications," Ms McKenzie said.

"The primary function of the station is to provide living and working facilities for a self-sufficient community for the next 50 years, and support scientific and long-term monitoring programs."

The brief is also the principle document for the Managing Contractor, VEC Civil Engineering Pty Ltd, appointed in July, to complete the design and construction, with assistance from the project team.

Among the design principles enshrined in the brief are maintaining year-round operations, minimising operational and maintenance costs, balancing station function and environmental impacts, and creating a sense of community. Common to all of these principles is a smaller station.

"One of our main goals is to reduce the number of buildings from 48 to between 15 and 20," Mr Thom said.

"A smaller station will be more efficient and have less impact on the island."

The station will be self-sufficient in its water, power and waste management needs, with adaptable and flexible buildings to accommodate scientific activities and population fluctuations. It will also be resilient to future environmental and climate impacts through the siting of the main station buildings more than 50 metres from the coast and at an elevation of at least 6.5 metres above sea level.

To minimise operational and maintenance costs, the team will use thermally efficient building materials, energy saving technologies and modern construction techniques.

"We will also use systems and materials that require limited specialist training to operate, maintain and to repair if damaged," Mr Thom added.

To help balance the functional needs of the station with its environmental impact, buildings with complimentary functions will be clustered together to keep the footprint small, allow efficient movement around the site, and provide spaces for resupply operations, recreation, revegetation and wildlife.

Fenced-off building clusters, with wildlife corridors between, will also help protect the station, people and wildlife (especially elephant seals), from each other.

Macquarie Island Executive Officer Mr Noel Carmichael, of the Tasmania Parks and Wildlife Service, said that during the breeding season, the beaches on either side of the isthmus, where much of the current station sits, are occupied by the largest concentrations of elephant seals in the reserve.

1. The new Macquarie Island research station will be sited further south of the isthmus (pictured here) and will reduce the number of station buildings from 48 to between 15 and 20. (Photo: Justin Chambers)

"The size and natural behaviour of elephant seals means they can damage buildings and services they may come in contact with," he said.

"Elephant seals can also be noisy and smelly, so you don't want them lying outside living quarters."

In March 2018 the project team took sketches of potential master planning options to the island, to gather feedback from expeditioners and better understand the environment and station operations.

The sketches were developed based on the functional design brief and two seasons of investigations along the length of the island, into wind effects, ground conditions, coastal processes, and the potential risk of rising seas and increasing storm surge frequency.

Antarctic Division staff at Kingston and at the station reviewed the sketches, teasing out design and operational issues, including how the station operations will transition from the old station to the new one.

Based on this work, in June a Selection Committee approved a site for the new station, just south of the existing station and using part of its current footprint (see map).

The site avoids intensive wildlife congregations, nesting areas and heritage artefacts related to the island's sealing days, as well as the swampy ground that exists further south. It's also outside the storm surge area on the isthmus and has good access for construction.

VEC Civil Engineering will now use the functional design brief, master plan, and a 360 degree virtual tour within and around the current station buildings (see side bar) to progress the next phase of design.

The new station is expected to be complete in 2022.

WENDY PYPER
Australian Antarctic Division

2. This map shows a preliminary master plan concept and indicative location for the new station buildings (red) relative to the existing station (blue), which will be decommissioned. The current station is located on a narrow isthmus that is subject to storm surges and often occupied by elephant seals. (Graphic: Alison McKenzie)

3. A 360 degree panoramic image of the main power house, where diesel generators produce electricity for Macquarie Island research station. (Photo: Sky Avenue/Australian Antarctic Division)

Take a virtual tour of Macquarie Island

The designers and builders of the new Macquarie Island research station (see main story) can now get a sense of space and place from the comfort of their office, thanks to a virtual tour of the current station site https://tourview.com.au/macca.html.

The new public interactive tour allows viewers to get an insight into life and work on the island, and provides a level of detail that will be critical to the design of the new station.

The virtual experience is made up of 1338 photos stitched together to form 360 degree panoramas.

"The Managing Contractor, VEC Civil Engineering, and their architects and engineers, will have limited opportunities to make site visits to the island, because there is only one or two resupply ships a year," Strategic Infrastructure Project Lead, Travis Thom, said.

"By using the virtual tour they'll be able to go inside buildings to see what kind of furnishing are in place, what kind of specialist equipment has been installed, and how the spaces have been configured.

"They can also get a good sense of the science that's conducted on the island, by visiting places like the biology and clean air laboratories, the radionuclide monitoring station and the surface weather observation yard."

The tour was developed by Hobart-based business Sky Avenue Photography and Design (see Freeze Frame), who visited the island in March this year (*Australian Antarctic Magazine* 34: 8, 2018).

The tour can be viewed on computers, tablets and mobile phones. Phone users also have an option to view the tour with virtual reality headsets. 'i' icons on points of interest in the tour provide more information, images and videos relevant to the location.

Could e-DNA enhance ecosystem monitoring?

Environmental DNA or e-DNA could be the next 'disruptive innovation' when it comes to monitoring changes in Southern Ocean ecosystems.

Australian Antarctic Division molecular ecologist, Dr Bruce Deagle, said the technology allows scientists to identify hundreds of species in an environmental sample – such as water or soil – by sequencing DNA in the sample.

The approach relies on 'barcodes', which are segments of DNA unique to different species. These genetic markers are amplified from the total DNA extracted from the sample, and their sequences are then compared to a reference database to identify the organisms.

"If we can collect a small volume of water and characterise what's in it, this technique could be very useful for monitoring changes in the occurrence of organisms in the Southern Ocean," Dr Deagle said.

"We can already monitor phytoplankton and bacteria using this method, but we want to see if we can identify larger zooplankton, like copepods and krill, as well as different fish species, and potentially even penguins and seals.

"e-DNA has been used in lakes and ponds, where the inhabitants don't move much and the water doesn't move in large volumes, but we don't know yet whether it will be useful for open ocean samples."

To find out, Dr Deagle and his colleague Andrea Polanowski collected about 200 two-litre water samples during a voyage to Macquarie Island in March this year*. At the same time, they collected zooplankton samples using a Continuous Plankton Recorder (CPR) – a century-old technology.

The CPR is towed behind the ship and catches phytoplankton and zooplankton on a silk mesh that slowly winds through the instrument. The organisms captured on the silk can then be identified under the microscope.

"We'll be able to compare the CPR zooplankton samples with our eDNA results to see how well they match," Dr Deagle said.

"While we don't have a direct comparison for fish, we'll compare our eDNA results with our knowledge of what fish species should be there. We'd expect to see a good fish community, but if we only get a handful of eDNA results, then that may suggest the method is not very useful.

"We'll also try to identify penguins and seals, just to see if we can detect free-floating DNA from these animals."

Dr Deagle and his team are now experimenting with different sample processing methods to find one that is easy to use and provides consistent and comprehensive results.

"We need to ensure that our processing method captures all the eDNA in the sample and not just a subset of what's there," he said.

If the technique works, it could open up new discussion in the Southern Ocean research community about whether it is a useful addition, or replacement, to existing ecosystem monitoring methods.

"DNA could be a good tool for monitoring but we have to decide if we want the data in that form – if it's going to be useful," Dr Deagle said.

"Use of the technology could disrupt old, long-term ecosystem monitoring datasets, but at his stage, our focus is on showing what's possible."

WENDY PYPER
Australian Antarctic Division

**Australian Antarctic Science Project 4313*

1. *Andrea Polanowski examines zooplankton specimens collected on silk by the Continuous Plankton Recorder (silver box on right) as it was towed behind the ship. (Photo: Bruce Deagle)*

2. *Dr Bruce Deagle is trialling methods to identify zooplankton and fish in seawater samples by amplifying environmental DNA. (Photo: Glenn Jacobson)*

1

Hungry humpbacks take migratory snack breaks

Satellite tracking data has identified new warm water feeding areas for south-bound humpback whales en route to the krill-rich seas of Antarctica.

A paper published in *Scientific Reports* in August, examined the movements of 30 humpback whales tracked via satellite tags over three consecutive summers, from 2008 to 2010.

Australian Antarctic Division marine mammal scientist and the paper's lead author, Dr Virginia Andrews-Goff, said the research* is the first to examine the foraging habits and migration path of East Australian humpbacks.

"For the first time we have been able to see the varied routes East Australian humpbacks take on their migration to Antarctica, some of which were unknown until now," Dr Andrews-Goff said.

"The satellite data shows us they travel east via New Zealand, south via Tasmania, or west via the Pacific Ocean."

The research also showed that the whales fed more during their migration than previously thought, spending time foraging in warmer temperate waters on their way to Antarctica. This counters traditional assumptions that humpbacks adopt a 'feast and famine' approach to migration – feasting in Antarctica and then fasting for the rest of the year as they migrate to and from their low latitude breeding grounds.

"As the whales migrate south they are stopping for up to 35 days to forage for krill – either off the New Zealand coast, in Bass Strait, or off the east coast of Tasmania," Dr Andrews-Goff said.

"These observations of 'supplemental feeding', which have been observed in other Southern Hemisphere humpback populations, may help refuel their energy reserves prior to reaching their Antarctic feeding grounds."

The paper also examined the characteristics of the Antarctic feeding ground, which scientists believe could be responsible for the strong recovery of the population after whales were hunted to near extinction in the 1950s and early 1960s.

"The whales time their arrival for when the ice is retreating rapidly towards the continent, and the data shows they concentrate their foraging where the ice was located two months prior," Dr Andrews-Goff said.

"We can see that the whales move with the ice as it melts and retreats, and it's this melt that releases new production, triggering the accumulation of Antarctic krill."

While the marginal ice zone in the whales' foraging area provides good foraging and protective habitat for adult and larval krill, Dr Andrews-Goff said the timing and location of sea ice formation within the area was highly variable.

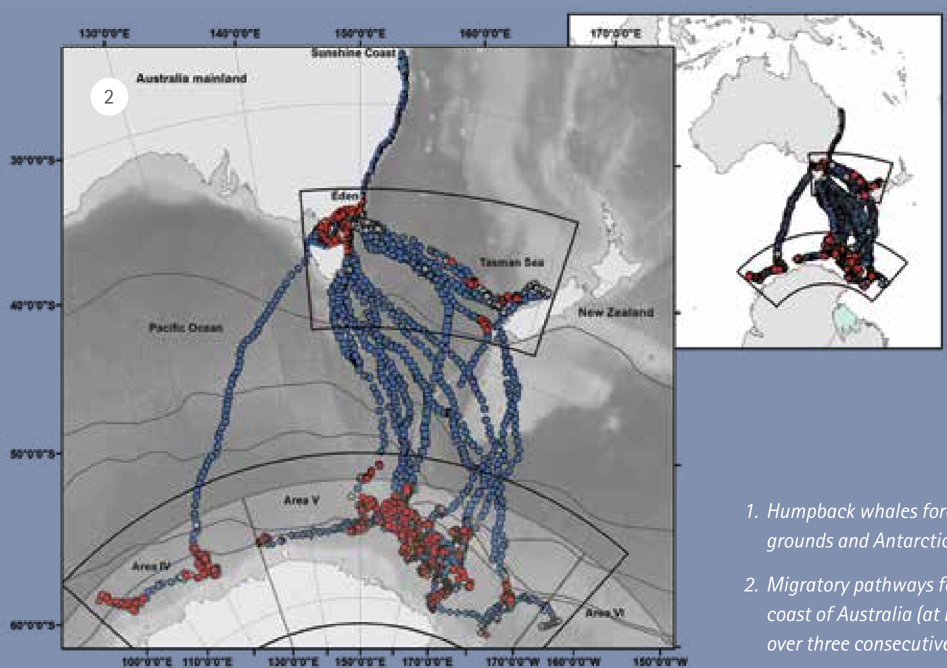
"The overall trend indicates an increase in ice season duration over the past 30 years, along with decreasing sea surface temperature and primary productivity, which ultimately may result in less food for krill," she said.

"So ongoing monitoring of the humpback population is important to understand and predict the whales' ability to adapt."

The research will help inform whale management and conservation policy.

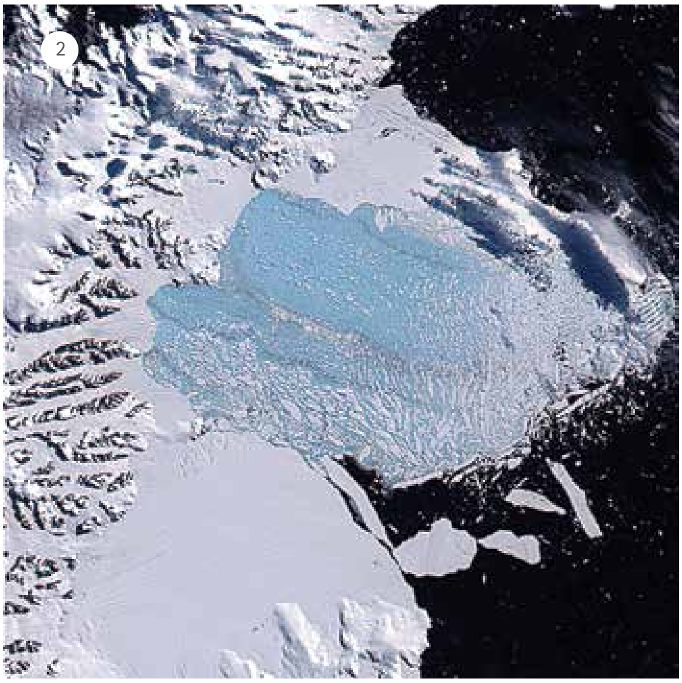
ELIZA GREY and WENDY PYPER
Australian Antarctic Division

Australian Antarctic Science Project 4101



1. *Humpback whales forage extensively between their breeding grounds and Antarctica. (Photo: Ari Friedlaender)*
2. *Migratory pathways for 30 humpback whales, satellite tagged off the east coast of Australia (at Eden and the Sunshine Coast) and in Antarctica, over three consecutive summers. (Photo: Australian Antarctic Division)*

SCIENCE



Antarctic ice shelf collapse triggered by wave action following sea ice loss

Storm-driven ocean swells can trigger the catastrophic disintegration of Antarctic ice shelves following regional loss of adjacent sea ice, according to research* published in *Nature* in June.

Lead author, Dr Rob Massom, of the Australian Antarctic Division and the Antarctic Climate and Ecosystems Cooperative Research Centre, said that reduced sea ice coverage off the Antarctic Peninsula since the late-1980s exposed ice shelves to storm-generated ocean swells, causing their vulnerable outer margins to flex and eventually break.

"Sea ice acts as a buffer to protect ice shelves, by damping destructive ocean swells before they reach the ice shelf edge," Dr Massom said.

"But where there is regional loss of sea ice, storm-generated ocean swells can readily reach the exposed ice shelf and cause its outer few kilometres to flex.

"The cumulative effect of this flexing is to enlarge pre-existing fractures until long, thin 'sliver' icebergs calve off the shelf front."

This calving removes "keystone blocks" that provide structural stability to the ice shelf. If the ice shelf is severely weakened by decades of extensive surface melting and fracturing, this outer-margin calving causes the abrupt and rapid runaway collapse of the weakened shelf behind (see satellite images).

"Disintegration marks an unprecedented departure from naturally-recurring calving of large icebergs every decade or so, to a sudden onset and catastrophic large-scale fracturing and calving," Dr Massom said.

Study co-author Dr Luke Bennetts, from the University of Adelaide's School of Mathematical Sciences, said the findings highlight the need for sea ice and ocean waves to be accounted for in ice sheet modelling.

This will be a key step towards enabling scientists to more accurately forecast the fate of the remaining ice shelves and better predict the contribution of Antarctica's ice sheet to sea level rise, as climate changes.

"The contribution of the Antarctic Ice Sheet is currently the greatest source of uncertainty in projections of global mean sea level rise," Dr Bennetts said.

"Ice shelves and floating glacier tongues that fringe about three quarters of the Antarctic coastline play a crucially important role in moderating sea level rise, by buttressing and slowing the transfer of land-based glacial ice from the interior of the continent to the ocean.

"While ice shelf disintegrations don't directly raise sea level, because the shelves are already floating, the resulting acceleration of the tributary glaciers behind the ice shelf, into the Southern Ocean, does.

"These dramatic events are in addition to ocean-driven thinning of ice shelves in recent decades, which also reduces the buttressing capacity of non-disintegrating ice shelves."

Study co-author, Dr Phil Reid, from the Australian Bureau of Meteorology, said the research identifies a previously under-appreciated link between sea ice loss and ice shelf stability.

"Our study also underlines the importance of understanding and modelling the mechanisms driving recent sea ice trends around Antarctica, to improve prediction of future coastal exposure, particularly in regions where sea ice acts as a protective buffer against ocean processes," he said.

The discovery comes after the international research team combined satellite images and ocean wave data with surface observations and mathematical modelling, to examine five major ice shelf disintegration events that occurred on the Antarctic Peninsula between 1995 and 2009.

These included the abrupt and rapid losses of 1600 square kilometres of ice from the Larsen A Ice Shelf in 1995, 3320 square kilometres from the Larsen B Ice Shelf in 2002, and 1450 square kilometres from the Wilkins Ice Shelf in 2009. Each disintegration event occurred during periods when sea ice was significantly reduced or absent, and when ocean waves were large.

In only a matter of days, the collapse of the Larsen B Ice Shelf in 2002 removed an area of ice shelf that had been in place for the previous 11 500 years. Removal of the ice shelf buttressing effect also caused its tributary glaciers to flow eight times faster in the year following disintegration, contributing more to sea level rise.

Dr Massom said not all remaining ice shelves are likely to respond in the same way in coming decades to sea ice loss and ocean swells.

"Their response will also depend on their glaciological characteristics, physical setting, and the degree and nature of surface flooding," he said.

"Some remaining ice shelves may well be capable of surviving prolonged absences of sea ice."

WENDY PYPER

Australian Antarctic Division

**Australian Antarctic Science Project 4116*

Also involved in the study were Dr Ted Scambos of the National Snow and Ice Data Center (NSIDC) at the University of Colorado Boulder (USA), Dr Sharon Stammerjohn of the Institute of Arctic and Alpine Research at the University of Colorado Boulder, and Prof. Vernon Squire of the University of Otago (New Zealand).

Massom, Robert A., Theodore A. Scambos, Luke G. Bennetts, Phillip Reid, Vernon A. Squire, and Sharon E. Stammerjohn. Antarctic Ice shelf disintegration triggered by sea ice loss and ocean swell. *Nature*, 2018 (https://www.nature.com/articles/s41586-018-0212-1; doi: 10.1038/s41586-018-0212-1)

1. *Sliver icebergs calve off the Larsen B Ice Shelf on February 17, 2002. (MODIS satellite image: NSIDC/NASA)*
2. *By March 7, 2002, most of the Larsen B Ice Shelf had disintegrated. (MODIS satellite image: NSIDC/NASA)*
3. *Storm-generated ocean swells can contribute to the break-up (calving) of outer ice shelf margins by flexing and working pre-existing fractures. (Photo: Ian Phillips)*
4. *Reduced sea ice coverage since the late 1980s has led to increased exposure of ice shelves on the Antarctic Peninsula to ocean swells. (Photo: Nick Roden)*

Yellow submarine prepares for first Antarctic mission

A high-tech yellow submarine will head to Antarctica this summer for its first mission under an ice shelf.

The seven metre-long, 1600 kilogram autonomous underwater vehicle (AUV), will be deployed around and beneath the Sørsdal Glacier, near Davis research station, to study the sea floor and underside of the ice shelf, and develop the AUV's capability for future missions under larger Antarctic ice shelves.

The project, led by Professor Richard Coleman, Director of the Australian Research Council's Antarctic Gateway Partnership*, will see a team of scientists and engineers deploy the torpedo-shaped AUV from the station's boat ramp and travel alongside it in a small boat to the glacier, about 11 km south-east of Davis.

While the AUV is at the surface the team will communicate with it over WiFi, but once under the ocean surface and ice shelf it must have all the information it needs to operate autonomously. To provide this the team use a geographic information system package to draw mission lines for the vehicle to follow and establish 'rules' for encountering changes in the environment, such as what to do if the sea floor is shallower than expected or the ice surface is too close, and when to come 'home'.

AUV engineer Peter King, from the University of Tasmania's Australian Maritime College, said that the team will use a range of on-board sensors to survey the front of the ice shelf and, all going well, venture beneath it, with increasing distance and duration as the AUV's performance is assessed.

"First we'll test the AUV in open water to ensure all the systems are performing as required, then we'll survey the open water in front of the ice shelf, to understand the density layers and currents in the water column," Mr King said.

"As we get closer to the face of the ice shelf we'll build a map of the sea floor and the depth of the ice face below the surface, to understand the shape of the cavity opening. From there we'll plan our safest entry path and venture beneath."

The AUV has a multi-beam echosounder that emits sound waves and listens to the returning echoes, to build a picture of the environment. The echosounder can point downward to map the bathymetry (shape and depth) of the sea floor, or upward to map the shape and roughness of ice. A side-scan sonar can point sideways to map the shape of ice walls. Also onboard are a sub-bottom profiler that can see beneath sea floor sediment, instruments to measure water temperature, depth, salinity and velocity, and a magnetometer that measures the magnetism of geological features.

The upward looking echosounder will provide critical information to ice-ocean modellers, Dr David Gwyther, from IMAS, and Dr Ben Galton-Fenzi, from the Australian Antarctic Division, who are working to understand the speed of ice shelf retreat in East Antarctica and the contribution of ice shelf melt to sea level rise.

"One of the difficulties of estimating future sea level is understanding how the Antarctic ice sheet will contribute," Dr Galton-Fenzi said.

"Half of the mass loss of the ice sheet is melted off the underside of ice shelves by the ocean, but we know little about how the ocean interacts with the ice sheet because these regions are so difficult to access."

Dr Gwyther said the AUV would provide the very first look at the shape of the underside of the Sørsdal Glacier.

"The topography of the underside of the ice shelf is important because its 'roughness' creates turbulence in the water as it flows past the ice shelf," he said.

"The rougher the surface, the more heat is mixed up from the ocean cavity below, and this affects melting.

"The side-scan sonar may also help us discriminate between ice that is melting, which will appear smoother, and ice that is refreezing, which will appear rougher."

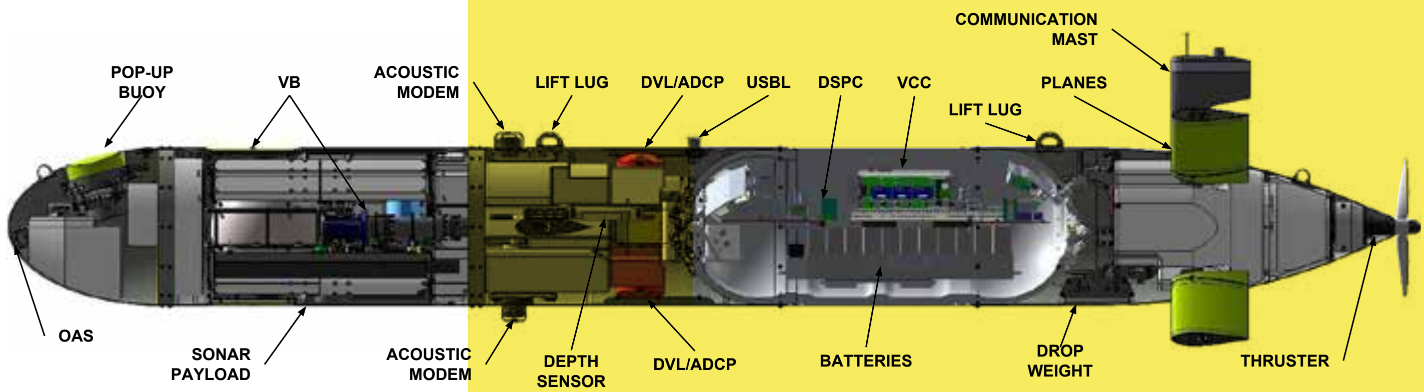
Measurements of ocean characteristics beneath the ice shelf will also provide important information on the temperature of the water that enters the cavity and where it has come from (such as warmer water from the continental shelf), and the speed the water is moving. This information will help scientists improve models of ice-ocean interactions, essential for projections of sea level rise.

For IMAS PhD student Erica Spain, the information revealed by the downward-looking echosounder is of most interest to her project investigating underwater habitats.

"I'd like to see if there are any glacial features under the ice, such as glacial moraines and cold seeps, which can tell us about the glacial and geological history of the region," she said.

"We may also see some biology, as any time you have thick sediments and long residence times, you often get a build-up of methane and biological communities around it."

1. *Erica Spain from the Institute for Marine and Antarctic Studies pushes the AUV into Lake St Clair. (Photo: Wendy Pyper)*



(Photo: ISE)

This cut-away of the Explorer class AUV, developed by International Submarine Engineering in Canada, shows the various technologies that allow it to operate autonomously and collect information about its environment.

Ms Spain has been working closely with the AUV team for the past 12 months to test the vehicle's capabilities for mapping sand waves and sponge gardens in northern Tasmania and Bass Strait.

"We've been mapping features at spatial scales we expect to find under the Sørsdal Glacier and looking to see how much data we can get out of it with minimal processing, and how accurate that data is," she said.

"Most recently we conducted a full dress rehearsal at Lake St Clair in Tasmania's highlands in winter – the closest we could get to simulating Antarctic conditions."

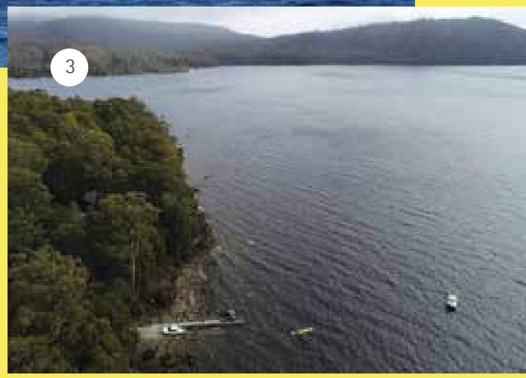
After a year of preparation and practice the team are confident the AUV will perform as expected, but there will no doubt be challenges and learnings in this first of many icy missions.

"The lessons learned from this deployment of the AUV will help shape future deployments at locations that are likely to be more critical for sea level rise, such as the Totten and Amery ice shelves," Dr Galton-Fenzi said.

The AUV (named *nupiri muka* or 'eye of the sea' in palawa kani, the language of Tasmanian Aborigines) is funded by the Australian Government through the Antarctic Gateway Partnership — a $32 million Special Research Initiative of the Australian Research Council that aims to provide new insights into the role of Antarctica and the Southern Ocean in the global climate system. The Australian Maritime College contributed $3 million to the cost of the vehicle.

WENDY PYPER
Australian Antarctic Division

**The Australian Research Council's Antarctic Gateway Partnership is hosted at the Institute for Marine and Antarctic Studies, University of Tasmania. Professor Coleman leads Australian Antarctic Science Project 5138.*



At the front of the vehicle is an obstacle avoidance system (OAS) and the scientific hardware – the side-scan and bathymetric echosounder ('sonar payload'). A variable ballast (VB) system helps the AUV maintain its position in the water.

An acoustic modem enables communication with the vehicle when it's below the surface, to transfer data such as vehicle status. When the vehicle is at the surface, the AUV team can exchange sensor data and updated mission tasks over WiFi.

The Doppler Velocity Log (DVL) is a velocity tracker to help calculate the distance travelled. The Acoustic Doppler Current Profiler (ACDP) measures water current velocities over a depth range using the Doppler effect of sound waves scattered back from particles within the water column.

The AUV is powered by rechargeable lithium ion batteries for 24 hours (140 km). This endurance can be doubled with a second battery.

The USBL, which stands for 'Ultra-Short Base Line', is part of the AUV's navigation system. VCC and DSPC relate to the AUV's power supply and information processing respectively.

The pop-up buoy and drop weight at each end of the AUV are part of its safety system. The drop weight is released when the AUV needs to quickly return to the surface in an emergency. The pop-up buoy can be triggered acoustically, releasing a floating tow line to aid in recovery.

2. The AUV will use on-board instruments to build a picture of the underside of the floating portion of the Sørsdal Glacier (pictured) and the sea floor beneath it. (Photo: Wendy Pyper)

3. In preparation for Antarctica the AUV was tested in Australia's deepest lake, Lake St Clair in Tasmania, which is about 167 metres at its deepest. The AUV ran a series of 10-plus kilometre missions at over 100 metres depth, supported by a small boat. (Photo: Guy Williams)

Krill, whales, and poo power

Do krill swarms affect the distribution and behaviour of whales, and does the potent mix of predators, prey and their poo, positively affect productivity in the Southern Ocean?

1. *Australian Antarctic Division marine mammal scientists Dr Elanor Bell (left) and Dr Mike Double (right) will lead the science contingent on the voyage. (Photo: Dave Brosha)*

2. *Dr Brian Miller will deploy sonobuoys (pictured) to pick up blue whale vocalisations from hundreds of kilometres away. (Photo: David Donnelly)*

SCIENCE

These are just some of the questions a team of krill, whale and biogeochemistry experts hope to answer during an ambitious 49 day voyage aboard the CSIRO Marine National Facility's RV *Investigator* this summer.

Voyage Chief Scientists from the Australian Antarctic Division, Dr Mike Double and Dr Elanor Bell, said krill swarms can be deep or shallow, dense or diffuse.

However little is known about how these different swarm types are distributed across the Southern Ocean and whether some are more attractive to whales than others.

"Previous research suggests that large, dense swarms may be targeted by fast-moving blue and fin whales that engulf their food, while smaller, deeper krill swarms may be suited to more manoeuvrable whales, like humpbacks and minkes," Dr Double said.

"Understanding which swarms are favoured by which whales will inform the development of ecosystem management tools for whales and the expanding krill fishery."

The voyage will look specifically at the distribution and behaviour of Antarctic blue whales in the Ross Sea region, in the presence and absence of Antarctic krill

"We'll track Antarctic blue whales in real time, from hundreds of kilometres away, using passive acoustic technology that detects their low frequency calls," Dr Bell said.

"Once we find whales we'll study their distribution and behaviour in the presence and absence of krill. We'll also look at the characteristics of krill swarms in the presence and absence of whales."

Biogeochemists on the voyage will test whether there is more iron in aggregations of feeding whales than in areas containing only krill, or neither species.

They will also investigate whether the iron in whale poo stimulates phytoplankton and bacteria growth in the local area, and if this has broader effects on the ecosystem.

"This voyage will provide the first detailed, three-dimensional description of the variability of krill swarms in East Antarctica, and the first assessment of iron fertilisation by whales and krill and its effects," Dr Double said.

A range of modern technologies will be used throughout the voyage.

To begin with, Australian Antarctic Division acoustician, Dr Brian Miller, will use small underwater listening devices, called sonobuoys, to track and locate blue whales once the ship leaves Hobart.

Sonobuoys can detect blue whale vocalisations up to 1000 kilometres away, and once the team get within about 50 kilometres of the vocalising whales, multiple sonobuoys can be deployed to triangulate their precise location.

Once whales are located within the survey area, the team will count and photograph the whales and use video tracking technology to record movements, swimming speeds, and blow and diving intervals. These recordings can then be used to compare whale activity in areas with and without krill.

Throughout the voyage, the ship's multibeam echosounders will be used to look for krill and to characterise the size and density of any swarms within whale aggregations and elsewhere. These instruments send pings of sound out in the environment, which reflect off organisms in the water column, providing information about their shape, size and density.

"Multibeam mapping will give us the three-dimensional structure of the krill, while target trawls for krill will provide information on the species, biomass and size," Dr Double said.

A team led by Dr Guy Williams, from the Institute for Marine and Antarctic Studies, also aims to deploy fixed-wing and multi-rotor drones to photograph the whales, and potentially collect samples of their blows and any faeces in the surface water.

"This is really new technology and we don't know what we'll be able to achieve," Dr Williams said.

"But we hope to have a system to collect the mucus in a blow when a whale exhales, which will contain the whale's DNA, as well as exhaled microbes and environmental contaminants.

"We'll also try to use the drone to collect faeces in surface water, as well as clean water samples away from whales and the ship, for the biogeochemists' iron studies."

Iron is an essential trace metal for phytoplankton growth in the Southern Ocean. However it is a 'limiting' nutrient, which means there's not very much of it available for growth, compared to other nutrients.

One theory is that whales can fertilise the ocean with iron, after consuming iron-rich krill and excreting the metal in their faeces. Whale faeces is also rich in other nutrients, such as dissolved organic carbon, which can stimulate bacterial growth.

Australian Antarctic Division biogeochemist, Dr Karen Westwood, along with Dr Lavenia Ratnarajah from the University of Liverpool, and Dr Bonnie Laverock from Auckland University of Technology, will conduct the first in-field experiments to test this theory.

"We'll aim to assess the effect of whale faeces on phytoplankton and bacteria locally, and whether it changes the production and composition of the community," Dr Westwood said.

"We'll also look at its effect on the production of gases by marine microbes that affect climate."

To do this the team will measure iron concentrations in water collected from different depths, in areas with whales and krill, whales only, krill only, and neither species.

Samples from these collection areas will be incubated in the ship's laboratories to see whether there is an increase in the growth of phytoplankton (primary production) and bacteria over time. Phytoplankton samples will be examined under the microscope to look at species composition, while microbial diversity will be assessed by DNA sequencing.

"Generally when there's a lot of iron around, you get a lot of large diatoms, which krill can feed on very efficiently," Dr Westwood said.

Water samples will also be measured for changes in bacteria-driven nutrient cycling, and the production of dimethyl sulphide (DMS) - a gas produced by phytoplankton that contributes to the formation of clouds.

Finally, the team aim to deploy a marker buoy into a suitable 'poo patch' and return to sample the patch each day over five days.

"The marker buoy will float with the body of water containing the faeces and repeated sampling will tell how fast the iron sinks, and whether primary production or bacterial communities in the patch change over time, as the iron potentially becomes more bioavailable," Dr Westwood said.

It's an exciting opportunity for three very different scientific disciplines to combine their expertise and technologies to build an understanding of the Southern Ocean ecosystem that will, as a result, be greater than the sum of its parts. And at the end of the day, who doesn't like a good poo story.

WENDY PYPER
Australian Antarctic Division

This research is supported by a grant of sea time on RV Investigator *from the CSIRO Marine National Facility.*

3. An international team of scientists will spend 49 days aboard the Marine National Facility's RV Investigator *studying Antarctic blue whales, Antarctic krill and Southern Ocean biogeochemistry. (Photo: Marine National Facility)*

4. Dr Karen Westwood and her biogeochemistry team will look at the effect of iron and other nutrients in whale faeces on the phytoplankton and bacterial communities in the Southern Ocean. (Photo: Stacy Deppeler)

5. Scientists aim to understand how different Antarctic krill swarms (shallow or deep, dense or dispersed) are distributed across the Southern Ocean and whether some swarm types are more attractive to Antarctic blue whales (pictured) than others. (Photo: Melinda Rekdahl)

Antarctic krills' secret weapon against ocean acidification

Adult Antarctic krill have a secret weapon for survival in a high carbon dioxide world, according to research published in* Communications Biology *in November.*

Australian Antarctic Program scientists have found adult krill have special ion pumps in their gills that allow them to maintain the pH of their body fluid (blood-like 'haemolymph') under a wide range of carbon dioxide (CO_2) concentrations.

PhD student Jessica Ericson, working with krill biologists Dr So Kawaguchi, of the Australian Antarctic Division, and Dr Patti Virtue of the Institute for Marine and Antarctic Studies, made the discovery after exposing adult krill to acidified seawater for one year.

"Oceans around the world are becoming more acidic as they absorb increasing amounts of CO_2 from the atmosphere," Ms Ericson said.

"Our research suggests adult Antarctic krill are resilient to this increasing ocean acidity and may not be affected by the predicted CO_2 levels for the next 100 to 300 years."

Ocean acidification has been proven to have negative effects on some marine organisms, reducing their ability to form shells, decreasing or delaying growth and reproduction, and causing abnormalities in offspring.

However Ms Ericson found that adult krill were able to survive, grow and reach sexual maturity when exposed to predicted near-future CO_2 levels.

"The krill were able to maintain the pH of their haemolymph and this may be the key to their successful survival, maturity and growth in a future high CO_2 world," Ms Ericson said.

"In contrast, eggs and embryos have no capacity to regulate the pH of their extracellular fluid, so they are totally at the mercy of their environment."

Ms Ericson cautioned that the ability for krill to maintain their haemolymph pH beyond one year and into their spawning season is currently unknown.

Her experiments also provided a constant food supply, rather than the regionally and seasonally variable food supply experienced by wild krill, which may have enabled the experimental krill to maintain their normal physiology.

While her research offers hope that this critical Southern Ocean species will endure in the face of climate change, Ms Ericson said the overall resilience of Antarctic krill will depend on long-term effects occurring at all life history stages, and how krill respond to ocean acidification in combination with other changes such as ocean warming.

Previous research at the Australian Antarctic Division has shown that krill egg hatch rates and embryonic development were impaired as ocean acidity increased (*Australian Antarctic Magazine* 25: 4-5, 2013).

WENDY PYPER
Australian Antarctic Division

**Australian Antarctic Science Project 4037*

This research was a collaboration between the Australian Antarctic Division, CSIRO, Institute for Marine and Antarctic Studies, Aker Biomarine and Griffith University through an ARC Linkage grant LP140100412.

1. *PhD student Jessica Ericson found that adult krill can survive, grow and reach sexual maturity when exposed to near-future ocean acidification, due to ion pumps in their gills that allow them to maintain the pH of their body fluid. (Photo: Wendy Pyper)*
2. *Jessica Ericson worked with Australian Antarctic Division krill biologist Dr So Kawaguchi at the Division's unique krill facility. (Photo: Wendy Pyper)*

Seeking molecules that scrub the sky

An international team of scientists will drill into the Antarctic ice sheet this summer to reveal the extent to which natural 'atmospheric detergents' cleanse the air of harmful gases.

While the majority of greenhouse gas emitted is carbon dioxide (CO_2), there are more than 40 other gases that contribute significantly to climate change and ozone depletion.

This season's expedition to Law Dome in East Antarctica, led by CSIRO atmospheric physicist Dr David Etheridge* and Dr Vas Petrenko from the University of Rochester in the United States, seeks to understand the natural processes that remove these 'other' gases from the atmosphere.

The research team will drill ice cores to depths of 250 metres, to measure pre-industrial atmospheric levels of hydroxyl radicals (OH molecules with an unpaired electron) from the air bubbles trapped inside.

Hydroxyl is a naturally occurring, highly reactive oxidant, which acts as an 'air purifier' by chemically destroying greenhouse gases like methane, and industrial chemicals that deplete ozone.

"Understanding how much of these pollutants are removed naturally by hydroxyl is fundamental to our climate models, if they are to more accurately predict the levels of all greenhouse gases into the future," Dr Etheridge said.

"For example, under a certain emissions scenario, what will be the amount of greenhouse gases or ozone depleting gases that remain in the atmosphere? What damage will they do to the ozone layer? How much warming will they cause?"

"Knowing how hydroxyl varies in the atmosphere is key to answering these questions."

To find out, scientists and a support team will traverse more than 100 kilometres from Casey research station and set up a temporary laboratory at Law Dome for three months.

Three drills run by collaborators from the United States Ice Drilling Design and Operations will extract ice cores to be processed and analysed in the field laboratory.

"Law Dome is the best place on the planet to get trapped old air for this project, because its enormous rate of snowfall traps air quickly and preserves it at depth for centuries," Dr Etheridge said.

The key challenge for the team, however, is that hydroxyl radicals cannot be sampled directly, because they are so reactive each lasts less than a second.

Instead, the researchers are seeking tracer molecules controlled by the chemical reaction with hydroxyl, like carbon monoxide (CO) that's been tagged by cosmic rays.

"Cosmic rays are constantly bombarding the atmosphere and producing small amounts of the isotope carbon-14 (^{14}C) that goes on to form carbon-14 monoxide (^{14}CO)," Dr Etheridge said.

1. Dr Etheridge extracts a core from the ice core drill at Law Dome during a project in 2015. (Photo: Gordon Tait)

SCIENCE

"This ^{14}CO is removed by hydroxyl so the amount that remains in the atmosphere will tell us about the hydroxyl levels."

While cosmic rays create a useful ^{14}CO tracer in air, they also penetrate the upper layers of snow and can alter the ^{14}CO levels in the snow-pack. This is where the high snowfall and rapid burial at Law Dome are important because this shielding minimizes any unwanted additional ^{14}CO production.

"Once the ice is brought to the surface, it is once again exposed to cosmic rays, and the process of contamination starts," Dr Etheridge said.

To get around this, the team will extract air from the ice cores as soon as they arrive at the surface. Each sample will melt hundreds of kilograms of ice to yield a few litres of air. This will be collected in canisters where the contamination process will stop.

Another challenge for the project is collecting enough material to analyse. The total mass of all the ^{14}CO in the atmosphere amounts to about one kilogram. Each air sample will contain a vanishingly small amount of the ^{14}CO tracer molecules, in the concentration of a few parts per hundred million trillion (10^{20}).

"The concentrations we're looking for are so miniscule it's like trying to spot one particular sand grain on a beach," Dr Etheridge said.

The amount of the ^{14}C isotopes of CO in each sample will be measured by an accelerator mass spectrometer at the Australian Nuclear Science and Technology Organisation in Sydney, after initial analysis and preparation in the United States.

"Once we've measured these samples across the past 150 years, and quantified the trend in the tracer that tells us how hydroxyl levels have changed over that period, we can start to provide data for earth systems models that simulate the chemistry and the physics of the atmosphere," Dr Etheridge said.

These tiny pieces of the puzzle will be crucial to improving the predictive powers of global climate models, and providing deeper insights into how the atmosphere will change in the future.

MARK HORSTMAN
Australian Antarctic Division

**Australian Antarctic Science Project 4425*

The Law Dome expedition is a US-Australian collaborative project involving glaciologists and atmospheric scientists from CSIRO, the Australian Nuclear Science Technology Organisation (ANSTO), the University of Rochester, Scripps Institution of Oceanography, the US National Science Foundation, and Australian Antarctic Division.

2. *This season David Etheridge will spend three months at Law Dome investigating the variability of hydroxyl radicals in the atmosphere, which act as a natural 'air purifier' by removing greenhouse and ozone-depleting gases. (Photo: Tony Fleming)*

3. *Dr Etheridge inside the drilling tent at Aurora Basin North in 2013. (Photo: Tas van Ommen)*

Melting beneath Totten Glacier driven by natural variability

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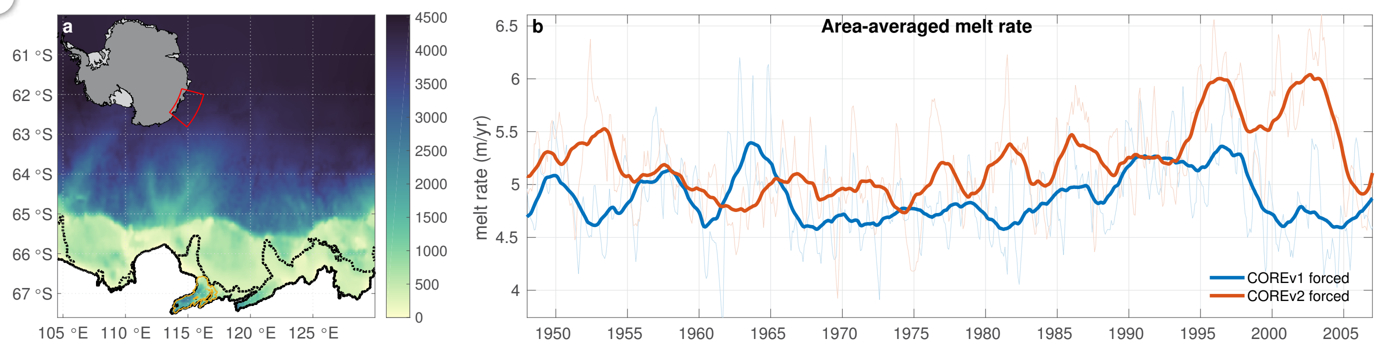


Melting beneath the Totten Glacier is strongly influenced by natural variability, according to research recently published in Nature Communications.

The Totten Glacier, near Casey research station, is thought to be the 'canary in the coalmine' for climate change in East Antarctica, holding back at least three metres of potential sea level rise. Previous studies have suggested that it is thinning and beginning to retreat.

In a new study I and my co-authors from the Australian Antarctic Division*, CSIRO, and University of Texas, used computer simulations (previously described in *Australian Antarctic Magazine* 21: 14-15, 2011) to pick apart how and why melting was varying beneath the Totten Ice Shelf.

To do this an ocean model was configured to simulate how warm water flows onto the continental shelf and below the Totten Ice Shelf. The atmospheric 'forcings' (factors like wind, heat loss and sea ice formation) for the model were chosen so that it represented a year of normal climate, and this was repeated for 200 years.

We were surprised to find that melting beneath the ice shelf did not just vary annually, but also fluctuated randomly and slowly over multi-year periods, even though we did not force the model with multi-year atmospheric data.

This demonstrates that the ocean is producing long-term internal or 'intrinsic' variability, separate from external climate forcings such as the El Niño–Southern Oscillation (a periodic variation in winds and sea surface temperatures).

We compared the impact of this intrinsic ocean-variability-only model, to another model run with the full climatic forcing from 1949–2007. We found that the changes in melting due to intrinsic variability are almost as large as the full climate-forced response (see graphic).

This finding is especially important for the detection and attribution of change in Antarctic ice shelves, where short-term trends are often prescribed as being as a result of a climate change.

Our finding indicates that caution is needed in interpreting changes observed over a short period. Rather than being a result of climate, there is the possibility that they are a natural response in the ocean system.

Any future satellite or field observations of ice shelf and glacier change should consider the internal response of the system, as well as the forced response due to atmospheric phenomena like ENSO or climate change.

Results from this study also predict regions of the Totten Ice Shelf that are less susceptible to natural, intrinsic variability. These locations would be useful for on-ice observations (*Australian Antarctic Magazine*: 33, 12-13, 2017) because any long-term changes will be detectable above any natural, intrinsic variability.

Numerical models allow us to examine the long-term impact of many different cryospheric processes in a way that you can't yet with observations. But we need to feed these results back in to field campaigns so that the data we bring back from these remote environments is as good as possible.

DAVID GWYTHER
Institute for Marine and Antarctic Studies, University of Tasmania

**Australian Antarctic Science Project 4287*

1. *Dr Gwyther and colleagues found that the change in melting beneath the Totten Ice Shelf, due to natural, intrinsic ocean processes (blue line) is comparable to that due to the full climate forcing (orange line). (Graphic:* Nature Communcations *9 (1), 3141, 2018 doi: 10.1038/s41467-018-05618-2)*

'Cucumber-cam' assists conservation

New underwater camera technology developed by Australian researchers is shining a light on previously unseen species in the Southern Ocean, to help improve marine conservation.

For the first time, a swimming sea cucumber, *Enypniastes eximia,* also known as a 'headless chicken monster', has been filmed in deep Southern Ocean waters off Heard Island and the McDonald Islands.

The unusual creature, which has only ever been filmed before in the Gulf of Mexico, was discovered using an underwater camera system developed for commercial long-line fishing by the Australian Antarctic Division.

Australian Antarctic Division fisheries scientist Dr Dirk Welsford, said the cameras are capturing important data that informs the international body managing the Southern Ocean – the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR).

"The housing that protects the camera and electronics is designed to attach to toothfish longlines in the Southern Ocean, so it needs to be extremely durable," Dr Welsford said.

"We needed something that could be thrown from the side of a boat, and would continue operating reliably under extreme pressure in the pitch black for long periods of time.

"Some of the footage we are getting back from the cameras is breathtaking, including species we have never seen in this part of the world.

"Most importantly, the cameras are providing information about the habitats and organisms on the sea floor where this type of fishing occurs, and the sensitive areas that should be avoided."

Dr Welsford said the discovery of the sea cucumber, about 1600 metres below the surface, off Heard Island, was a surprise.

"Sea cucumbers typically rest on the sea floor, but this one is interesting because it has fins and it swims.

"Scientists in the United States christened it the 'headless chicken monster' because it looks a bit like a chicken, it's got wings and it's about the size of a basketball."

Dr Welsford said other CCAMLR nations, such as Chile, France, and the United Kingdom are also using the super-strengthened camera devices, which are fabricated at the Antarctic Division's headquarters in Tasmania.

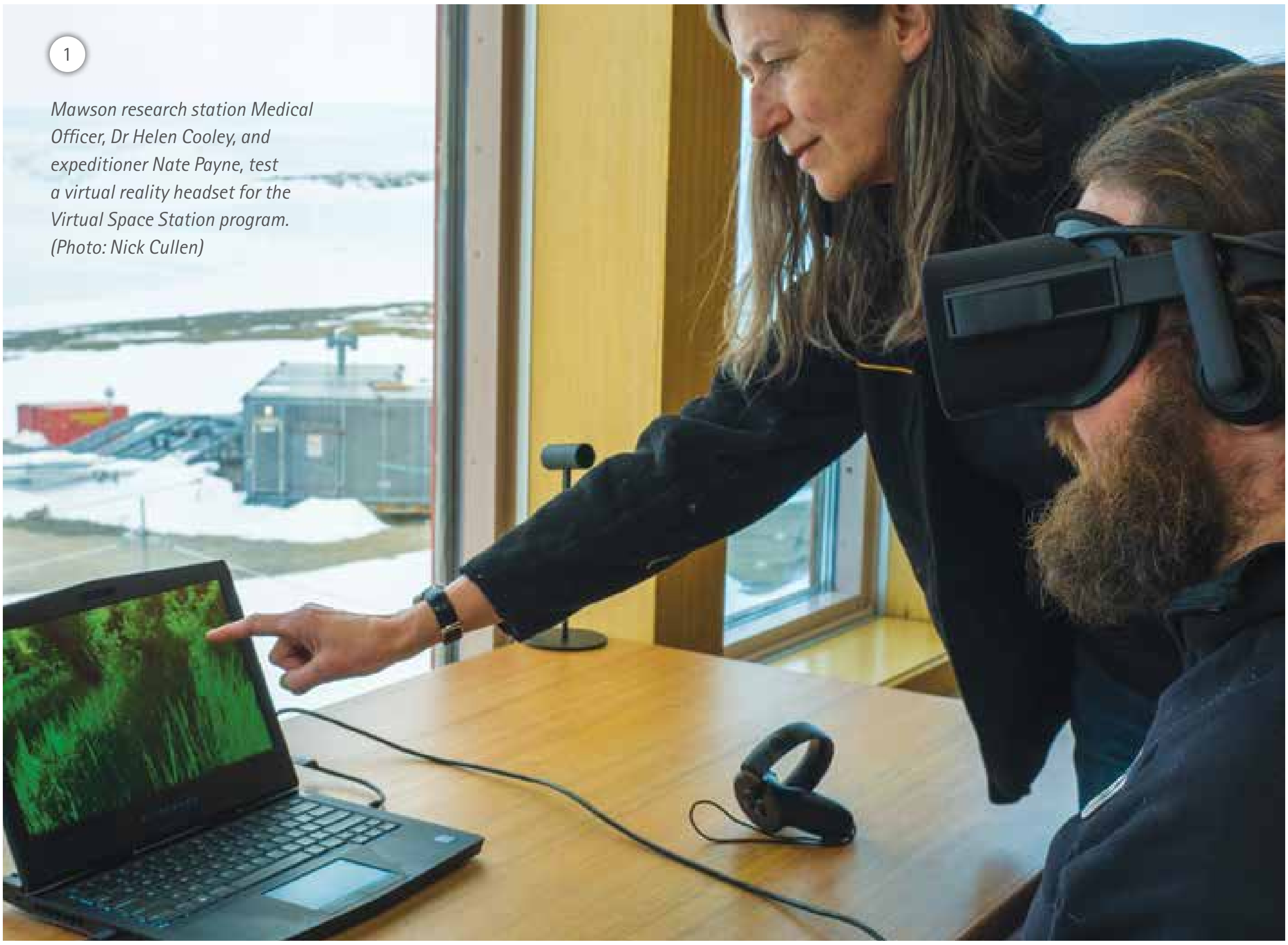
"It's a simple and practical solution that is directly contributing to improving sustainable fishing practices," Dr Welsford said.

The data collected from the cameras were presented at the annual CCAMLR meeting in Hobart in October.

DAVID REILLY and NISHA HARRIS
Australian Antarctic Division

1. *The swimming sea cucumber* Enypniastes eximia *is a deep purple-red colour which, in the deep ocean, makes it difficult for predators to see. (Photo: NOAA)*

2. *Two of the deep-sea cameras ready to be deployed on longlines. (Photo: Jessica Fitzpatrick)*



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Mawson research station Medical Officer, Dr Helen Cooley, and expeditioner Nate Payne, test a virtual reality headset for the Virtual Space Station program. (Photo: Nick Cullen)

Antarctic virtual reality trial to assist astronauts

Virtual Reality forests, beaches and cities are being trialled with expeditioners at Australia's Antarctic stations to inform the development of programs supporting astronauts on long-duration space flights – like a mission to Mars.

The trial is a collaboration between the Australian Antarctic Division's Polar Medicine Unit and Human Resources team, and the Giesel School of Medicine at Dartmouth College in the United States, to understand how virtual reality can help with mental health and well-being in isolated environments.

Australian Antarctic Division Chief Medical Officer, Dr Jeff Ayton, said wintering in Antarctica is analogous to a long-term space mission.

"Expeditioners at our Antarctic stations are isolated in a confined and extreme environment for up to nine months of the year, which is one of the longest confinements on earth," he said.

"This virtual reality research at Davis and Mawson stations, will help us understand whether a self-help tool can assist with training and support for the well-being and behavioural health of individuals and teams in such environments."

Expeditioners have the choice of virtual reality Australian beaches, European nature scenes or North American natural and urban environments – the polar opposite to the whiteness and silence of Antarctica.

Other program modules, which are self-directed and available on station, explore conflict management, stress and mood, to optimise expeditioner and team performance. The modules build on existing pre-departure training and support from the station community, the station doctor and experts in Australia.

Astronaut, physician and Professor at Dartmouth College, Jay C. Buckey Jr., said evidence suggested that the immersive nature of virtual reality could improve mental health.

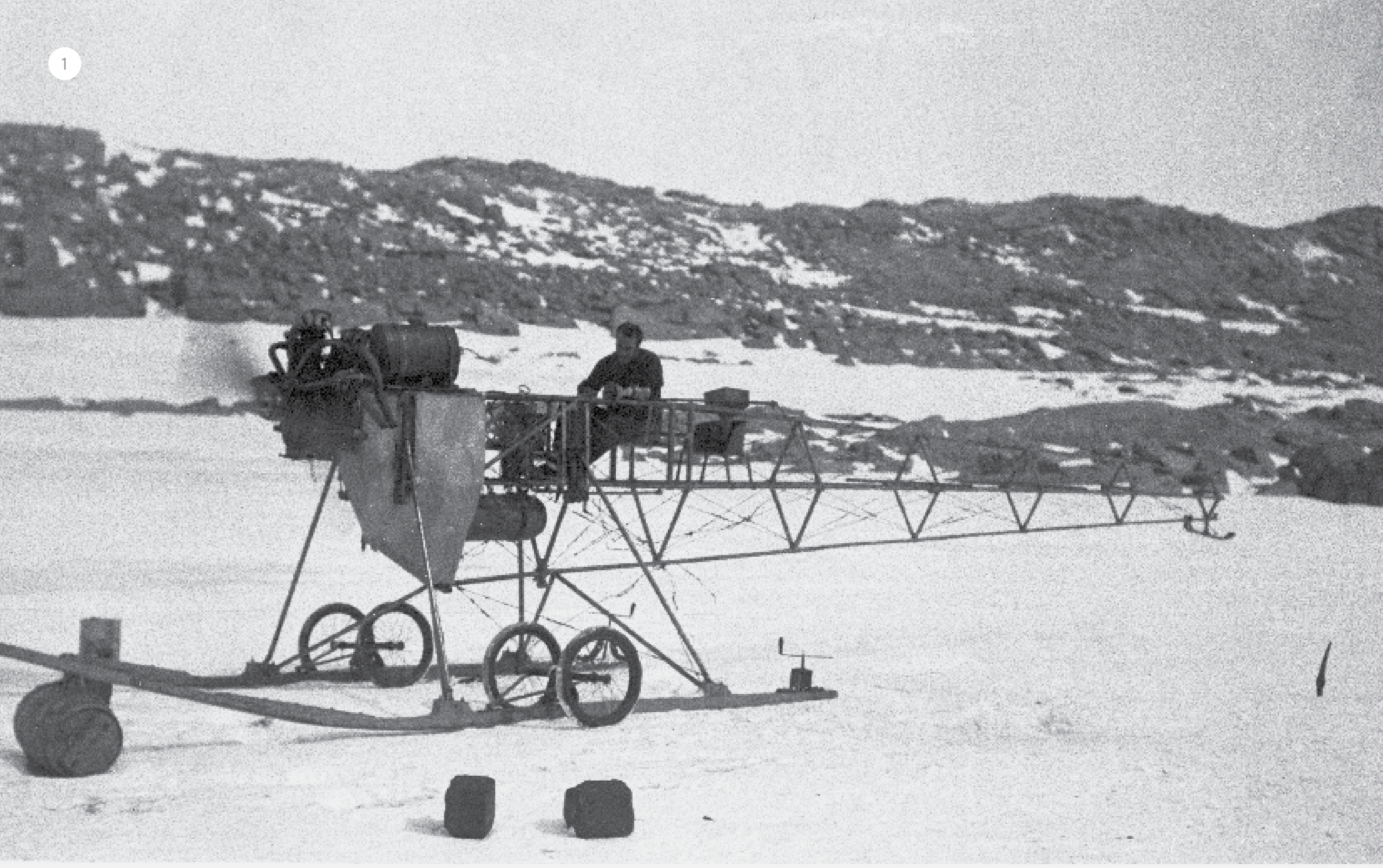
"Virtual reality allows you to immerse people in different natural settings, so they can be in the Bavarian Alps, or they can be on a beach in Australia, and there's evidence that exposure to nature, which we all like and seek out, can be restorative and help to relieve stress. It can also help perhaps improve people's attention and mental functioning," Professor Buckey Jr said.

"There aren't that many people who live in challenging, isolated, and confined environments, so the information we get from Antarctica will be so valuable because it will tell us how people in this kind of environment would use a tool like this."

Watch the video at http://www.antarctica.gov.au/news/2018/virtual-space-station

CORPORATE COMMUNICATIONS

Australian Antarctic Division



Opening up the Antarctic skies

This year marks the 90th anniversary of the first powered flight over Antarctica by Australian adventurer Sir George Hubert Wilkins, on 16 November 1928.

Since the earliest days of Antarctic exploration, the vast distances and the difficulties of overland traverse have made the prospect of surveying the continent by air extremely appealing. Some of the earliest Antarctic experiments with airborne craft included Robert Falcon Scott's ascent in a tethered hydrogen balloon in 1902, and Edgeworth David's use of box kites to carry meteorological instruments aloft in 1907.

Australia's Sir Douglas Mawson considered the potential of fixed-wing aviation for aerial surveying, as part of the Australasian Antarctic Expedition in 1911. A mere eight years after the Wright Brothers' famous flight at Kittyhawk, Mawson announced his plan to explore the frozen continent by air, with great fanfare. This was the same year that Scott and Amundsen would make their famous overland traverses to the South Pole, and the public appetite for daring polar adventure stories was high.

Mawson selected a Vickers REP monoplane, a wire and fabric contraption with an open-air cockpit, spoked wheels and a tiny 60 horsepower motor. This was state-of-the-art technology at the time, but unfortunately Mawson's flying machine crashed during a fund-raising demonstration flight over Adelaide just before departure. Undeterred, and reluctant to give up on the publicity opportunity, Mawson shipped the remnants of the airframe south, where it was repurposed as a propeller-driven sled.

After Mawson's setback, and with the arrival of the Great War in 1914, Antarctic aviation went into hiatus for almost 15 years. It was another Australian adventurer, Sir George Hubert Wilkins, who would claim the honour of making the first powered flight over Antarctica in November 1928, in a Lockheed Vega 1.

First powered flight

Wilkins had made a name for himself in April that year, when he made the first flight across the Arctic with former US Army pilot Carl Ben Eielson in a Lockheed Vega 1. With funding from the American publishing magnate, William Randolph Hearst, the two adventurers set their sights on Graham Land on the Antarctic Peninsula. Taking off from a rough airstrip at Deception Island in the South Shetlands, the 20 minute flight took them around the island and into the history books.

Wilkins and Eielson made many flights over the next few months, often in atrocious weather. On December 20, 1928, they flew over 2100 kilometres across the Antarctic Peninsula. Wilkins recorded all he saw, taking photographs and making sketches, exhilarated to note that "For the first time in history, new land was being discovered from the air". In one 11 hour journey, the two men surveyed an area that would have taken months to traverse by dog sled. Their triumphant return to civilisation heralded a new dawn for polar exploration. The modern aircraft was now an essential element of Antarctic expeditions.

1. Douglas Mawson's Vickers monoplane, with its wings removed and converted into an air tractor by Francis Bickerton. On its second outing the propeller was smashed and the engine failed. The frame was abandoned on the shores of Boat Harbour. (Photo: John Hunter)

Witnessing the success of Wilkins, and still determined to realise his own aviation ambitions, Sir Douglas Mawson voyaged south again in 1929 as part of the British, Australian and New Zealand Antarctic Research Expedition (BANZARE). He took a De Havilland Gipsy Moth aboard the ship *Discovery*, deploying the aircraft over the side suspended on a cable. The float-mounted biplane quickly proved useful in achieving the expedition's goals of collecting scientific data and laying claim to new territory (*Australian Antarctic Magazine* 22: 13-15, 2012).

Mawson and his fellow expedition pilot, Stuart Campbell, flew the aircraft ahead of *Discovery* on occasions, to identify routes through the pack ice. They successfully mapped a large stretch along the coastline of what would later become the Australian Antarctic Territory, from the Ross Sea to beyond Enderby Land. In a paper published in 1932, Mawson declared that "the aeroplane proved a most important factor in the prosecution of the geographical programme."

Adventurous aviators

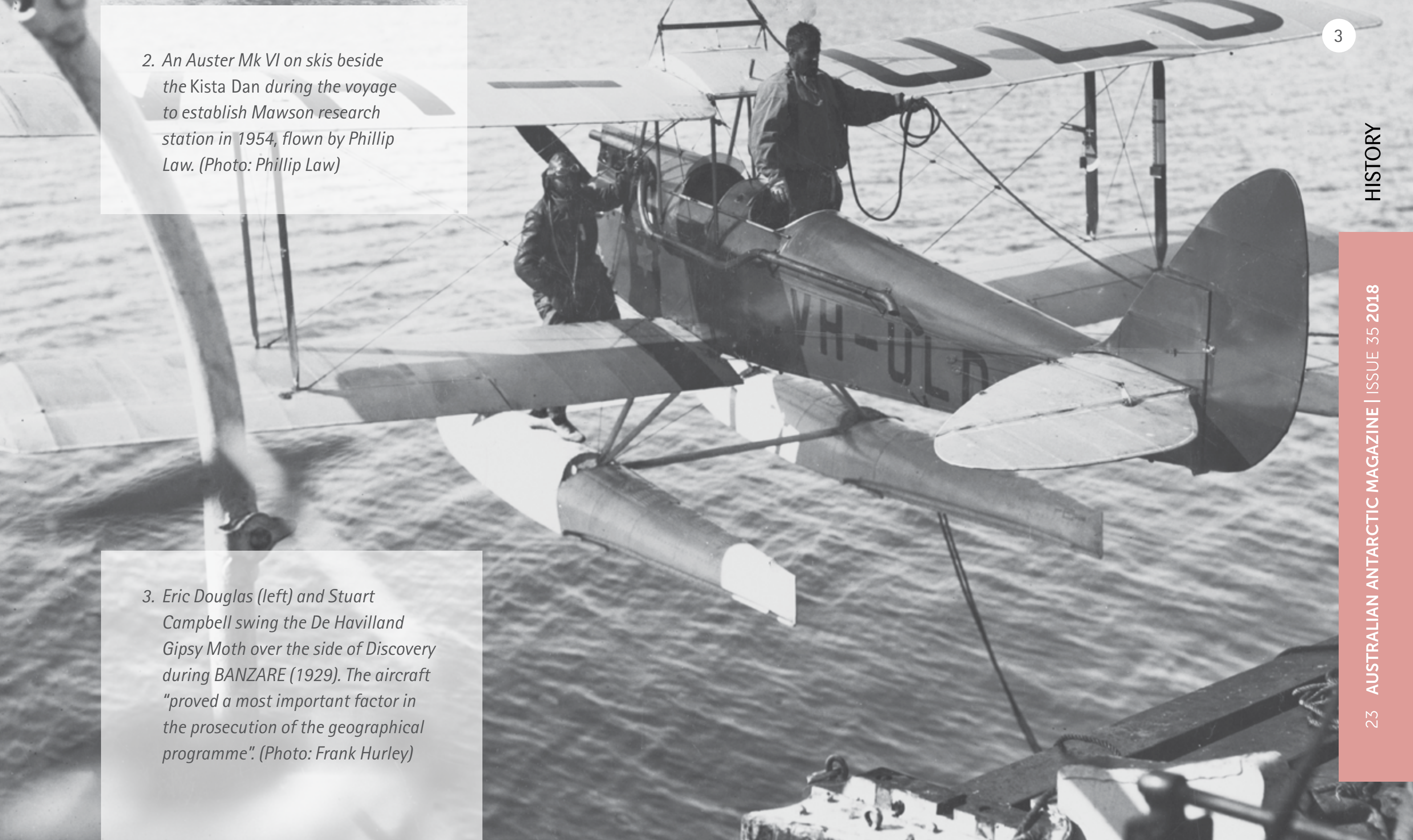
By the mid-1930s, Mawson and Wilkins were just two men among a colourful cast of adventure-seeking aviators. Among this new generation of explorers was the New York millionaire, Lincoln Ellsworth, who made three unsuccessful attempts in 1933 to make the first trans-Antarctic flight, in a Northrop Gamma, with Wilkins as the pilot. Ellsworth later made the first successful flight across the continent with fellow American, Herbert Hollick-Kenyon.

In 1938, Wilkins joined another Ellsworth-led Antarctic expedition sailing from Hobart aboard the *Wyatt Earp* with a single-engine, all metal Northrop Delta. Before their departure, Ellsworth had assured Wilkins that he had no intention of claiming land in Antarctica on behalf of his home country. Wilkins recalls that Ellsworth changed his story at sea, announcing plans to map land that had previously been claimed but not seen. Resolving to reassert Australian sovereignty over territory claimed by Mawson, Wilkins responded by flying to the northernmost point, landing at the Rauer Islands, then on to the south-western and the north-eastern extent of the Vestfold Hills. He flew the Australian flag and deposited a record of the visit in a rock cairn at each site.

Although the arrival of the Second World War placed the ambitions of Antarctic aviators on hold, the enormous technological advancements made during wartime would bring about a new era in Antarctic aviation. These bigger, sturdier and more powerful aircraft were equipped with sophisticated radio and navigation instruments, and would prove much more reliable under polar conditions.

During the post-war years, a variety of surplus Royal Australian Air Force (RAAF) aircraft were put into service by the Australian National Antarctic Research Expeditions (ANARE), particularly in and around the sub-Antarctic islands. This included the use of a Supermarine Walrus flying boat to establish a weather station at Heard Island in 1947. However, the aircraft made only one successful flight before it was ripped from its tie-downs in a blizzard and wrecked on a beach at Atlas Cove. Although this and other expeditions had mixed success, it was a period of productive experimentation that helped Australia refine and improve its Antarctic aviation capability. Progress was apparent in the first direct flight to the newly-established Macquarie Island station in a Catalina flying boat in 1948, and a successful airdrop to the island using an Australian-built RAAF Lincoln bomber.

2. *An Auster Mk VI on skis beside the* Kista Dan *during the voyage to establish Mawson research station in 1954, flown by Phillip Law. (Photo: Phillip Law)*



3. *Eric Douglas (left) and Stuart Campbell swing the De Havilland Gipsy Moth over the side of Discovery during BANZARE (1929). The aircraft "proved a most important factor in the prosecution of the geographical programme". (Photo: Frank Hurley)*

4. *Twin Otters and AS350 helicopters are a key part of today's modern Australian Antarctic Program. (Photo: Madi Gamble Rosevear)*

Continental flight

By the early 1950s it was clear that ship-based aviation could no longer serve the needs and ambitions of the Australian Antarctic program. A permanent continental base in Antarctica was required. Once a suitable ice-strengthened ship and logistic support was obtained, Australia established Mawson station in 1954. A de Havilland Auster Mark VI, flown by Dr Phillip Law, was used for locating and surveying the harbour and surrounding area.

As ANARE's activities on the continent grew, so did the use of ski-equipped aircraft for large-scale reconnaissance over the Australian Antarctic Territory. In 1956, a de Havilland Beaver and an Auster were used to carry out surveys near what later became Casey research station. The Beaver was also used to establish the first airlink between Mawson and Davis stations, and in the discovery of the mountains in Enderby Land and the Prince Charles Mountains.

Over time two more Beavers joined the fleet. These tough and reliable workhorses covered hundreds of thousands of square kilometres of exploration and discovery well into the 1960s. They were joined by other aircraft, including a Douglas DC3 at Mawson in 1959–60. Within a year of its arrival, the DC3 was destroyed in a four day blizzard. The aircraft was blown nearly 20 kilometres and finished up on the slope of a coastal ice cliff. This shut down regular inter-station flying for over a decade, and proved that being on the ground in Antarctica could be as hazardous to an aircraft as flying.

The reliance on ships to access the continent changed in 1964, with the first direct flight from Australia to Antarctica by a ski-equipped United States Navy C-130 Hercules. The four-engine heavy transport aircraft flew from Melbourne, undertook an airdrop of mail and newspapers at the South Pole and, after 16 hours and over 7000 kilometres, landed at Byrd Station. Dr Phillip Law, who was among the passengers on the flight, recalled that it had almost ended in disaster. The flight was plagued by bad weather and a series of potentially catastrophic technical failures, including radar malfunction, cabin depressurisation and jammed nose gear.

Despite the hitches, this pioneering flight had demonstrated the new possibilities that intercontinental air transport provided for rapid logistical support in Antarctica. In following years, Australia entered a number of cooperative agreements with other countries to leverage from existing intercontinental air operations. These friendly cooperative agreements, alongside other quid pro quo arrangements, remain a lynchpin of international scientific and logistics cooperation in Antarctica today.

From the 1970s there were continuous and steady improvements in Australia's aviation technology and operating procedures. Helicopters were increasingly important in intra-continental aviation, alongside an array of fixed wing aircraft, from the Pilatus Porter in the seventies to the de Havilland Twin Otter in the late eighties. A significant turning point came in the mid-nineties with the introduction of the Sikorsky S76 helicopters, which reopened the direct airlink between continental stations that was lost 30 years earlier when the Douglas DC3 was destroyed. In 1995, helicopter engineer Vanessa Noble became the first female air crew member to serve in Antarctica.

5. *The RAAF C17-A allows the Australian Antarctic Division to move high priority, outsize cargo that's too big to fit in the A319. The RAAF has been supporting the Antarctic Division through Operation Southern Discovery since 2016. (Photo: Justin Hallock)*

Antarctic aerodrome

In the decades after the first direct flight from Australia to Antarctica, ANARE investigated the possibility of establishing an intercontinental runway to Casey research station on at least three occasions. A trial compacted runway was constructed during the 1989–90 summer, in preparation for a planned RAAF Hercules trial flight late that season. Poor weather and heavy snowfalls prevented it from going ahead, and the project was not resumed. In 1999 the Australian Antarctic Division developed a proposal for a blue ice runway near Casey. Work on the aerodrome began in the early 2000s, with the first demonstration flights to the runway in an Airbus A319 LR in 2006–07, and the first official passenger flight the following year (*Australian Antarctic Magazine* 14: 23, 2008).

Named in honour of Australia's legendary Antarctic aviation pioneer, Wilkins Aerodrome brought to fruition a concept first mooted over 40 years before. Today, its blue ice runway operates between October and March each year, but closes at the height of summer due to surface melting. Even with its relatively short operating window, Wilkins Aerodrome has transformed the Australian Antarctic Division's science and logistics capability, opening up new possibilities for rapid, flexible and efficient transport of people and cargo to the continent using the A319.

Expanding possibilities

Since 2016, the Australian Defence Force has supported the Australian Antarctic Division through Operation Southern Discovery, with RAAF heavy-lift capability providing a regular program of flights using a C-17A Globemaster III aircraft. This air logistic support for oversize and time-critical cargo has been used for both land and aerial delivery missions (*Australian Antarctic Magazine* 30: 24-25, 2016).

While shipping remains central to Australian research and resupply operations, aviation is continuing to expand the limits of what's possible. This includes recent out of season airdrops of supplies and parts (prepared by the Australian Army's 176th Air Dispatch Squadron) to Casey and Davis research stations, by the C-17A. To give the aircraft the range to make the airdrop mission to Davis, it needed an air-to-air refuel from a KC-30A Multi Role Tanker Transport on the southbound leg of the journey (*Australian Antarctic Magazine* 33: 7, 2017).

In 2016, through the *Australian Antarctic Strategy and 20 Year Action Plan*, the Australian Government funded the investigation of options to deliver year-round aviation access between Hobart and Antarctica. This was followed in early 2018 with the announcement of the Government's intention to construct Antarctica's first year-round paved runway near Davis research station, subject to environmental approvals. The project will be another step change in Australia's ability to conduct world-class scientific research, and our operational capacity, particularly our ability to respond to emergencies. It will also overcome the seasonal limitations associated with ice runways, which are expected to increase as the climate warms

A team of geotechnical engineers has identified a location for the runway in the Vestfold Hills, one of a handful of areas in East Antarctica that remains largely ice-free throughout the year. Almost 5000 kilometres from Hobart, and with a flight time of around six hours, it would be the most remote intercontinental runway on Earth.

As we mark 90 years since Sir Hubert Wilkins' historic first flight, it is timely to reflect on the progress made in opening up the skies over Antarctica. What began with a cold and bumpy 20 minute flight over Deception Island on 16 November 1928, has become an integrated and high-tech transport logistics system, supporting a year-round program of vital scientific research. Advances in manufacturing, navigation and weather forecasting have led to improvements in aviation that pioneers like Wilkins, Mawson and Law could scarcely have dreamed of.

DAVID REILLY

Australian Antarctic Division

Information for this article was sourced from: David Wilson, *Alresco Flight. The RAAF Antarctic Experience*. Royal Air Force Museum. An Occasional Series No.3, 1991.

Pat Quilty

Antarctic community mourns loss of science leader

Former Australian Antarctic Division Chief Scientist, Professor Patrick (Pat) Quilty AM, who passed away on 26 August, played a leading role in the international Antarctic science community.

After graduating in 1962 with a Bachelor of Science (Honours) degree from the University of Western Australia, Professor Quilty first visited Antarctica in 1965 as a field palaeontologist with the University of Wisconsin. He received his PhD from the University of Tasmania in 1969.

Professor Quilty led the Australian Antarctic Division's science program between 1980 and 1999 and published more than 200 scientific research papers.

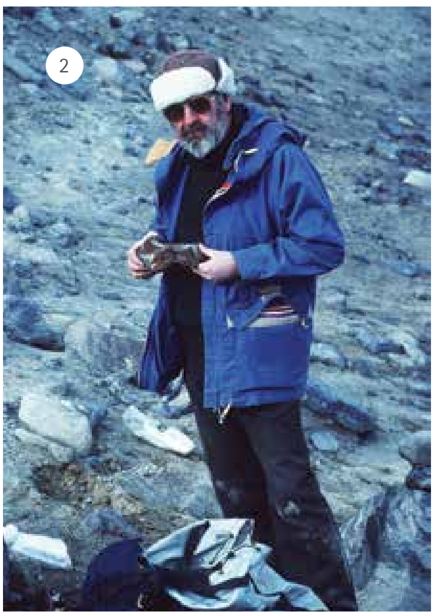
In interviews, Professor Quilty said that one of his career highlights was his discovery of fossil whale and dolphin bones in 1984, at Marine Plain in the Vestfold Hills near Australia's Davis station. It is the only site in Antarctica where fossil vertebrates have been found, which are dated after the continent was glaciated 34 million years ago (Ma).

"We were wandering around the edges of one of the lakes, and then about 10-15 metres away I saw a pile of fragments on the ground…I went over…and put a bit of it under the hand lens….and it was bone. I immediately recognised the significance of it, because here was vertebrate material, 3.5–4 million years old. The only other vertebrate material known from Antarctica is 40 million years old or more.

"I didn't know what I'd found…..A couple of larger ones that told me it wasn't just a piece of leg bone or a rib, it was something interesting. And so I wrapped these…sketched the area, photographed it, numbered all the large fragments, re-photographed it, collected it carefully in bags. I brought this lot back to Australia - and it turned out to be the first of the dolphins. "

Through the discovery of fossil vertebrates and microfossils in Pliocene (ca. 2.6–5.3 Ma) sediments, Professor Quilty theorised that Antarctica was considerably warmer at various times in the past than present and suggested that changes towards the present glacial regime were later and more rapid than previously thought.

This discovery earned Professor Quilty international recognition and he had five fossils named after him. To recognise Marine Plain's exceptional scientific interest and relevance to the palaeoecological and palaeoclimatic record of Antarctica, the Antarctic Treaty Committee designated the site an Antarctic Special Protected Area (ASPA).



1. *Professor Quilty was a hard-working, intellectual, gentleman scientist, who mentored a generation of Antarctic scientists. (Photo: Glenn Jacobson)*
2. *Professor Quilty at Marine Plain in 1988, where he discovered fossil whale and dolphin bones. This discovery, and that of other marine fossils, led to the designation of Marine Plain as an Antarctic Specially Protected Area. (Photo: D. Adamason)*

Professor Quilty was active in international Antarctic leadership, serving as vice-president of the Scientific Committee on Antarctic Research (SCAR) from 1994–1998. He also served as Chair of the 20th SCAR meeting in Hobart in 1988, as well as symposia on the Vestfold Hills and Macquarie Island.

At a national level, he was President of the Association of Australasian Palaeontologists, and Federal Secretary of the Geological Society of Australia. He also served on both state and federal councils of the Australian & New Zealand Association for the Advancement of Science. Professor Quilty convened the 17th Australian Geological Convention in Hobart in 2004, and the Mawson Symposium for the Royal Society of Tasmania in 2011.

After leaving the Australian Antarctic Division, Professor Quilty undertook teaching and research at the University of Tasmania. In later years, he was Honorary Research Professor at the University of Tasmania's School of Earth Sciences.

Professor Quilty's significant contribution to science was recognised throughout his career. He was the recipient of the United States Antarctic Services Medal 1974, Royal Society of Tasmania Medal 1996, Distinguished Alumnus - University of Tasmania 1997, Member of the Order of Australia (AM) 1997 and the Phillip Law Medal 2016.

The Australian Antarctic Names Committee named Quilty Bay in the Larsemann Hills, near Davis station, in recognition of his contributions.

The United States Antarctic Research Program named Quilty Nunataks, a group of nunataks extending over eight miles in West Antarctica, to recognise his contribution as field party geologist for their program.

CORPORATE COMMUNICATIONS
Australian Antarctic Division

A passionate gentleman scientist

Pat Quilty was a close colleague and friend of many years, who mentored a generation of Antarctic scientists. He enriched the lives of all who had been fortunate to know this hard-working, intellectual, gentleman scientist.

I observed another side of Pat Quilty – a public persona reflecting a gregarious, easily engaged and popular person, while privately placing family, including Irish ancestry, and faith above all; and very conscious of opinions.

In discussing a high profile voyage to Antarctica in summer 1985–86, on which there were many distinguished passengers, including international and national researchers, Pat revealed how chuffed he was that only the Voyage Leader received more mentions than he did, in the index of a book describing the voyage. It was acknowledged that this assessment was unscientific.

The book was *Sitting on Penguins*, written by academic, historian and author, the late Stephen Murray-Smith, who was sent on the voyage by the Minister, Barry Jones, as an unpaid 'Ministerial Observer', with the charge to "give me your views on what you think is going on".

Murray-Smith met Pat for the first time just prior to sailing. A week later, after an emotional day inspecting Mawson's Hut and the site of the Australasian Antarctic Expedition at Commonwealth Bay, Murray-Smith recalls returning to the ship...

"And so to that shower, and Pat Quilty into the cabin for a whisky, and we talk for an hour or more with affection and warmth of comrades who feel they have done something dramatic together – about the day, and the place, and Patrick's ancestors, and much more."

Later Murray-Smith and other journalists visited Pat at Marine Plain, where he was doing more work on the fossils he had discovered. Six pages of the book are devoted to Marine Plain and the dolphin and whale fossils, with Murray-Smith stating: "All the way to Davis in the ship Pat, when he had time left from talking about icebergs, had been spouting about his dolphin". Such was the effect Pat's passion had on those that met him.

DES LUGG

Former Head of Polar Medicine,
Australian Antarctic Division

Vale Pat

When Pat Quilty joined the Australian Antarctic Division in 1980 the glaciology section, where I worked, was still based at the University of Melbourne, so my initial personal contacts with him were limited.

Even so, it quickly became obvious that Pat had a genuine enthusiasm for, and strongly supported, all disciplines of scientific research. He always maintained his own active research interests throughout his time as an administrator, with a microscope always prominent in his office.

After spending time with Pat on *Nella Dan*, and especially after glaciology moved to Hobart, I got to know the other facets of his personality. He also had a keen interest in the history of science, and especially Antarctic exploration and science, and he was an excellent raconteur, always delighted to share his interest and knowledge. Pat also had *joie de vivre*, a sense of humour and enjoyment and appreciation of the finer side of life, which combined to give him a positive outlook, whatever happened. He never took a bad turn of events personally or was bitter about anything. Every experience was just an opportunity to move on to something new and larger (and develop a story around it).

Pat had an overwhelmingly positive conviction of his own self-worth and status in life. But this was always expressed with honesty and good humour. During the "career-summary" seminar he gave on retirement from the Antarctic Division, a small group in the audience ran a competition ($2 per entry) to guess how many "famous" people he would mention (with double points for vice royalty and significant religious figures). The final number was only 26 because, in the last half of his hour-long seminar, Pat spoke more about the philosophy and ethics of science than his personal involvement. Instead of "winner-take-all" we decided to turn the prize into liquid refreshments for an after-work BBQ. Pat caught us laughing about the arrangements, asked what it was about, and when told was delighted and asked if he could also come. He duly arrived bearing two bottles of bubbly to celebrate.

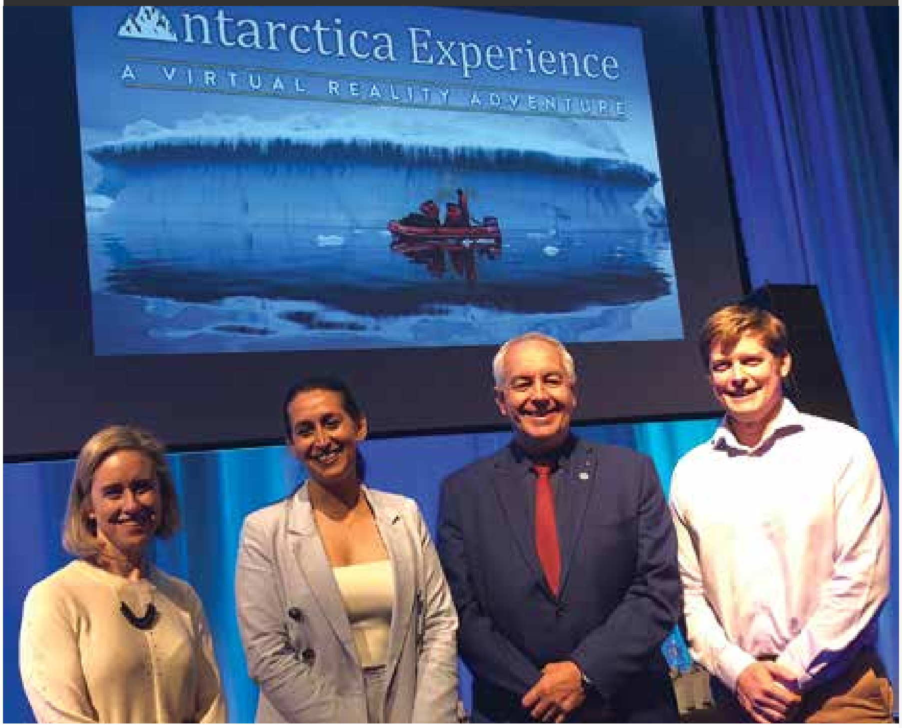
Retirement from the Antarctic Division was not a retirement from science, and Pat continued as an active researcher, an enthusiastic advocate for science and a disseminator of Antarctic information. Over the last 25 years I spent a lot of time with him on the small flight deck of a B747, jointly providing commentary for tourist overflights of Antarctica. We were both inspired to continue doing these flights by the delight and exuberance of those seeing the continent for the first time. Since we covered somewhat different aspects of what you can see from 20,000 feet above the ice, we worked well as a team. Invariably though, Pat's commentary was lengthier than mine.

IAN ALLISON

Former Program Leader,
Australian Antarctic Division

*3. Professor Pat Quilty and research assistant Natalie Schroder at the site of the fossil dolphin discovery (*Australodelphis mirus*) at Marine Plain in the Vestfold Hills. (Photo: AAD)*

Briege Whitehead (second from left) at the premiere of her virtual reality film *The Antarctica Experience*, with Minister Simone McGurk (left), WA Museum CEO Alec Coles and Australian Antarctic Division Operations Manager and former Davis Station Leader Robb Clifton (right). (Photo: Nisha Harris)



The Antarctica Experience

A lucky audience received an immersive virtual reality (VR) experience of Antarctica at the premiere of *The Antarctica Experience* at the Western Australian (WA) Maritime Museum in August.

The 360-degree 3D film allowed viewers to learn more about life at Davis research station, penguin research, and climate science on the Sørsdal Glacier, alongside Australian Antarctic Division personnel.

The film was shot at the station in February by Perth film maker Briege Whitehead, London-based VR and digital producer Phil Harper, and Perth drone operator Dean Chisholm (*Australian Antarctic Magazine* 34: 6-7, 2018).

During post-production Ms Whitehead worked with sound designer David Raines at Warner Bros and in consultation with Dolby Atmos, in Los Angeles, to create an immersive sound experience for the film. She also collaborated with multiple award-winning special effects firm DNEG (who have worked on the Harry Potter and Marvel films, amongst many others) to do the visual effects. Her final coup was snagging Australian actor David Wenham to provide narration.

The film featured at the WA Maritime Museum until October and is now touring Australia and internationally.

WENDY PYPER

Correction: In our last issue we ran a story about *The Antarctica Experience* on page 6. We neglected to mention that the film received funding support from the Western Australian Museum, Screenwest, Lotterywest and Screen Australia. Atlantic Productions were not involved with the film.

Airdrop ensures Australia's Antarctic runway opened on schedule

An airdrop of mechanical equipment to Casey research station in September, ensured Australia's Antarctic runway opened in time for summer operations.

A Royal Australian Air Force (RAAF) C-17A Globemaster III dropped 600 kg of parts to the station, for two Wilkins Aerodrome snow blowers.

Australian Antarctic Division Operations Manager, Robb Clifton, said the snow blowers were essential for preparing the glacial runway surface.

The RAAF C-17A drops spare parts for snow blowers near Casey research station. (Photo: Dominic Hall)

"The blowers are used to remove the snow that builds up over winter," Mr Clifton said.

"Unfortunately, both blowers had separate mechanical issues and we had to source replacement parts from Germany and Norway.

"The airdrop ensured our intercontinental flights could start as scheduled at the end of October."

It took the C-17A about 10 hours to make the 7000 kilometre return trip from Hobart to Casey station. The snow blowers were repaired on station and driven the 70 kilometre inland to Wilkins Aerodrome.

The RAAF has been supporting the Australian Antarctic Program through Operation Southern Discovery since 2016.

NISHA HARRIS

The performance space for *Polar Force*. (Photo: Clare Britton)

Aurora Australis contract extended

The contract of the icebreaker *Aurora Australis* has been extended, taking the ship's Antarctic service through to 2020, when Australia's new icebreaker, RSV *Nuyina*, is due to arrive in Hobart.

The existing contract between the Australian Antarctic Division and the *Aurora Australis*'s owner and operator, P&O Maritime, was due to end in March 2019.

Polar Force tour

Sound artist and former Australian Antarctic Arts Fellow (2009, 2015) Dr Philip Samartzis will present work arising from his fellowship in a national tour early next year.

The immersive and multi-sensory performance of *Polar Force* is set inside a white, inflatable, temperature controlled performance space.

Custom-built instruments made for the live manipulation of pressurised air, ice and water, will combine with high-fidelity multi-channel field recordings of Antarctica.

"Polar Force explores our relationship to the natural world by addressing notions of human fragility and isolation from the perspective of the coldest, windiest and driest continent on earth," Dr Samartzis said.

The sound installation has been developed in collaboration with Speak Percussion.

The next performance is at the Perth Institute of Contemporary Art from January 20-24, 2019.
Further information at http://speakpercussion.com/projects/featured/#5320

WENDY PYPER

Antarctic drama for the small screen

Dr Jesse Blackadder (pictured) will join Jane Allen to develop a television drama set in Antarctica. (Photo: David Hosken)

The first television drama series set at an Australian Antarctic research station will be developed this summer as part of the Australian Antarctic Arts Fellowship.

Leading TV screenwriter Jane Allen (*Cleverman, Janet King, Wentworth, Love Child)* and award-winning novelist Dr Jesse Blackadder (*Sixty Seconds, Chasing the Light*) have been jointly awarded the 2018 Fellowship.

During their three month trip to Mawson research station they will research, devise and write a TV series, *The A-Factor*, which will delve into the daily life of expeditioners at an Antarctic research station.

"This is a rare opportunity to be immersed in an Antarctic community, working alongside other expeditioners and hearing stories first-hand, which will bring an intimate authenticity to the project," Ms Allen said.

"*The A-Factor* will explore the challenge, thrill, beauty and character of the icy continent and those that live and work there."

In addition to the TV program the pair will also write an Antarctic adventure book series for young readers.

"In our series of adventure novels, six kids are chosen from an international competition to stay at the first children's station in Antarctica, where they are unexpectedly forced to survive on their own," Dr Blackadder said.

Dr Blackadder has written nine novels for adults and children. She is founder of StoryBoard creative writing and is an emerging screenwriter.

Ms Allen is one of Australia's most experienced television writers, producers and creators. She has written for over twenty different TV series, including Australian classics *Blue Heelers, McLeod's Daughters, Secret Life of Us,* and *Neighbours*.

Arts Fellows receive financial support through a partnership with the Australian Network for Art and Technology. Create NSW will also provide development funding for the TV series.

SACHIE YASUDA

Phillip Law Medal

Dr Patricia Selkirk AAM was awarded the Phillip Law Medal at a dinner marking the 70th anniversary of Macquarie Island research station in August.

Dr Selkirk undertook 11 expeditions to Macquarie Island between 1979 and 2004 to study plant taxonomy, adaptations and genetics, landscape ecology, and vegetation mapping. She also undertook five expeditions to the Antarctic continent, one to Heard Island and one to Îles Kerguelen as a member of Australian, New Zealand and French Antarctic expeditions.

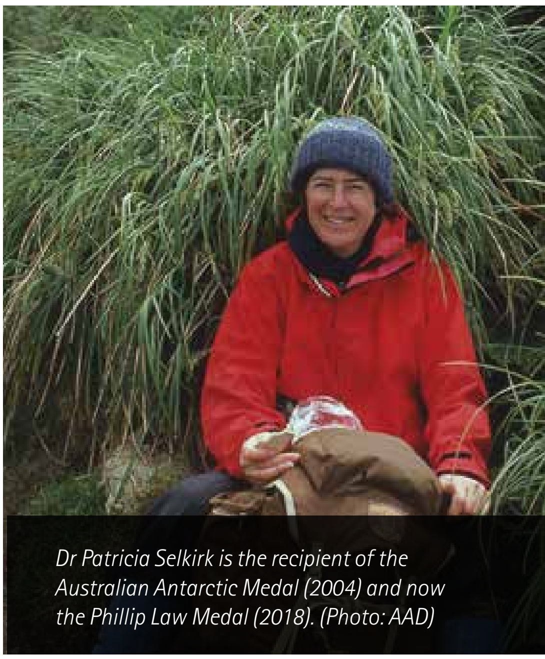
In 2004 she was awarded the Australian Antarctic Medal for her contribution to the Australian Antarctic Program.

Throughout her career Dr Selkirk led and participated in many multi-disciplinary research projects and was instrumental in developing an Antarctic research unit at Macquarie University. She continues her research work today as an Honorary Fellow at the university.

Dr Selkirk has over 80 refereed Antarctic and sub-Antarctic publications, which include the major reference work *Subantarctic Macquarie Island: Environment and Biology* (Cambridge University Press 1990) – a definitive reference on the physical and biological features of Macquarie Island.

The Phillip Law Medal was established by the Australian National Antarctic Research Expedition Club in 2011, to celebrate the life and achievements of Dr Law. Dr Law was the founding Director of the Australian Antarctic Division, a position in which he served from 1949 until 1966.

ELIZA GREY



Dr Patricia Selkirk is the recipient of the Australian Antarctic Medal (2004) and now the Phillip Law Medal (2018). (Photo: AAD)

Nuclear monitoring facility certified

The Davis Infrasound Facility (IS03), which monitors nuclear explosions in the atmosphere, became operational in September after being officially certified by the Comprehensive Nuclear-Test-Ban Treaty Organisation (CTBTO).

Certification and acceptance of IS03 completes Australia's obligation under the Comprehensive Nuclear-Test-Ban Treaty of establishing and operating 21 facilities in Australia, including the Australian Antarctic Territory.

Data generated by the facility is now available for integration into the International Monitoring System (IMS) — a system of 337 facilities around the world that verify compliance to the Treaty.

During the 2017–18 summer season a Geoscience Australia field team, supported by the Australian Antarctic Division, installed and commissioned a seven sensor array and associated power and fibre optic cabling to the Central Power Distribution Facility, which was constructed and commissioned in 2016–17 (*Australian Antarctic Magazine* 32: 14-15, 2017).

Over the six months since the installation, Geoscience Australia and the Australian Antarctic Division, in coordination with the CTBTO, performed the initial testing and validation of the facility.

The IS03 sensing array consists of seven sensing nodes (one pictured here) that detect infrasound frequencies generated by atmospheric disturbances, including nuclear explosions. Each node consists of a wind noise reduction system connected to a central vault containing the electronics that record the data. (Photo: Sara Pearce)

This summer, Geoscience Australia and the Antarctic Division's Antarctic Infrastructure section will perform minor works to finalise the installation and commence the operational maintenance phase of this program.

ASHLEY PYM

Electrical Technical Specialist, Australian Antarctic Division

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Sealers, shipwrecks and survivors inspire new names on Heard Island

Prominent features along the rugged shore of sub-Antarctic Heard Island have been named after sealers, shipwrecks and survivors.

The Australian Antarctic Division's Place Names Committee officially named 13 places on Heard Island, 5355 kilometres from Hobart, and six in Antarctica, in August.

Thirteen prominent features along the rugged shore of Heard Island have been named after sealers, shipwrecks and survivors. (Photo: Matt Curnock)

Heard Island's rich history is reflected in the new names, which were suggested by a range of individuals with an interest in the island.

"Alfred Point is named after the whaling schooner, *Alfred*, which was wrecked on Heard Island in 1854," Committee Chair, Ms Gillian Slocum, said.

"Watson Rock and Kelly Rock are named for survivors of the shipwrecked whaling bark, *Trinity*, which ran aground in 1880."

In Antarctica, the Committee named an island near Mawson research station Maggs Island, after the late Tom Maggs, who contributed to the Australian Antarctic Program for more than four decades as a station leader, voyage leader and leading Australia's involvement in the Antarctic Treaty system (*Australian Antarctic Magazine* 34: 25–27, 2018).

Other Antarctic place names include Wild Nunataks in Queen Mary Land, named in recognition of John Robert Francis 'Frank' Wild, a member of five Antarctic expeditions including the Australasian Antarctic Expedition (1911–14).

Mukluk Island near the Vestfold Hills is named after a soft book traditionally made by Inuit people from sealskin, and was a style of footwear worn by Australian expeditioners in the early days of the Australian Antarctic Program.

ELIZA GREY

Director retires

Australian Antarctic Division Director and former Chief Scientist, Dr Nick Gales, retired in November.

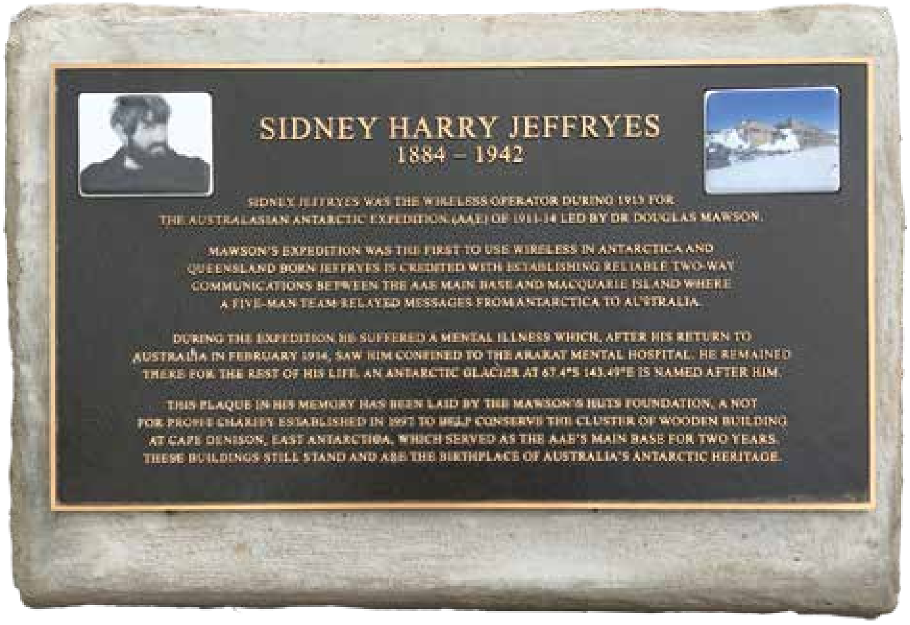
Dr Gales' began his career as a veterinarian in Western Australia working with marine mammals, before moving into applied research working in Antarctica and undertaking a PhD on Australian sea lions. After periods running marine mammal research programs for the Western Australian and New Zealand governments, Dr Gales and his family moved to Hobart in 2001 where he took on a senior research role at the Australian Antarctic Division. Here, among other things, he established the Australian Marine Mammal Centre and led the Australian science effort in the International Whaling Commission; a role that culminated in acting as a witness for Australia in the successful International Court of Justice finding against Japan's Southern Ocean whaling program (*Australian Antarctic Magazine* 26: 6, 2014).

In 2011 Dr Gales became the Division's Chief Scientist. He implemented the first phase of the *Australian Antarctic Science Strategic Plan (2011–2021)* to deliver a high-impact range of research outputs involving strategic partnerships between the University sector and publicly funded research agencies.

In 2015 Dr Gales was appointed Director, responsible for delivering Australia's Antarctic Program. He was instrumental in the development and staged implementation of the *Australian Antarctic Strategy and 20 Year Action Plan* which was announced in April 2016. In June of that year he was appointed as Australia's new Commissioner to the International Whaling Commission.

Dr Gales said it had been a huge privilege to lead Australia's Antarctic Program through a period of rapid change and growth (see *From the Director* on page 1). He plans to spend more time with his family and cruising the world in his home-built yacht.

Australian Antarctic Division Director, Dr Nick Gales, retired in November. (Photo: Adam Roberts)



The bronze plaque marking the site of Sidney Jeffryes grave in Ararat, commissioned by the Mawson's Huts Foundation. (Photo: Elizabeth Leane)

Sidney Jeffryes remembered

Heroic era radio operator, Sidney Jeffryes, and his contribution to Douglas Mawson's Australasian Antarctic Expedition (AAE) of 1911–14, has been recognised with a plaque at his formerly unmarked grave, at a cemetery in Ararat, Victoria.

Jeffryes died in 1942 after 28 years in the Ararat Hospital for the Insane. His illness manifested during the AAE in his role as a wireless operator.

Jeffryes joined the AAE in February 1913, from his position as a shipboard radio operator aboard the SY *Aurora*, replacing the original AAE wireless operator, Walter Hannam.

The AAE team had been due to depart Commonwealth Bay aboard the *Aurora*, but Jeffryes and five of the original AAE men remained behind to wait for Mawson and his two companions, Belgrave Ninnis and Xavier Mertz, who were late returning from a sledging journey. Only Mawson returned, with Ninnis and Mertz having perished in disastrous circumstances (*Australian Antarctic Magazine* 22: 4-7, 2012).

Jeffryes established wireless contact with Australia in March 2013, allowing the men to communicate with their loved ones. This was the first time two-way communication had been established between Antarctica and the rest of the world (Walter Hannam had sent a couple of messages, but never received any).

By June, Jeffryes began exhibiting unusual behaviour and symptoms consistent with what we now classify as schizophrenia. He was later relieved of his duties by Mawson, until the *Aurora* returned in late 2013. Jeffryes was committed to the Hospital for the Insane in March 1914 and later to its high-security facility, J-Ward.

The bronze plaque at his grave site, commissioned by the Mawson's Huts Foundation, states that "Mawson's expedition was the first to use wireless in Antarctica and Queensland born Jeffryes is credited with establishing reliable two-way communications between the AAE Main Base and Macquarie Island where a five-man team relayed messages from Antarctica to Australia".

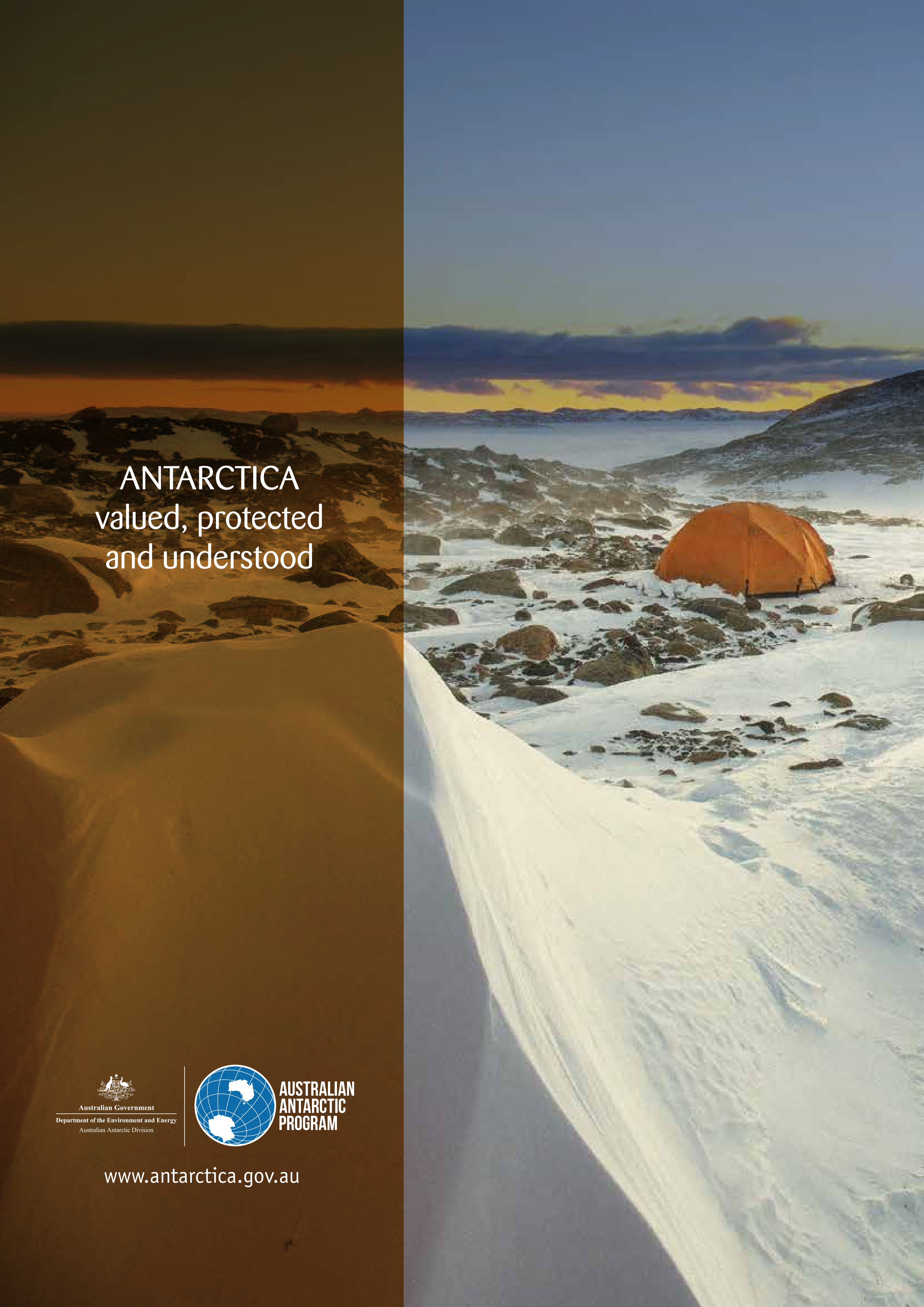
Thanks to Associate Professor Elizabeth Leane for assistance with this article.

PHOTO WENDY PYPER

Freeze Frame

David and Madeleine Rayward from Sky Avenue Photography and Design, took this 360° image of Macquarie Island research station during a visit in 2018 to photograph the station and surrounds for a virtual tour (see page 7). They used a DJI Mavic Pro drone set at 1/2000 sec and f2.2, from 70 metres up. This photo provides a sense of scale and context for the research station. It is made up of 34 images stitched together to form a 360° aerial panorama that sets the scene for the virtual tour.

Father-daughter team David and Maddy Rayward established their Tasmanian-based business in 2013. David is chief photographer and Maddy is the graphic and web designer. Their better known work includes virtual tours of the Marine National Facility RV *Investigator*, the Burj Al Arab Hotel in Dubai, and drone footage of the Hobart waterfront. See more of their work at https://skyavenue.com.au/



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