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PROCEEDINGS OF THE COMNAP SYMPOSIUM 2023: Antarctic Innovations and Collaborations

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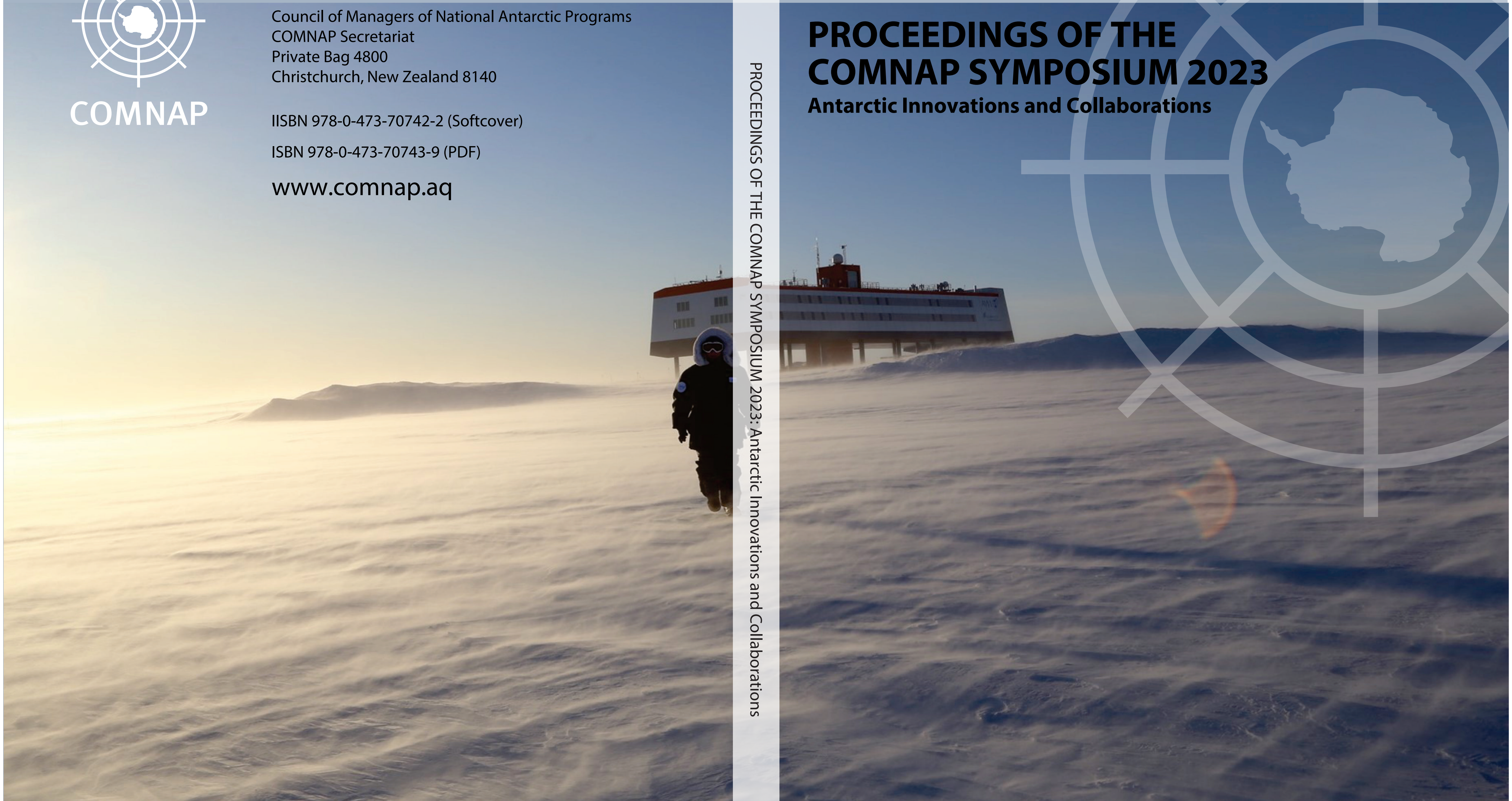
Antarctic Innovations and Collaborations



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ANTARCTIC INNOVATIONS AND COLLABORATIONS

26 JUNE 2023

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THE COUNCIL OF MANAGERS OF
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Foreword

The COMNAP Symposium 2023 was held in Hobart, Tasmania, Australia, on 26 June 2023, with the support of one of our COMNAP Members, the Australian Antarctic Division (AAD).

The very first symposium was held in 1962 and now, 61 years onwards, it is still important to share the knowledge we have gained over these years in which all the national Antarctic programmes have supported, enabled, and made possible small and big scientific projects in a challenging and changing environment while guaranteeing the safety of personnel and protecting the pristine Antarctic environment.

Assisted by working together in COMNAP, our Membership has achieved much in the Antarctic over the past 60 years. That Membership comprises the national Antarctic programmes that are the responsible entities charged with implementing their governments' operations and enabling research in the Antarctic Treaty Area. Such implementation requires individual expertise and qualities – such as tenacity and resolve – and also organisational innovation and collaboration.

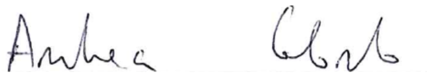
In regard to Antarctic operations there has been much innovation: some simple and often overlooked, including improvements in facility design and advancements in clothing; some more complicated, such as our understanding of addressing environmental impacts, increased focus on safety in operations, development of sophisticated science-support systems and communications, and traverse capabilities and use of remote sensing.

Increased collaboration has allowed programmes to work together on large research projects, including land, marine, atmospheric, sub-glacial, and biological studies, human medicine and psychology, and humanities, social science, and history projects. Much of that research would not have been possible through one programme's actions and support alone. Collaboration has included the opportunity to freely exchange information and ideas and to share best practice amongst the Membership.

Innovations have allowed for turning problems into progress. Successful collaborations are inclusive and embrace the diversity found within our Membership.

This 20th symposium was a celebration of all the successes that all national Antarctic programmes had in the past half century. But, while celebrating is important, we also need to reflect on the challenges we faced and what we learn from these, and to think how we can apply our knowledge to advance research operations in Antarctica to support the understanding of the importance of the Antarctic region to all of humanity.

The Symposium started with two enlightening and provocative talks from the keynote speakers, Dr Tim Heitland, medical officer of the Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research, and Professor Deneb Karentz, from the University of San Francisco and the Vice President for Science for the Scientific Committee on Antarctic Research (SCAR). Their presentations were made publicly available on the COMNAP YouTube channel, 20th Symposium Playlist. We are grateful to the two keynote speakers for sharing their expertise and time – to them, and to all the presenters of oral or poster information for making the Symposium a success.



Andrea Colombo
Symposium Project Manager

Acknowledgements

These proceedings are a record of the 20th COMNAP Symposium, which focused on innovations and collaborative endeavours of all national Antarctic programmes and celebrates the work of those programmes and their people.

The objective of the Symposium was to support COMNAP Member national Antarctic programmes in their role as facilitators of Antarctic research and to provide a forum to aid the conversations between engineers, technologists, health and safety managers, scientists, environmental managers, and the range of people involved in projects, such as the current Antarctic facilities modernisation projects.

The Symposium included presentations covering, exploring, and answering the following questions:

- What were the key innovations of the past 60 years in Antarctica?
- Which collaborations succeeded and what was the recipe for their success?
- How can we use these innovations and collaborations to advance research operations from Antarctica for the next 100 years and how can we apply our knowledge to understand the importance of the Antarctic region to all of humanity?
- How can COMNAP as an organisation and COMNAP Member programmes learn from our past experiences and achievements and how do we improve to meet, and excel beyond, our common goals?

The topical Innovation sessions included six subjects and themes:

a. Antarctic Roadmap Challenges (ARC) Outcomes
b. Building and Energy Efficiencies
c. Communications and Data
d. Marine Platforms and Vessels
e. Safety
f. Telemedicine

The topical Collaboration sessions included six subjects and themes:

g. Air Network
h. COVID-19 Preparedness and Response
i. Education, Outreach, and Training
j. Environmental
k. Science and Science Facilitation
l. Search and Rescue

The number and quality of the applications for oral and poster presentations was very high and we are very grateful to everyone who submitted an abstract for consideration. The success of the Symposium is, no doubt, due to the work of the authors, co-authors, and presenters of the oral presentations and posters.

Thanks go to each and every one who dedicated time and effort into the Symposium presentations and posters and who also provided the abstracts and papers that appear in this Symposium proceedings publication.

Also, a special thank you to the Symposium Review Committee members and co-conveners – COMNAP Vice-Chair Associate Professor Gen Hashida, National Institute of

Polar Research, Japan; COMNAP Vice Chair, Ms Patricia Ortúzar, Dirección Nacional del Antártico, Argentina; Mr Miki Ojeda, Spanish Antarctic Programme; and Dr Christine Wesche, Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research, Germany – for their hard work in selecting 22 incredible talks and more than 30 posters. Special thanks to Symposium Project Manager Dr Andrea Colombo for leading the Symposium to fruition and to copy-editor, Ms Janet Bray, for her work on these Proceedings.

Michelle Rogan-Finnemore
COMNAP Executive Secretary

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Appendices

Keynote presentations

COMNAP's proactive development and response to the SARS-CoV-2 pandemic[1]

Tim Heitland
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The COVID-19 pandemic presented unprecedented challenges to international expeditions, including those in Antarctica. This article delves into the proactive development and response of the Council of Managers of National Antarctic Programs (COMNAP) to the evolving pandemic. By examining the formation of subcommittees, operational strategies, and the broader implications for future preparedness, this article offers a comprehensive analysis of COMNAP's role in safeguarding Antarctic research activities amidst global health crises.

Introduction

The emergence of the COVID-19 pandemic in late 2019 disrupted scientific expeditions worldwide, prompting rapid adaptations to ensure the safety and continuity of research activities. Against the backdrop of these challenges, COMNAP emerged as a pivotal player in co-ordinating Antarctic operations and responding to the pandemic's multifaceted impacts. This article aims to provide an in-depth exploration

[1] The video of this presentation is available at https://youtu.be/X_Ocyipkydo.

of COMNAP's proactive approach, shedding light on the complexities of pandemic response in the unique Antarctic environment.

Creation of Subcommittees

The proactive response to the COVID-19 pandemic necessitated the rapid establishment of specialised subcommittees within COMNAP to address various operational aspects (Figure 1). These subcommittees, comprising experts from diverse fields, were tasked with developing tailored recommendations, co-ordinating logistics, and devising mitigation strategies. By leveraging collective expertise and collaborative decision-making, COMNAP successfully navigated the challenges posed by the pandemic, ensuring the safety and well-being of expedition members while upholding scientific integrity.

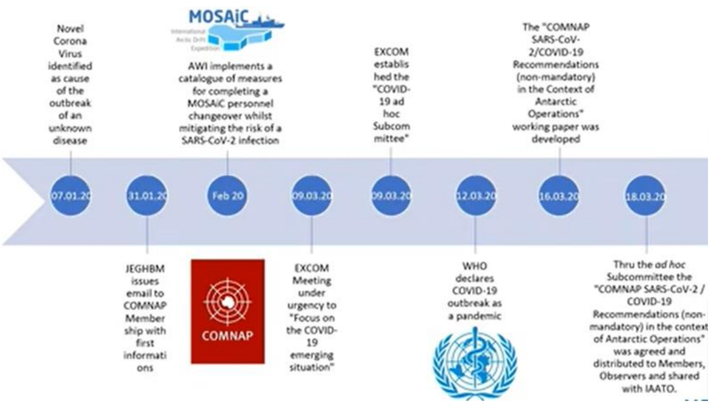

Figure 1: COMNAP proactive development and response to the SARS-CoV-2 pandemic. (Credit: Author)

Operational Strategies

The implementation of operational strategies during the COVID-19 pandemic required careful consideration of logistical, scientific, and health-related factors. COMNAP's approach encompassed a range of measures, including non-mandatory COVID-19 recommendations, protocols for personnel exchanges, and the transition from elimination to mitigation strategies. These strategies, rooted in evidence-based practices and informed by global health guidelines, underscored COMNAP's commitment to maintaining scientific continuity amidst unprecedented circumstances.

Adaptation and Innovation

The COVID-19 pandemic prompted Antarctic programmes to adapt rapidly to evolving health and safety requirements, leading to innovative solutions and novel approaches. From employing remote data collection methods to virtual collaboration platforms, COMNAP embraced technology and creativity to overcome logistical challenges and ensure research continuity. These adaptive strategies not only facilitated scientific endeavours but also fostered resilience and resourcefulness within the Antarctic research community.

Lessons Learned

The COVID-19 pandemic served as an opportunity for learning and growth, offering valuable insights into the resilience and adaptability of Antarctic operations. Key lessons emerged in the areas of communication, preparedness, and community engagement. Transparent communication channels facilitated the dissemination of information, fostering trust and collaboration among stakeholders. Preparedness efforts, including the development of comprehensive guidelines and contingency plans, proved instrumental in navigating uncertain terrain. Furthermore, community engagement and solidarity played a pivotal role in mitigating the impacts of the pandemic and fostering a sense of collective responsibility.

Looking Ahead

As the world transitions towards a post-pandemic reality, COMNAP and Antarctic programmes must remain vigilant and adaptable in the face of future challenges. Continued collaboration, innovation, and preparedness will be essential in safeguarding the integrity and resilience of Antarctic research activities. By embracing the lessons learned from the COVID-19 pandemic, COMNAP and its stakeholders can forge a path forward that prioritises safety, sustainability, and scientific excellence in Antarctica and beyond.

Conclusion

In conclusion, COMNAP's proactive response to the COVID-19 pandemic exemplifies the organisation's commitment to scientific integrity and global collaboration. By navigating uncharted waters with resilience, adaptability, and innovation, COMNAP has reaffirmed its key role in Antarctic research co-ordination. As the world confronts ongoing and future challenges, the lessons learned from the pandemic will continue to inform and inspire efforts to safeguard the Antarctic environment and advance scientific knowledge for generations to come.

The author extends sincere gratitude to all Members of COMNAP, expedition leaders, and personnel involved in

Antarctic operations for their dedication and resilience during the COVID-19 pandemic. Special thanks to the global scientific community for their collaborative spirit and unwavering commitment to advancing knowledge in challenging times. This keynote is dedicated to the spirit of exploration, discovery, and solidarity that defines Antarctic research endeavours.

SCAR: Serving for over 60 years to facilitate international scientific collaboration in the Antarctic and Southern Ocean[2]

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University of San Francisco (United States of America) and the Scientific Committee on Antarctic Research Vice President for Science

Introduction

Antarctica, with its pristine environment and unique ecosystems, offers scientists unparalleled opportunities for exploration and discovery. However, conducting research in this remote and challenging region requires international co-operation and co-ordination. Recognising this need, the Scientific Committee on Antarctic Research (SCAR) was established in 1958 to facilitate collaboration among scientists from different countries and disciplines. Over the decades, SCAR has become a global leader in Antarctic science, spearheading initiatives to address pressing research questions and promote scientific collaboration on a global scale.

Organisational Structure

At the core of SCAR's operations lies a robust organisational structure comprising various committees, working groups,

[2] The video of this presentation is available at https://youtu.be/Cknz81UBoU8.

and subsidiary bodies. The delegates, representing national Antarctic programmes, form the backbone of SCAR's governance framework and elect the organisation's president and vice presidents. Supported by the Secretariat in Cambridge, United Kingdom, SCAR's executive committee oversees the implementation of its mission and strategic objectives. The organisational chart (Figure 1) illustrates the intricate network of science groups, standing committees, expert groups, and action groups, each contributing to SCAR's overarching goal of advancing Antarctic science and research.

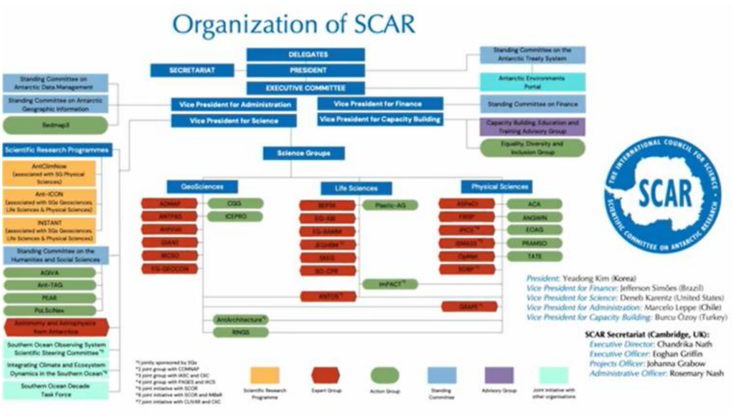

Figure 1: SCAR Organisation chart. (Credit: SCAR)

Mission and Objectives

SCAR's mission revolves around two main pillars: providing scientific leadership and offering expert advice to the Antarctic Treaty System and other international bodies. SCAR fosters collaboration among scientists, facilitates research initiatives, and disseminates scientific knowledge through various platforms. The organisation's strategic objectives, outlined in its recent strategic plan, indicate its commitment to climate research, diversity and inclusion, scientific advice, and international collaboration, underscoring its dedication to advancing Antarctic science and conservation efforts.

Activities and Initiatives

SCAR's activities encompass a wide array of initiatives aimed at promoting scientific research and collaboration in Antarctica. Biennial delegates meetings, science conferences, workshops, and symposiums provide platforms for scientists to exchange ideas, discuss research findings, and forge collaborations. SCAR also actively participates in the Antarctic Treaty Consultative Meetings (ATCMs) and collaborates with international organisations such as the Intergovernmental Panel on Climate Change (IPCC) and the Southern Ocean Observing System (SOOS). Moreover, SCAR co-ordinates scientific research programmes, addresses key challenges identified in the Antarctic Horizon Scan, and supports initiatives such as the Fifth International Polar Year and the UN Decade of Ocean Science for Sustainable Development.

Collaborations and Partnerships

Collaboration lies at the heart of SCAR's endeavours, as it collaborates closely with national Antarctic programmes, international organisations, and scientific communities worldwide. SCAR's joint initiatives with organisations such as COMNAP and its engagement with the Antarctic Treaty System exemplify its commitment to fostering international co-operation and addressing global challenges. By leveraging partnerships and collaborations, SCAR enhances the impact and relevance of Antarctic research, contributing to global scientific endeavours and policy development.

Challenges and Future Directions

While SCAR has made significant strides in advancing Antarctic research and collaboration, it faces several challenges that warrant attention. Securing funding for research initiatives, co-ordinating logistics for international projects, and addressing disparities in research capabilities among national Antarctic programmes are among the key challenges. Moving forward, SCAR aims to address these issues by prioritising research questions, enhancing collaboration with international partners, and advocating for increased support for Antarctic science. By embracing diversity, equity, and inclusion principles, SCAR seeks to create a more inclusive and equitable scientific community and ensure the sustainability of Antarctic research for future generations.

Conclusion

Through its interdisciplinary approach, strategic initiatives, and collaborative partnerships, SCAR continues to drive innovation and excellence in Antarctic science. By fostering international co-operation, addressing key research priorities, and advocating for sustainable research practices, SCAR contributes to global efforts to address pressing environmental challenges and promote scientific discovery in the Antarctic region.

Oral in-person presentations

Transforming Antarctic operations: Management of change and modernisation of operations at the British Antarctic Survey[3]

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Introduction

Over the past decade, the British Antarctic Survey (BAS) has undergone a profound transformation, echoing the global shifts in technological landscapes, aging infrastructure, and evolving operational paradigms. This paper outlines some of the risks and issues BAS has encountered and what has been done to mitigate them along with some of the lessons learned along the way that may smooth the transition during this time of change.

Setting the Stage for Change

The impetus for change at BAS emerged in 2013 when it was confronted with the confluence of challenges posed by aging vessels and intercontinental airbridge aircraft. Concurrently, a range of buildings and infrastructure were coming towards, or were past, their end of life, and many of BAS business systems and processes were becoming outdated or unsupportable. BAS had aspirations for modernised infrastructure, anticipating the surge in technology and

[3] The video of this presentation is available at https://youtu.be/iiiWLD_Ljwo.

digital applications in scientific endeavours. The realisation of a significant gap between current capabilities and future aspirations prompted the formulation of BAS's transformation roadmap for navigating the intricate way to renewal.

It All Started with a Ship

The envisioned future encompassed modernised infrastructure, improved station life, and a paradigm shift toward technology and digital solutions.

The transformation roadmap materialised with the agreement on a new polar ship in 2013. This marked the commencement of planning not only for the ship but also for the associated projects, including wharf infrastructure at King Edward Point and Rothera. A new science and operations building at Rothera to replace multiple aging buildings was also planned. The early stages of projects, as challenging as the subsequent construction, demanded a clear understanding of strategic requirements, a crucial insight that set the tone for the transformative journey.

Overcoming Challenges and Integrating Change

The laying of the ship's keel in 2016 marked a pivotal moment, with a dedicated team of mariners having overseen the project from its inception. This approach fostered a profound sense of ownership and commitment, a strategy that now bears fruit with the operational readiness of the new polar ship. The integration of construction teams into station teams in 2018, with the construction teams residing on-station, was a conscious decision accompanied by significant cultural challenges. This integration necessitated strategic resource investment to facilitate seamless collaboration.

However, the transformative trajectory encountered an unexpected global challenge with the arrival of the COVID-19 pandemic. The crisis altered the organisational focus, posing difficulties in securing the time and attention of key individuals. Despite the adversities, BAS exhibited resilience, ensuring the continuity of change projects and maintaining progress toward key milestones, notably with the operational trials of the RRS *Sir David Attenborough* in 2020 (Figure 1).

Figure 1: RRS *Sir David Attenborough*. (Credit: BAS)

Transition Planning, Business Transformation, and the Human Element in Change

The pandemic-induced disruptions underscored the importance of early transition planning, a lesson learned through hard-won experience. Currently, the focus is on planning the transition to the new Discovery Building at Rothera, offering a dedicated period to align change plans before obtaining occupancy. This transition planning involves a comprehensive evaluation of training, equipment, personnel, infrastructure, documentation, technology, logistics, and aviation capabilities, ensuring a seamless transition to the envisioned future.

BAS's commitment to change extended beyond physical infrastructure to encompass a fundamental restructuring of business processes and systems. The initiation of a business transformation programme in 2018 aimed at modernising finance and HR processes, aligning with contemporary best practices. Simultaneously, a digital transformation programme unfolded, leveraging technology, GIS, AI, and autonomous vehicles to enhance operational efficiency and support scientific initiatives.

The journey began with the appointment of the author of this paper in 2018 to facilitate the transition from a dual-ship to single-ship operation. Over time, the team expanded to nine individuals, combining change management expertise with subject matter knowledge. This evolution underscored BAS's commitment to addressing the intricate human dynamics inherent in the change process.

Categorising Risks and Mitigation Strategies

In navigating the intricate landscape of change, BAS identified three overarching risk themes: people, safety, and delivery. Acknowledging people as one of the greatest factors in the failure of change projects, BAS emphasised the engagement of the right individuals at the right time to prevent perpetuation of outdated cultures in new paradigms. Retaining skilled and experienced staff and ensuring the acquisition of necessary skills were imperative components of this strategy.

Safety considerations were intricately linked to understanding the implications of change. Without a nuanced understanding, risks to personnel safety and operational continuity escalated. The imperative of comprehending the changes introduced by new projects became evident, highlighting the direct correlation between understanding, successful project outcomes, and advancements in scientific endeavours.

Lessons Learned and Future Outlook

Communication emerges as the key aspect, underscoring its pivotal role from the initiation of change through the handover and beyond. Transparency of plans and intentions is paramount, preventing disengagement resulting from the perception of decisions being made behind closed doors.

Early planning surfaces as another crucial lesson, emphasising its role in shaping transitions and managing stakeholder expectations effectively. The tangible benefits of documenting plans and having a Target Operating Model became evident, providing a comprehensive understanding of the change impact and facilitating a smooth transition.

In conclusion, the transformational narrative of BAS offers profound insights into the nuanced dynamics of change within complex operational frameworks. The organisation's success is not a testament merely to overcoming challenges, but also to a strategic orchestration of physical, organisational, and human facets. As BAS continues its journey, navigating in the Antarctic winds of change, the lessons learned not only resonate within the realm of Antarctic operations, but also serve as guideposts for other organisations undertaking transformations amid dynamic global conditions. The imperative of engaging, planning, and ensuring safety echoes beyond the polar regions, resonating as universal in the ever-evolving landscape of change management.

An introduction to the research on Co-operative Mobile Robotic System technology for polar region development and exploration[4]

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This article explores a pioneering research project initiated by the Korea Polar Research Institute (KOPRI), focussed on Co-operative Mobile Robotic Systems for Antarctic exploration. In the challenging and unique environment of Antarctica, traditional data collection methods face geographical and environmental limitations. This research project aims to overcome these obstacles by establishing an annual continuous monitoring environment using wideband communication networks and mobile robots. The comprehensive system involves strategically placed wireless control stations, observatories, and mobile robotic platforms, fostering a collaborative approach among specialised institutes.

Introduction

Antarctica, with its extreme conditions, presents formidable challenges for scientific data collection. Traditional methods relying on satellite communication and manual downloading

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[4] The video of this presentation is available at https://youtu.be/ddI-CGWhWaI.

have limitations due to the continent's geographical and environmental constraints. To address these challenges, KOPRI has embarked on a transformative research project – Co-operative Mobile Robotic Systems. The research project leverages innovative approaches, introducing wideband communication networks and mobile robotic platforms. The project's primary goal is to establish an annual continuous monitoring environment, overcoming the challenges posed by Antarctica's unique conditions.

System Operation Scenario
The project's system operation scenario is designed to ensure efficient data collection in Antarctica. It involves strategically placed wireless control stations, observatories collecting data within a 20-kilometre range, and a robust communication network transmitting data to the stations. Mobile robotic platforms are integrated within a 50-kilometre range from wireless control stations, enabling remote-controlled operations in the challenging Antarctic terrain (Figure 1).

Collaborative Approach
Recognising the multifaceted nature of the research project, a collaborative system has been established among specialised institutes. KOPRI oversees observation and information technology, the Korea Institute of Robotic and Technology Convergence focusses on mobile robotic platforms, and the Korea Institute of Ocean Science and Technology handles wideband high-speed communication. This collaborative approach ensures a comprehensive and systematic development process.


Figure 1: Robotic system data transfer scenario. (Credit: KOPRI)

Research Objectives

The research project encompasses three main research areas: observation and information systems, mobile robotic platforms, and communication networks. Each area has specific objectives, including the development of diverse observatories and observation equipment, and establishing data processing platforms. The collaboration among specialised institutes allows for a focussed and co-ordinated effort to achieve these objectives.

Research Roadmap

A detailed research roadmap outlines the phased approach to the project, spanning design, validation, prototype production, integration testing, field testing, performance validation, and optimisation. The collaborative efforts of the specialised institutes ensure a comprehensive and systematic development process. The roadmap serves as a guide for the project's progression, ensuring key milestones are met in a timely manner.

Observation and Information System Technology
The development of the Extreme Cold Region Smart Observation System consists in the establishment of five types of observatories (i.e. weather, seismic, GNSS, astronomy, ecology) and a wireless control station. Also required is the development of equipment for glacial movement and vibration observation and algorithms for automatic crevasses recognition from radar data. Lastly, the extreme cold region and data information processing system will guarantee the efficient utilisation of collected data.

Achievements from Phase 1
Significant achievements from the first phase include the development of smart observation systems, completion of prototype testing for various observatories, and successful design and testing of wireless control stations. Additionally, advancements in observation equipment, such as for glacial movement and vibration, showcase the project's progress. These achievements form the foundation for the project's continued development in subsequent phases.

Mobile Robotic Platform Development

- Mechanism of Mobile Robotic Platform: (a) Design and manufacture of the prototype; (b) Top speed and long-distance driving tests in challenging terrains.
- Sensors for Autonomous Navigation: (a) Design and production of multimodal sensor prototypes; (b)

Continuous monitoring in low-temperature environments (Figure 2).

- Autonomous Navigation Technology: (a) Experiments for stable crevice-avoidance driving based on crevice maps; (b) Autonomous return to base without manual intervention.

Figure 2: Robot testing in low-temperature environment. (Credit: KOPRI)

Long-Distance Communication Networks

- Wide and High-Speed Communication Technology: (a) Development of communication devices, gateways, antennas, and batteries; (b) Tests for waterproofness, vibration, impact, and drop.
- IoET Communication for Observatories: (a) IoET device design and testing for extreme cold environments; (b) Antenna gain tests and long-distance communication experiments.
- Wireless Speakers Vehicle Network: (a) Development of communication equipment for vehicle networks; (b) Long-distance communication experiments.

Future Steps

The project's second phase involves the integration of developed prototypes, initial interworking tests in Antarctica, and comprehensive system integration testing. The third phase will focus on optimisation, ensuring the finalisation of the developed technologies. The systematic approach outlined in the research roadmap ensures a logical progression toward the project's ultimate goal to potentially redefine the landscape of Antarctic exploration, fostering advancements in scientific understanding and data collection methodologies.

Concordia solar array and solar energy potential on Dome C site[5]

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In the vast, icy expanse of East Antarctica, where temperatures plummet to an unforgiving minus 60 to 70 degrees Celsius, researchers at the Concordia station are embarking on a groundbreaking initiative – the Concordia Solar Array Project. This venture, initiated in 2018, with earlier studies dating back to 2010, aims to harness the solar potential of the region, which is characterised by continuous summer sunlight and prolonged winter darkness.

Geographical Setting

Concordia station, a collaborative Italian–French research facility, stands as a testament to human resilience in the face of extreme conditions. Perched on the high plateau of East Antarctica, it is strategically positioned, lying 1,000 kilometres away from coastal stations such as Mario Zucchelli and Dumont d'Urville. The station's co-ordinates – latitude 75° south and longitude 123° east – add a unique dimension to the solar exposure it receives. The sun's trajectory in this

[5] The video of this presentation is available at https://youtu.be/Ayc31xB56NM.

region results in continuous sunlight during the summer and complete darkness during the winter.

Solar Potential and Design Challenges

The region's solar potential, juxtaposed with the daunting environmental challenges, sets the stage for the Concordia Solar Array Project. The team faced intricate design challenges to create solar panels capable of efficient energy capture in an environment notorious for its frigid temperatures. Calculations revealed an optimal panel orientation of 75 degrees, striking a delicate balance between maximising direct solar radiation and considering the reflective properties of the snow-covered terrain (Figure 1).

Figure 1: Solar panels structure at Concordia. (Credit: IPEV)

One of the primary design challenges was formulating the solar panel support structure. Meticulous planning resulted in a structure accommodating 24 panels on each side, totalling 48 panels facing west and east. Additional panels, 24 each, were strategically placed to capture sunlight from the north and south. This innovative A-shaped design not only allows for flexibility and maintenance space but also ensures cost-effectiveness, a crucial factor in the harsh Antarctic conditions (Figure 2).

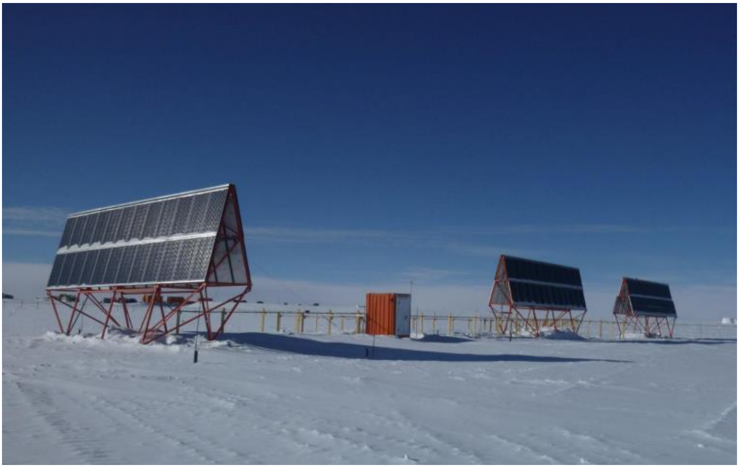

Figure 2: Solar panels array. (Credit: IPEV)

Implementation and Operational Results

The practical implementation of the solar panel supports commenced during the summer season of 2021, with the complete set assembled during the subsequent summer campaign. The one-year operation prediction yielded a commendable 62.5 megawatt-hours, surpassing the initial theoretical estimate of 51 megawatt-hours. A notable aspect of the project was the unexpected contribution of energy from south-facing panels, attributed to the phenomenon of snow albedo.

Detailed analysis of the monthly and daily production charts illuminated the project's resilience against cloud impacts, leveraging the typically clear skies of the Concordia region. While the reduction in diesel power generation was modest, marking an 8.4 per cent reduction in fuel consumption, it served as a promising initiation of the project.

Operational Results: A Promising Start

As the solar panels began their operational journey, the results surpassed expectations. The one-year prediction of 62.5 megawatt-hours showcased the project's efficacy in generating solar energy in Antarctica. The unexpected contribution from south-facing panels, attributed to snow albedo, added an unexpected dimension to the operational dynamics.

Monthly and daily production charts highlighted the project's ability to withstand cloud impacts, capitalising on the favourable weather conditions of the Concordia region. The reduction in diesel power generation, though modest at 8.4 per cent, marked a significant step towards sustainability in power generation for the research station.

The success of the operational phase not only demonstrated the feasibility of solar energy in Antarctica but also laid the foundation for future developments. It served as a testament to human innovation and adaptability, showing that even in one of the harshest environments on Earth, renewable energy sources can thrive.

Future Prospects and Expanding Horizons

The achievements of the Concordia Solar Array Project have paved the way for future endeavours and expansion. While the initial reduction in diesel consumption is promising, the research team is now poised to explore further scenarios. These scenarios range from pragmatic approaches, such as complementing diesel production within a 30 per cent limit, to ambitious aspirations involving complete shutdowns during the summer with modest one-day storage capacities.

Moreover, the researchers are contemplating audacious scenarios, including extending solar coverage into the winter periods. These aspirations demand advanced storage solutions capable of navigating prolonged darkness. While challenges persist, the success of the initial phase propels the team towards envisioning a more sustainable and energy-efficient future for polar research stations.

Conclusion

The Concordia Solar Array Project stands as a testament to human ingenuity and adaptability. From overcoming design challenges posed by the harsh Antarctic environment to achieving promising operational results, the project has set a precedent for sustainable energy solutions in extreme conditions. As the journey continues, the project serves not only as a beacon of hope for polar research stations but also as a symbol of our commitment to a greener and more sustainable future. The collaborative efforts, meticulous planning, and innovative design elements underscore the transformative power of sustainable practices. The Concordia Solar Array Project is not merely a technical achievement; it symbolises our collective pursuit of a more sustainable and resilient planet.

The energetic modernisation of Neumayer Station III[6]

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Embarking on a journey that intertwines historical transformations with contemporary sustainability goals, Neumayer's modernisation project represents a pioneering effort in the quest for energy efficiency in extreme environments. This article provides a detailed exploration of Neumayer's historical evolution, the complex design challenges encountered during its modernisation, and the promising operational results that mark a significant stride toward sustainable practices in Antarctica.

Introduction

Established in 1981, Neumayer has been a scientific hub on the Antarctic ice shelf, witnessing incremental expansions and operational refinements. The recent energetic modernisation initiative signifies a paradigm shift, placing environmental consciousness and operational efficiency at the forefront. This article aims to unravel the historical trajectory of Neumayer, to scrutinise the intricate design

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[6] The video of this presentation is available at https://youtu.be/PkuS7GARU8w.

challenges faced during its modernisation, and to shed light on the tangible operational outcomes of this groundbreaking endeavour.

Historical Overview

Neumayer's journey from its early tube-like structures to the commissioning of Neumayer III in 2009 reflects a commitment to adapting to the evolving needs of Antarctic research (Figure 1). The expansion, doubling air-conditioned room space, marked a significant juncture. To address the environmental impact of increased fuel consumption, a block heat and power plant with heat recovery mechanisms was implemented. Despite heightened overall fuel consumption, specific fuel consumption per cubic metre and per year witnessed a notable reduction, laying the groundwork for future sustainability endeavours.

Figure 1: Neumayer III station. (Credit: AWI)

Design Challenges

The modernisation of Neumayer presented a unique set of challenges, stemming from its geographical and climatic context. Exposed to the Antarctic elements for many years, Neumayer demanded not just upgrades but also a comprehensive modernisation strategy. The overarching goals were to minimise the station's CO_2 footprint and to ensure the safety of wintering teams. The feasibility study involved sophisticated dynamic simulations, utilising annual records of temperature and wind speeds. The decision-making process navigated complexities, resulting in the replacement of heat power units, and the installation of windmills, photovoltaic systems, and batteries (Figure 2). The exclusion of heat pumps and of the conversion of sea water to fresh water highlighted the nuanced decision-making in balancing efficiency with feasibility.

Figure 2. Wind turbine at Neumayer III station. (Credit: AWI)

Operational Results

As the modernisation plan unfolds, the installation of the first vertical-axis wind turbine stands as a testament to overcoming logistical challenges in the Antarctic environment. The need for elevating wind turbines every second year to combat snow accumulation adds a layer of complexity to maintenance. Current fuel consumption, approximately 700 litres per day, indicates the station's dependence on conventional energy sources. The projected reduction of up to 50 per cent with the installation of all five windmills signals a promising shift toward sustainability. Preliminary results showcase a noticeable decrease in Neumayer's carbon footprint, setting a precedent for future Antarctic research stations.

Conclusion

The energetic modernisation of Neumayer exemplifies the delicate interplay between scientific ambition and environmental responsibility in Antarctica. While historical expansions enhanced operational capabilities, the ongoing modernisation initiative aligns Neumayer with contemporary sustainability imperatives. The challenges encountered during the design and implementation phases underscore the need for adaptive strategies in extreme conditions. Neumayer's trajectory toward sustainability not only contributes to the evolving landscape of Antarctic research but also serves as a beacon for future endeavours in mitigating environmental impact in challenging terrains.

Energy efficiency: New Antarctic scientific stations projects[7]

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This paper presents a strategic initiative for the overhaul of key scientific stations in the Antarctic Peninsula. The project, aimed at enhancing the capabilities of existing stations and introducing new, state-of-the-art infrastructure, is a pivotal component of the Chilean national Antarctic scientific programme. The plan spans over 1,500 kilometres, encompassing various regions within the Antarctic Circle. The geographical scope includes stations in the South Shetland Islands, the central Antarctic Peninsula, and the Antarctic Circle at the northern border of Marguerite Bay.

Strategic Overview

The strategic plan encompasses diverse locations, ranging from the northern tip near King George Island to the extensive Union Glacier station. The key stations in this strategy, are the scientific hub Julio Escudero station, Yelcho station, and the marine-focussed Luis Carvajal station (Figure 1). The last-named is set for a comprehensive renewal, preserving historical significance while integrating modern design principles.

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[7] The video of this presentation is available at https://youtu.be/QqmlXebmvx8.

Figure 1: Rendering for a modernised Chilean station. (Credit: INACH)

Architectural and Environmental Considerations

The stations are designed to withstand the extreme climatic conditions of the Antarctic, with a particular focus on energy efficiency and sustainability.

The Carvajal station, for instance, is conceptualised as an all-year-round facility, accommodating 68 individuals during the summer and 22 for wintering-over. Some of the architectural innovations presented are dual envelopes, incorporating blown panels and living modules, and an intermediate space utilising equipment-generated heat.

These projects adhere to international standards concerning energy efficiency, thermal envelopes, and ventilation. The incorporation of Non-Conventional Renewable Energies (NCRE), specifically photovoltaic panels and wind turbines, plays a pivotal role in reducing the carbon footprint of these stations. The goal is to achieve up to 30 per cent of the stations' energy needs through renewable sources. The photovoltaic panels will provide a total of 54,966 kilowatt hours annually. As for the wind turbines, each one is expected to generate 6,000 to 12,000 kilowatt hours per year, depending on wind conditions, among other factors. During the operation phase, the generation will have optimisations of the generating equipment as technological development progresses, in order to increase the contribution of NCRE, and to therefore have an annual saving of oil diesel of 5,161 litres.

Ongoing programmes are analysing the technical and economic pre-feasibility of an energy transformation and transition project that promotes the use of green hydrogen for the Julio Escudero station in conjunction with the German Society for International Co-operation (GIZ). The aim for the future is to have stations that not only achieve a natural carbon footprint but also aspire to be carbon-negative through the integration of emerging hydrogen technologies.

Technological Advancements and Sustainability Measures
The modular design of the stations, tested across various national Antarctic programmes, showcases a commitment to efficiency, with fully assembled units ready for on-site installation. The utilisation of renewable energies, along with ongoing advancements in technology, is expected to optimise energy generation during operation (Figure 2).

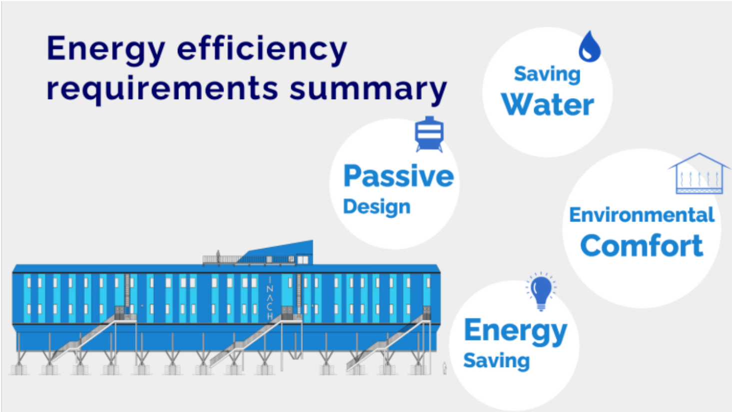

Figure 2: Energy efficiency requirements summary. (Credit: INACH)

The project considers regulating or eliminating the use of luminaires that emit blue light, preferring warmer or green luminaires, as well as prohibiting the installation of permanent luminaires facing the sea and reducing unnecessary lighting as much as possible. The execution of all project activities has been planned to comply with current national regulations.

Operational Challenges and Results

The implementation of this ambitious project has not been without its challenges. Some of these have been finding compatible vertical-axis wind turbines, procurement of new crawler cranes, and the impact of skyrocketing steel prices during the pandemic. Operational challenges also include the periodic elevation of wind turbines due to snow accumulation, adding a layer of complexity to the maintenance regime.

Despite these challenges, the first turbine is operational, and the station has already reduced fuel consumption significantly. The project aims to achieve a 50 per cent reduction in fuel consumption with the installation of all five planned wind turbines.

Conclusion

The comprehensive approach, encompassing architectural design, renewable energy integration, and future-proofing through green hydrogen initiatives, sets a precedent for sustainable infrastructure development in one of the world's most challenging environments.

As we look towards the future, this project not only addresses the immediate needs of scientific exploration but also positions Antarctic stations as pioneers in environmentally conscious and sustainable practices.

Innovation developments in Japanese Antarctic Research Expedition activities by the National Institute of Polar Research for its 50 years commitments[8]

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Introduction

This article provides a comprehensive overview of the remarkable journey over the past five decades of the National Institute of Polar Research (NIPR) in Japan. Founded in 1973, the Institute has played a pivotal role in conducting extensive research and observations in both polar regions, with a particular focus on Antarctica. As the Institute celebrates its 50th anniversary, the authors shed light on the evolution of facilities, technological advancements, and scientific achievements that have characterised Japan's polar exploration.

Historical Context

The foundation of the NIPR in 1973 marked a significant milestone for Japan's exploration of polar resources. With a mandate encompassing comprehensive research and observations, the institute collaborates with around 17 institutions under the Ministry of Education, fostering

[8] The video of this presentation is available at https://youtu.be/VBa41_buPx4.

partnerships with universities across Japan. Boasting an annual budget of approximately four billion Japanese yen, excluding for ice-breaker operations, the Institute comprises a team of about 240 individuals, including 80 professors and scientists, along with 20 PhD students.

Central to Japan's polar research endeavours is the Syowa Station, established in 1957 in East Antarctica (Figure 1).

Figure 1: Syowa Station. (Credit: NIPR)

The geographical location of Syowa Station, an island surrounded by very thick sea ice, requires a very powerful ice-breaker (Figure 2) to approach the station. The ice-breaker, now in its fourth generation, represents a substantial leap in capabilities. Over the years, these vessels have not only increased transportation capacity but have also enhanced the ability to break through thicker ice, making access to the Syowa Station more feasible.

Figure 2: *Shirase II*. (Credit: NIPR)

Scientific Facilities and Achievements

Over the years, the station has been a hub for various projects, including a rocket range, geodetic observations, and atmospheric studies. Notably, the installation of a large antenna system in 1989 marked a substantial advancement, facilitating downlink operations and Very Long Baseline Interferometry (VLBI) observations.

The introduction of the PANSY radar system in 2015, representing the largest radar facility in Antarctica, has significantly contributed to understanding atmospheric phenomena. International collaborations and campaigns have further expanded the station's role in unravelling the complexities of general atmospheric circulation and teleconnections.

The evolution of communication technologies over the last 50 years has been transformative for polar research. An example is the shift from HF radio communication in 1981 to the introduction of internet connectivity in 2004, with subsequent upgrades to 6.4 Mega VPS. The authors also noted Japan's pioneering achievement in live TV broadcasting from Antarctica in 1979, showcasing the station's technological prowess.

In recent years, the NIPR has embraced collaborative efforts with educational institutions. Live interactive lectures were conducted from the Syowa Station to 10 junior high schools in Japan. This innovative educational outreach, facilitated by stable internet connections, exemplifies the institute's commitment to fostering scientific curiosity and knowledge dissemination.

Expansion and Challenges

The continuous expansion of the Syowa Station has posed challenges, particularly in terms of energy consumption and waste management. With an annual electricity consumption of 1.5 to 2 gigawatt-hours, efforts are underway to address the environmental impact of the station's operations. Additional challenges are posed by varying sea ice conditions, emphasising the need for stable transportation to ensure the uninterrupted flow of supplies and researchers to Antarctica.

Conclusion

The journey from the institute's inception to its current standing as a key player in Antarctic exploration reflects Japan's commitment to scientific excellence and technological innovation in extreme environments (Figure 3).

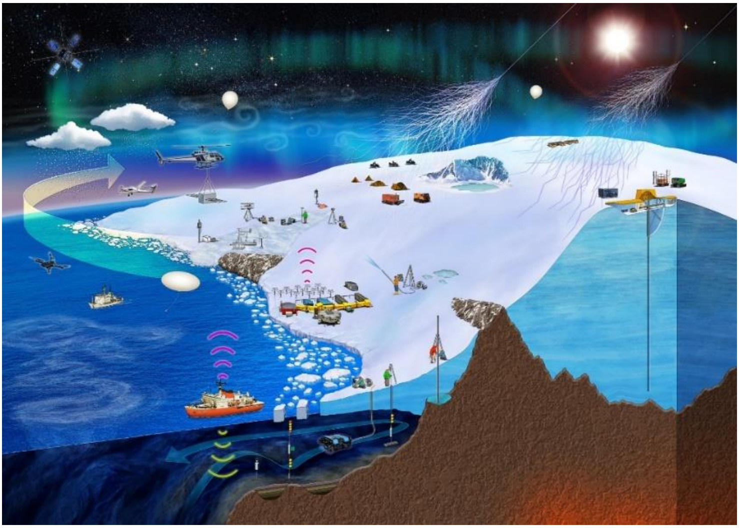
Figure 3: Snapshot of Japan communications and science activities at Syowa Station. (Credit: NIPR)

As the Institute looks toward the future, addressing challenges and embracing sustainable practices will be paramount in ensuring continued success in polar research.

Safety in ship-based polar expeditions: An example of the Turkish Polar Programme[9]

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This article provides an in-depth examination of the Turkish Polar Programme's safety protocols governing ship-based expeditions to both the Arctic and Antarctic regions. Celebrating its 50th anniversary, the programme has a commitment to comprehensive research and observation that is underscored by a stringent selection process for researchers, strategic field operations, meticulous communication strategies, innovative training methods, and a robust documentation system. The intricate synergy of these elements contributes to the success and safety of polar expeditions, positioning the Turkish Polar Programme as a model for other nations engaged in polar research.

Introduction

The Turkish Polar Programme, inaugurated in 1973, stands as a testament to Türkiye's enduring commitment to advancing scientific knowledge in the polar regions.

[9] The video of this presentation is available at https://youtu.be/ncYtt-iK4Xo.

Established with the mandate to conduct comprehensive research and observation, the programme has evolved into a multifaceted initiative, encompassing a diverse range of scientific disciplines. Over the five decades of its existence, the Turkish Polar Programme has become a cornerstone of Türkiye's scientific endeavours, contributing significantly to the global understanding of polar environments.

Selection Process

The success of polar expeditions relies heavily on the expertise and dedication of the researchers involved, and for this reason the Turkish Polar Programme's selection process is designed to ensure that only the most qualified and well-prepared researchers partake in these challenging endeavours.

The annual open call, announced through various channels, invites researchers to submit their projects. These submissions undergo a rigorous peer-review process, ensuring scientific merit and feasibility. Following this, nominated researchers undergo logistical evaluations, assessing their preparedness for the demanding conditions of polar expeditions.

The selection process is not merely about scientific credentials; it also considers the diversity of expertise. The programme seeks a collaborative, multidisciplinary approach, recognising the complex interplay of scientific disciplines required for comprehensive research in the polar regions.

Field Operations

A significant portion of the Turkish Polar Programme's research activities is conducted through ship-based expeditions. The programme's vessels, equipped with advanced ice-breaking capabilities, play a pivotal role in facilitating scientific research.

In addition to ship-based operations, the programme engages in land-based scientific projects, further diversifying its research portfolio. This dual approach enhances the programme's capacity to study a broad spectrum of polar phenomena, from the dynamics of sea ice to terrestrial ecosystems.

Importance of Communication

Effective communication is paramount in the success and safety of polar expeditions.

Communication begins with the researchers themselves, fostering collaboration and co-ordination among team members. Regular interval-based communication protocols ensure that all researchers are accounted for, enhancing safety and situational awareness during fieldwork.

Beyond the interpersonal communication among researchers, the programme places a significant emphasis on collaboration with mainland facilities. Access to real-time information on weather forecasts and ice conditions is critical for decision-making during polar expeditions. The establishment of a communication system covering entire islands, exemplified by the programme's system on Horseshoe Island, reflects the commitment to seamless information flow.

Training Methods

Training emerges as a pivotal component of the Turkish Polar Programme's safety framework. This section details the programme's five-step training approach, encompassing general information, maritime safety, survival in cold environments, fire safety, and psychological well-being.

The general information module provides researchers with foundational knowledge about polar environments, including legislative frameworks and regulations specific to the Arctic and Antarctic. The maritime safety training ensures that researchers are well-versed in safety systems aboard vessels, best practices, and effective communication within the expedition hierarchy.

Survival in cold environments is a core aspect of the training, involving practical scenarios that allow researchers to experience the challenges of polar climates. Fire safety training covers the identification of fire types, proper use of extinguishers, and familiarity with fire-fighting equipment.

In recognising the psychological challenges posed by isolation and extreme conditions, the Turkish Polar Programme collaborates with universities to incorporate psychological evaluations into its training modules. This holistic approach ensures that researchers are not only scientifically adept but also mentally resilient in the face of polar challenges.

Collaborations with government bodies and universities bring specialised expertise to these diverse training modules. Through partnerships with the Coast Guard of Türkiye and mountain federations, the programme ensures that its researchers receive comprehensive and industry-standard training, preparing them for the unique challenges posed by polar environments.

Documentation

A comprehensive training manual serves as a guide for researchers, covering essential safety protocols. This section details the contents of the manual, its role in training, and the ongoing efforts to create a portable handbook for researchers in the field.

The training manual, akin to a curriculum, encapsulates the core safety protocols and procedures that researchers need to internalise. It acts as a reference guide throughout the training process, providing a structured framework for understanding the nuances of safety in polar expeditions.

Efforts are underway to transform this comprehensive manual into a portable handbook, allowing researchers to carry essential safety information with them into the field. This initiative aligns with the programme's commitments to continuous improvement and to ensuring that safety guidelines are readily accessible to researchers during their expeditions.

In addition to providing traditional documentation, the programme is exploring the integration of virtual reality (VR) and augmented reality (AR) technologies into its training methodologies. These technologies aim to simulate polar environments, offering researchers a realistic and immersive experience before they embark on field expeditions. By incorporating cutting-edge technologies, the Turkish Polar Programme seeks to enhance the efficacy of its training programmes and better prepare researchers for the challenges of polar environments.

Future Developments

Looking ahead, the Turkish Polar Programme envisions several advancements to augment safety measures. The programme aims to foster collaborations with the shipping industry and to establish online training modules accessible to a broader audience.

The future development of safety measures within the Turkish Polar Programme is characterised by a commitment to innovation and collaboration. Introducing an ISM coding number aligns with global maritime safety standards, underscoring the programme's dedication to adopting best practices from the shipping industry.

Expanding the documentation library reflects the programme's ambition to contribute to a broader knowledge base on safety in polar expeditions. By curating a comprehensive repository of safety-related documentation, the programme aims to share its wealth of experience with the broader scientific community, fostering a culture of safety and best practices.

Collaborations with the shipping industry represent a strategic initiative to leverage industry expertise and ensure that the Turkish Polar Programme remains at the forefront of safety standards. By engaging with professionals in maritime safety, the programme seeks to continuously improve its safety protocols and align with global benchmarks.

The establishment of online training modules represents a pioneering step toward democratising safety knowledge in polar expeditions. Aspiring researchers, irrespective of geographical location, can access these modules, enhancing the programme's commitment to knowledge dissemination and contributing to a global culture of safety in polar research.

Conclusion

In conclusion, this article synthesises the multifaceted approach of the Turkish Polar Programme to safety in ship-based polar expeditions. The programme's commitment to excellence in research, safety, and the cultivation of a new generation of polar scientists is evident throughout its 50-year history. As the programme continues to evolve, it sets the stage for a sustainable and collaborative approach to polar research, offering valuable insights for the broader scientific community engaged in polar exploration.

The Turkish Polar Programme stands as a beacon of success, exemplifying the delicate balance between scientific discovery and safety in one of the world's most challenging environments. By sharing its experiences, innovations, and future aspirations, the programme contributes to the collective knowledge that underpins safe and effective polar research globally.

Multinational collaboration to overcome airlift challenges in the 2022/23 season[10]

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What do you do when you have a plan for operations in Antarctica – and then everything changes while you are attempting to execute that plan? You turn to your friends in other national Antarctic programmes.

Prior to the start of the 2022/23 season, the stage was set with "normal operating conditions" at the United States Antarctic Program (USAP) Phoenix and Williams airfields, the Italian National Agency for New Technologies, Energy, and Sustainable Economic Development (ENEA) Terra Nova Bay (TNB) Ice Runway, and the Australian Antarctic Division (AAD) Wilkins Aerodrome. However, as "go time" approached, conditions began to prove anything but normal. The TNB Ice Runway was actually open water and Wilkins was blanketed with metres of snow – and would require significant clearing prior to receiving any wheeled aircraft. On a positive note,

[10] The video of this presentation is available at https://youtu.be/CzWBXxWZzrc.

Phoenix and Williams airfields were open and ready to receive aircraft – and to serve as staging bases for intracontinental movements to/from Mario Zucchelli (MZS), Casey, Dumont d'Urville (DDU), and Jang Bogo (JBS) stations. To counter that positive note, the US Air Force C-17deployed in Christchurch completed one intercontinental mission to start the season and then was down for maintenance for 19 days. As a large-scale people mover, the Royal New Zealand Air Force (RNZAF) 757 was poised to make several season-opening runs between Christchurch and McMurdo Station (MCM). But weather and maintenance delays changed the mission time frames to mid–late October.

With deployers backed up in Christchurch (and Hobart) for USAP, Antarctica New Zealand, ENEA, French Polar Institute Paul-Émile Victor (IPEV), and Korea Polar Research Institute (KOPRI), the AAD-contracted A-319 came into play and deployed more than 170 personnel representing all five of these national Antarctic programmes. With the A-319 and 757 serving as the main people movers in mid–late October, the Italian Air Force C-130 quickly became the only cargo aircraft for most of October – helping to keep science cargo flowing to scientists that were already on-continent. This story continues with additions such as pre-positioning AAD personnel at Wilkins for snow remediation, medical evacuation support for KOPRI, transport of a head of state, IPEV shuttles to/from Mario Zucchelli, a new gravel runway at Boulder Clay, and more – all while simultaneously dealing with COVID-19 sneaking into MCM.

Airlift in 2022/23 Season

Phase 1

Though the plan had been to start off the season with C-17 and 757 missions to transport personnel to Antarctica, the season actually began with A-319 and the Italian Air Force C-130 (Figure 1) missions to keep six national Antarctic programmes as close to planned schedules as possible.

Figure 1: Italian Air Force C-130. (Credit: ENEA/PNRA)

The ENEA Basler arrived at MCM and transported the station-opening team to MZS. Shortly after that, participants from KOPRI began arriving at MCM and moved directly from intercontinental aircraft to the ENEA Basler for onward movement to MZS and ultimately JBS. IPEV participants had an even longer commute, arriving at MCM by intercontinental airlift, moving directly to the ENEA Basler before onward movement to MZS and then one last leg from MZS to DDU.

Phase 2

The next piece of the puzzle involved the arrival of the USAP Basler and Twin Otter aircraft. AAD had prepositioned a runway opening crew at MCM for transit to Casey Station by USAP Basler. That link sounds fairly straightforward, but the Basler had weather delays transiting from Punta Arenas and across Antarctica to MCM. After it arrived at MCM, there were further weather delays, which resulted in a delayed departure from MCM to Casey – this led to a common sighting of AAD personnel watching the flight status monitor outside of the galley in hopes that one day a flight might actually go to Casey; and eventually it did (29 October 2022) and they got the runway prepared for wheeled aircraft in several stages of snow removal. The arrival of the USAP Basler also enabled season opening of the USAP South Pole Station.

Phase 3

The Prime Minister (PM) of New Zealand was scheduled for a multi-day visit to Antarctica in late October and both Antarctica New Zealand and USAP were prepared to support the visit. While en route to Antarctica, the RNZAF C-130 encountered weather that necessitated a return to Christchurch. The next day, a C-17 was already scheduled for a mission to MCM, and it would have been ideal to add the PM to that flight. However, permission to move a head of state on a USAF asset required approval from back in Washington DC in a timely manner to meet the scheduled launch time. At 0430, we received approval to have the PM on the flight scheduled to depart Christchurch at 0900 hours. The PM’s visit went great, and, two-and-a-half days later, when it was time to return to Christchurch, the RNZAF C-130 pre-staged at MCM needed a propeller swap. Simultaneously, the C-17 was again down for repairs. The Italian C-130 was again on the forefront and this time we needed approval to move the PM on an Italian Air Force aircraft (and the local time was midnight). ENEA came through with approval to transport the PM within 20 minutes.

Phase 4
Time for a few contingency responses and adjustments. The RNZAF C-130 remained at MCM while the New Zealand team quickly put together a repair team–parts–equipment package. A propeller change on the Ice is no easy task, with crane, shelter, and other requirements. But the RNZAF team made the repairs and away went the C-130 to Christchurch. At any given time, an aircraft could make it to the Ice and be down for repairs – it doesn't matter what aircraft, who owns it, how new/old it is – Antarctica gets a vote when it comes to aircraft operations. Contingency planning for maintenance issues is a must-have for all national Antarctic programmes. A second contingency occurred when a medevac was required to support a partner national Antarctic programme in the Ross Sea Region. Similar to aircraft readiness, medical contingencies can happen at any time with any national Antarctic programme and the response plan is critical and close collaboration amongst national Antarctic programmes is the key to success.

Phase 5
In late October, there were cases of COVID-19 at MCM. The number of cases began to increase substantially – which

resulted in a two-week pause in the deployment of personnel to MCM. During this pause, we had to work closely with ENEA, IPEV, and KOPRI to ensure weather permitted the direct transfer of inbound personnel at the airfield, with no overnight stays at MCM. Also, USAP personnel were starting to stack up in Christchurch while they were awaiting the restart of southbound passenger moves. Meanwhile, lodging at MCM was completely full as we attempted to isolate COVID-19- positive personnel – also impacting how many USAP participants could deploy after the pause.

Phase 6

The USAF LC-130s arrived at MCM and were ready to begin on-continent missions. But, with the pause in deployments from Christchurch, there weren't many personnel to move to Amundsen–Scott South Pole Station and field camps were yet to be opened for the season. Eventually, the flow of deployers resumed to MCM, and then weather impacted LC-130 missions to West Antarctica and the South Pole. As mentioned previously, the need for aircraft maintenance can strike at any time, and at multiple times an LC-130 remained overnight at the WAIS Divide camp and Amundsen–Scott South Pole Station awaiting repairs. Also, an LC-130 had a maintenance issue in Christchurch and was removed from the aircraft line-up. The USAF obtained approval to use a LC-130 that was coming out of depot maintenance in Christchurch in order to add an aircraft back into the line-up and keep intercontinental and intracontinental operations on schedule.

Figure 2: United States LC-130 on ice. (Credit: USAP)

Phase 7

The C-17 and 757 returned for missions in February and experienced no maintenance issues to wrap up the season. In addition, the Italian Air Force conducted the first landing on the boulder runway at MZS. Looking ahead to future seasons, this runway can/will be an asset for ENEA and a divert runway for other aircraft in the region. After the MCM station-close for the winter in February, the 757 executed a mission in March and the C-17 executed a mission in May with night-vision goggles.

Final Thoughts

Supporting science in Antarctica with intercontinental/intracontinental airlift is extremely complicated and multiple factors must be in place to execute missions – namely, a fully mission-capable aircraft, a serviceable runway, and good weather. If any factor is missing, the delays begin, and contingency planning goes into effect for science projects and station operations. At some point, all national Antarctic programmes in a region become reliant upon each other for some level of support. Last season was a perfect example of multinational collaboration to solve airlift challenges in Antarctica. Next season will bring a new set of challenges!

Snow runway for Ilyushin heavy aircraft in the Larsemann Hills (East Antarctica): Renovation, statistics for the first season, and future prospects[11]

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This article delves into the project undertaken by the Russian Antarctic Expedition (RAE), emphasising the reconstruction of the snow runway at Progress Station to accommodate heavy aircraft, specifically the Ilyushin 76. The article explores the challenges faced in traditional air transportation, the development and execution of the project, and the project's subsequent success. The three year-round stations – Progress, Bharati, and Zhongshan – situated within the Larsemann Hills, play a crucial role in supporting scientific endeavours. This article specifically focusses on Russia's Progress Station, which emerged as a key player in the construction of the new Vostok Station building, necessitating advancements in transportation infrastructure.

Challenges in Traditional Air Transportation in the Larsemann Hills

The logistical challenges of Antarctic transportation are manifold, with limitations in maritime communication,

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[11] The video of this presentation is available at https://youtu.be/RKHUXJcqtnI.

especially during the austral summer months from December to March. This, coupled with the time constraints of land traverses, posed significant challenges for timely and efficient transportation. Conventional small aircraft, such as the Basler (Figure 1), faced limitations in terms of passenger capacity, cargo transport, and the ability to operate in early summer, often leading to delays in scientific programmes that require an early start, as early as November.

Figure 1: Basler aircraft delivering cargo and personnel. (Credit: AARI/RAE)

Innovative Solution: Reconstruction of Progress Station's Snow Runway

Recognising the limitations of traditional air transportation, an innovative solution was proposed: the reconstruction of the existing snow runway at Progress Station. The original runway, measuring 1,500 metres in length and 60 metres in width, underwent a transformation to meet the requirements for the successful landing of the Ilyushin 76 aircraft. The project aimed to extend the length to 3,000 metres and to compact the upper snow layer to create a robust, one-metre-thick slab with a hardness of at least 0.8 megapascals.

The project's inception in February 2022 marked the beginning of a multifaceted approach to infrastructure development. Basic engineering studies, including ground-penetrating radar (GPR) surveys, jet X-ray analyses, and the set-up of a glaciological polygon, were conducted. Subsequent snow compaction experiments and active construction phases, involving artificial accumulation and compaction, were meticulously executed (Figure 2). A commission, comprising a glaciologist, a geophysicist, a pilot, and the head of the Aviation Group, arrived at Progress Station in November 2022 to examine the runway's quality. Following a series of tests, the runway was accepted and certified under the name "Zenith”.

Figure 2: Runway feasibility studies and preparation. (Credit: AARI/RAE)

The successful landing of the Ilyushin 76 on 7 November 2022 marked a historic achievement for the project. Over the course of the first season, a total of 337 passengers were transported, accompanied by 18.8 tons of cargo. Flights from Cape Town to Progress and back were efficiently performed, with the last flight of the summer season executed on 1 March 2023. These achievements underscore the transformative impact of the project on Antarctic transportation capabilities.

Future Perspectives

The construction of a new runway capable of receiving heavy wheeled aircraft represents a fundamental advancement in the air network of the region (Figure 3).

Figure 3: Ilyushin 76 landed at Progress Station's snow runway. (Credit: AARI/RAE)

Observations indicate the stability of the runway in the glacier, offering the opportunity for the early arrival of large groups of people and substantial cargo deliveries. The success of this project also sets the stage for future collaboration with several national Antarctic programmes in the Larsemann Hills region. The new-found capabilities of the runway open avenues for early arrivals, critical for wintering stations requiring heavy spare parts or machinery deliveries.

Conclusion

The innovative reconstruction of Progress Station's snow runway stands as a testament to the dedication and expertise of the RAE. This project not only addresses the immediate challenges of enhanced air transportation but also paves the way for sustained scientific exploration and logistical support in the Antarctic region. As the global scientific community looks towards the future, the success of this initiative provides a blueprint for overcoming challenges in extreme environments through ingenuity and collaboration.

This transformative project exemplifies the potential for innovation in Antarctic infrastructure, ensuring that scientific exploration can thrive in the face of logistical challenges. The collaboration, dedication, and ingenuity showcased in the reconstruction of Progress Station's snow runway mark a significant milestone in Antarctic research and set the stage for continued advancements in polar exploration.

Air operations in the polar depths: Public–private co-operation and the use of natural blue-ice runways[12]

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This article explores the historical progression, ongoing collaboration, and technological advancements in Antarctic air operations, focussing on the instrumental role played by the Chilean Air Force and strategic partnerships with private entities. Antarctica's proximity to South America presents an opportunity for efficient and safe air operations. The evolution of Antarctic air operations has been shaped by these collaborative efforts between the Chilean Air Force and private entities, marking significant milestones in the exploration of this remote and challenging region.

Historical Activities

King George Island, hosting the largest concentration of bases from various countries, serves as a critical hub for Antarctic programmes. The airstrip at Frei on King George Island has been pivotal in facilitating air traffic to and from the Drake Passage, thanks to extensive meteorological information covering the region. However, the unforgiving weather conditions, including fog, limited visibility, and

[12] The video of this presentation is available at https://youtu.be/KL7lrlRwzlk.

katabatic winds, have historically posed challenges to safe air communication. In 1984, the Chilean Air Force initiated the Polar Star operation, representing a historic milestone in Antarctic exploration. Overcoming the unpredictable weather and inhospitable conditions, the Chilean Air Force successfully reached the South Pole in November 1984, covering a distance of 4,626 kilometres (Figure 1). This expedition, accomplished after meticulous planning and co-ordination, highlighted the Chilean Air Force's determination to establish air communication with the interior of Antarctica.

Figure 1: Preparation for the flight to South Pole, 1984. (Credit: Author)

Blue-Ice Runways: A Game-Changer

The concept of blue-ice runways emerged in response to the limitations of long-range flights. In 1984, entrepreneurs, including American climbers Frank Wells and Dick Bass, approached the Chilean Air Force seeking support for their expedition to Mount Vinson. This collaboration led to the exploration of blue-ice fields, specifically around the Ellsworth Mountains. The surveys conducted in 1986 paved the way for Adventure Network International Company to land a DC-4 aircraft on blue ice near Wilson Nunatak in 1987. The success of subsequent missions, employing DC-6 and Hercules C-130 aircraft, demonstrated the viability of blue-ice runways for shorter, economically sustainable flights.

Ongoing Collaboration and Technological Advancements
Building on the success of blue-ice runways, the collaboration between the Chilean Air Force and Adventure Network International contributed to the establishment of key research stations. In 1999, the Teniente Rodolfo Marsh station was disestablished and subsequently reassembled as the Union Glacier Joint Scientific Polar Station, a testament to the transformative impact of blue-ice runways on Antarctic logistics.

These bases, serviced by the versatile Hercules C-130s, have become vital hubs for scientific research and international collaboration. The Union Glacier station, in particular, stands as the southernmost in Chile and exemplifies the success of public–private partnerships in advancing Antarctic exploration.

The collaboration between the Chilean Air Force and private entities, such as Antarctica Logistics & Expeditions, remains robust and dynamic. Ongoing efforts focus on modernising facilities and equipment to meet the evolving needs of scientific research in Antarctica. Technological advancements, including improvements in aircraft capabilities and navigation systems, contribute to safer and more-efficient air operations.

In recent years, the integration of cutting-edge technologies has enhanced communication, navigation, and weather forecasting. These advancements are crucial for overcoming the inherent challenges of Antarctic conditions, including extreme cold, unpredictable weather patterns, and vast, remote landscapes.

As technology continues to evolve, the collaborative efforts between public and private entities stand as a beacon of success in Antarctic exploration. The commitment to ongoing collaboration and technological innovation ensures that Antarctic logistics remain at the forefront of scientific research and international co-operation.

Logistical challenges on future upgrades of Syowa Station[13]

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This article provides a thorough examination of the logistical challenges encountered during the continuous upgrades of the Syowa Station in Antarctica. Delving into ongoing innovations and waste treatment strategies, the discussion aims to shed light on the complexities and solutions involved in maintaining a sustainable and efficient research station in the challenging Antarctic environment. Syowa Station's unique location, logistical intricacies, and phased upgrade approach offer valuable insights into the evolving landscape of polar research stations.

Logistical Challenges

Syowa Station's unique location on an island four kilometres away from the Antarctic continent, often surrounded by sea ice, poses inherent logistical challenges for transportation, infrastructure maintenance, and energy generation. Maintaining the station on the island, which encompasses approximately three square kilometres, requires strategic planning to maximise the island’s utilisation while minimising

[13] The video of this presentation is available at https://youtu.be/O-5gl4ppPg4.

environmental impact. The station relies on sea ice for the transportation of fuel from ships to the station, employing a system of moored stakes and pumping mechanisms for efficiency.

Syowa Station Zoning

The central zone of the station houses critical facilities, including the main building, accommodations for winter-overs, and dedicated observation structures (Figure 1).

Figure 1: Syowa Station zoning. (Credit: NIPR)

The age of some structures exceeds 50 to 60 years, prompting a phased upgrade approach. The first completed phase (2013–2023) focussed on reducing the number of buildings and relocating observation functions to a new, more modern structure. The second phase (2022–2029), involving the relocation of generators and the storehouse to optimise energy efficiency, presents significant challenges due to the necessity of proximity to water reserves. A unique and ambitious solution involves utilising a nearby lake, with a planned system for circulating water to heat various buildings. This intricate plan encompasses constructing a new storehouse, moving equipment, and ultimately reducing reliance on the older generator building. The projected completion for this phase is set for 2029, highlighting the long-term commitment to station sustainability. Despite the logistical complexities, the phased approach is designed to minimise environmental impact and reduce the station's overall carbon footprint, and it ensures that the station remains operational while undergoing necessary improvements.

Buried Waste Treatment

Syowa Station grapples with the complex issue of buried waste accumulated over its long history. Approximately 40 metres from the station, waste disposal practices led to the burial of various materials. Excavation efforts, guided by ground-penetration surveys, aim to assess the extent of waste and permafrost depths. The station employs a step-cut excavation method, dividing the area into sections to systematically manage the removal of waste. The concern for potential contaminants is addressed through the creation of channels to redirect melted snow water away from the sea.

Sustainability Initiatives and Environmental Responsibility

The challenges faced by Syowa Station underscore the importance of sustainability initiatives and environmental responsibility in polar research. The station's continuous commitment to reducing its carbon footprint and adopting innovative solutions aligns with global efforts to mitigate the impacts of climate change. The complexities involved in waste treatment further emphasise the need for meticulous planning and execution to ensure minimal environmental impact.

As one of the key research stations in Antarctica, Syowa Station plays a vital role in advancing scientific understanding in this unique and challenging environment. The ongoing upgrades and logistical challenges encountered by the station provide valuable lessons for other research facilities operating in the region. Syowa Station's journey exemplifies the adaptability required to thrive in the ever-evolving landscape of polar research.

Conclusion

In conclusion, the comprehensive analysis of Syowa Station logistical challenges, ongoing innovations, and waste treatment strategies highlights the station's commitment to sustainability and environmental responsibility. The phased approach to upgrades demonstrates a pragmatic and thoughtful strategy to ensure operational continuity while addressing infrastructure needs. The treatment of buried waste reflects a meticulous approach to environmental preservation, showcasing the station's dedication to minimising its impact on the delicate Antarctic ecosystem. As Syowa Station continues its journey of exploration and research, its experiences provide valuable insights for the broader scientific community engaged in polar research and environmental conservation.

Argentina and Australia collaboration on environmental biotechnology[14]

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Introduction

This article considers the collaborative efforts of Argentina and Australia to address environmental challenges posed by fuel spills at Antarctic research stations. Focussed on the principles of environmental stewardship and the application of bioremediation techniques, the collaboration provides a unique insight into the complexities and successes of large-scale environmental clean-up in the polar regions. The article explores the significance of such initiatives, the science behind bioremediation, a comparative analysis of approaches, operational challenges, and the broader implications for future environmental stewardship in Antarctica.

The Significance of Environmental Stewardship

Antarctica, a continent renowned for its pristine and fragile ecosystems, faces environmental threats due to human

[14] The video of this presentation is available at https://youtu.be/9QL2iukgr0E.

activities, particularly those associated with research station operations. This article aims to shed light on the joint efforts of Argentina and Australia in remediating fuel spills, emphasising the significance of international collaboration in addressing environmental concerns in this sensitive region. The commitment to environmental stewardship is evident in the applied science programmes developed by both nations, demonstrating a dedication to preserving Antarctica's unique environment.

Understanding the importance of preserving Antarctica's ice-free areas, which constitute biodiversity hotspots, is paramount. The overlap of permanent infrastructure with ecologically diverse regions heightens the risk of contamination. This article underscores the necessity for effective environmental stewardship, emphasising the role of dedicated science programmes in finding solutions for managing and remediating fuel spills. It recognises the delicate balance between scientific exploration and environmental preservation in Antarctica.

Bioremediation as a Sustainable Solution

Bioremediation emerges as a sustainable and natural solution to fuel spills in Antarctica. The technique involves stimulating native soil microorganisms to break down fuel contaminants, offering an environmentally friendly alternative to traditional clean-up methods. Optimising soil conditions, such as moisture, temperature, and nutrients, allows the microorganisms to actively contribute to reducing fuel concentrations in the soil (Figure 1). Scientific evidence supporting the effectiveness of bioremediation in polar regions highlights its potential for widespread application, not only in Antarctica but also in other sensitive ecosystems.

Figure 1: Bioremediation activities at Carlini and Casey stations. (Credit: DNA/IAA and AAD)

Comparative Analysis of Bioremediation Approaches

A central aspect of the collaboration involves a comparative analysis of bioremediation approaches at the Casey (Australia) and Carlini (Argentina) stations. Recognising that not all fuels are identical, the teams meticulously analysed different components within the soil. This includes considering the toxicity, mobility, and impact on microbial degradation of various fuel components. Understanding the unique composition of fuels used in different Antarctic research stations is crucial for developing site-specific and effective bioremediation plans. Different components of fuel mixed together will determine the toxicity and mobility and the influence the components have on microbes munching the fuel. This will also support the development of a chemical library of fuels used across Antarctica to better inform our collective understanding of environmental risk.

Operational and Logistical Challenges

Working in Antarctica poses unique operational and logistical challenges, influencing the design and implementation of remediation programmes. It extends beyond managing contaminated soil piles, requiring the development of systems within the operational context of research stations. The operational challenges underscore the need for innovative solutions tailored to the specific conditions of each research station, such as containment areas, passive warming of the soil, and containerised water treatment systems to manage leachate. These considerations ensure the success of remediation efforts in the harsh Antarctic environment.

Benefits of International Collaboration

The collaboration between Argentina and Australia yields numerous benefits. The concurrent programmes accelerate learning and progress, providing an opportunity to test and prove the practicality and robustness of different approaches. International collaboration facilitates access to experienced personnel, forming multinational field teams for comprehensive remediation campaigns. The article emphasises the contributions to the *Antarctic Clean-Up*

Manual, a vital resource that guides Antarctic Treaty Parties in addressing environmental risks posed by contaminated sites. The collaborative nature of the effort not only enhances the scientific understanding of bioremediation but also fosters a spirit of shared responsibility for environmental protection in Antarctica.

The collaboration between Argentina and Australia serves also as a model for scientific exchange and knowledge sharing. The comparative analysis of bioremediation approaches contributes valuable insights to the global scientific community. It provides a platform for scientists and researchers to learn from each other's experiences, ultimately advancing the understanding of environmental stewardship in polar regions. The scientific implications of this collaboration extend beyond the immediate remediation efforts, influencing future research endeavours and environmental management strategies.

Future Directions and Implications

Looking ahead, both countries plan to continue their scientific collaboration on fuel spill remediation and environmental risk assessments. The focus extends to developing tools for evaluating risk, decision-making on prioritisation, remediating sites, and monitoring the restoration of these sites. Collaborative efforts with other national Antarctic programmes facing similar clean-up challenges are considered, enhancing the collective benefits and application of environmental stewardship science in Antarctica.

Conclusion

In conclusion, this article highlights the significance of environmental stewardship, the science behind bioremediation, operational challenges, and the broader implications for future environmental clean-up in Antarctica. The commitment to international collaboration and the exchange of scientific knowledge serve as a beacon for effective environmental stewardship in one of the world's most pristine and environmentally sensitive regions. As we navigate the challenges posed by human activities in Antarctica, collaborative efforts underscore the shared responsibility of the global community in safeguarding the integrity of this unique and invaluable ecosystem.

Success through international collaboration in microgrid operation on Ross Island[15]

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Introduction

Antarctica New Zealand and the United States Antarctic Program (USAP) operate a Joint Logistics Programme (JLP) between the two national Antarctic programmes. As part of New Zealand's contribution to the JLP, the provision of renewable power was proposed in 2007, with the original Ross Island Wind Energy project constructed from 2008 to 2010.

In the years following project commissioning, ongoing collaboration between Antarctica New Zealand and the USAP has been required to ensure the day-to-day operation of the microgrid and to work through any issues arising. This paper will offer an update to the operation of the Crater Hill Wind Farm in the years since construction, and to the operation of the wider Ross Island Energy Grid.

The Ross Island Energy Grid in 2023

One of the main reasons the programmes collaborate is the logistics challenge, as there is no year-round access to Ross Island, and seats across aircraft are limited. Antarctica New

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[15] The video of this presentation is available at https://youtu.be/iXA3krkNZhY.

Zealand and the USAP utilise both in-house resource and specialist contractors to operate, maintain, and, where possible, streamline their assets. Having a robust operations and maintenance plan is important for any asset being operated in Antarctica. The Ross Island Energy user group meets monthly in a virtual capacity to discuss the operation of the system over the previous month and any forthcoming plans that will affect the availability of plant (Figure 1).

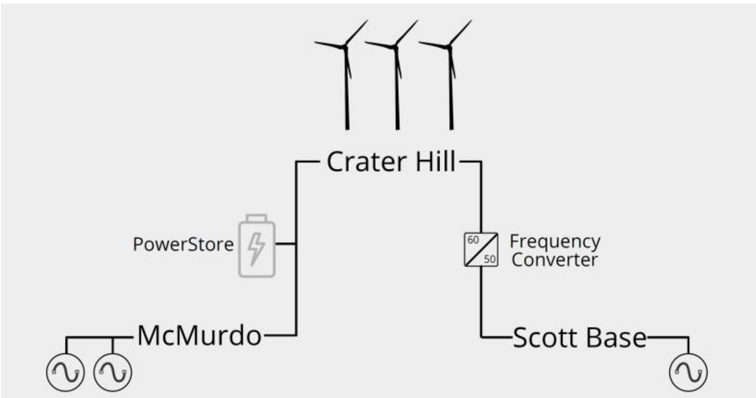

Figure 1: Typical configuration of the Ross Island Energy Grid. (Credit: Author)

The typical configuration of the Ross Island Energy Grid at present has the three turbines at Crater Hill, and one or two generators at McMurdo Station and one generator at Scott Base operational or available for operation.

An important part of this configuration is the PowerStore, which acted as a small-capacity battery to ensure microgrid stability. The PowerStore has not been operational since 2019 due to a failure of a non-replaceable component.

Wind Turbine Operations

The wind turbines presently in operation at the Crater Hill Wind Farm are three Enercon E-33 direct drive units (Figure 2). Over the past 13 years of operation, Antarctica New Zealand has refined its maintenance regimes to suit the conditions. One example is that the periods between re-greasing components are able to be longer than is standard in other parts of the world, due to the climate and the dry environment.

Figure 2: Nacreous clouds above wind turbines. (Catherine Niven 2021)

Because of the inoperability of the PowerStore, since 2019 the wind turbines have been curtailed to 33 per cent of their capacity, so as to maintain microgrid stability due to the variable nature of wind energy generation. If this change had not been made, there would be an increased risk of a ”blackout”, or loss of power across both McMurdo Station and Scott Base. This is because, should wind energy drop out, the required AN8 (JP8) fuel generation to replace it would not be available soon enough. Through a testing period in

2019, it was found a stable microgrid can be ensured if each wind turbine is curtailed to 100 kilowatts.

Fuel Generators and Wider Grid Operations

Across the Ross Island Energy Grid, there are several Caterpillar fuel generators that have been de-rated to use AN8 (JP8) fuel. There are five generators available at McMurdo Station and three at Scott Base.

Where it is possible, the programmes streamline their resources. For generator servicing in the 2020/2021 and 2021/2022 seasons, the same contractor was engaged for specialist generator servicing, which in turn helped to save seats required across the programme. During day-to-day operations, there is in-kind lending of spare parts between stations.

In 2014, fuel generator operation was automated at Scott Base, to enable the Scott Base generators to be called on by the microgrid as “peaking units”. Prior to 2014, oftentimes two McMurdo Station generators were forced to be online for periods, where a single McMurdo Station generator in co-operation with a generator or generators at Scott Base would have been sufficient. The inclusion of Scott Base generators into the automated loading schedule has led to a number of benefits for both stations, such as lower run times on McMurdo Station generators and reduction of fuel required, the reduction of thermal load at Scott Base through the 1:1 recovery of electricity generation to thermal heat, and the simplified manner in which Scott Base generators can be brought online, leading to a reduction in complexity for operators.

Outcomes

The Ross Island Energy Grid and the Crater Hill Wind Farm have been in operation since 2010, with, as described throughout this paper, some periods of inoperability during the past 13 years to overcome issues and work through solutions.

Figure 3 below shows the lifetime wind energy generated per year, against the forecast values shown in red.

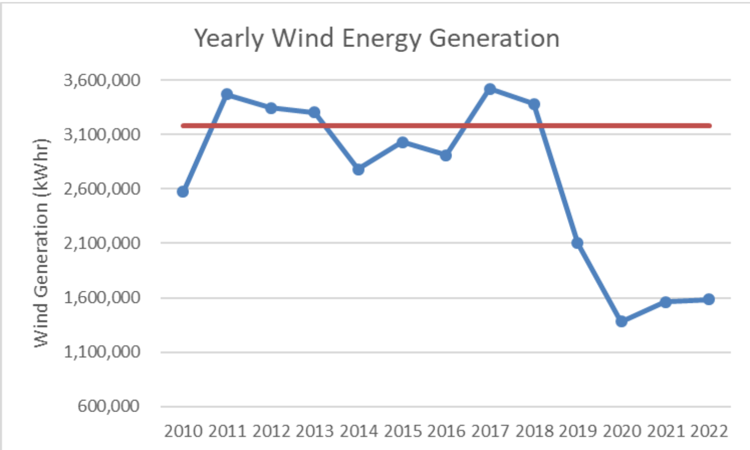

Figure 3: Lifetime Crater Hill Wind Farm generation. The red line shows forecast values. (Credit: Author)

It also clearly shows when the PowerStore became inoperable in 2019. The performance of the wind farm is dictated by a number of variables, including wind availability, turbine availability, and microgrid reliability. The figure illustrates that even with perfect wind turbine availability in some years, there are times the actual output performs below the design forecast. This echoes the results of recent study across a number of Antarctic facilities, which found that a mix of renewables such as wind and solar energy at stations was most effective in efforts to decarbonise.

Figure 4 shows the energy share between McMurdo Station and Scott Base, averaged over the period of operation. This is also reflective of the disparity in power demand between the stations, with McMurdo Station supporting up to 1,200 persons over the summer, compared with a present peak of 89 persons at Scott Base during summer.

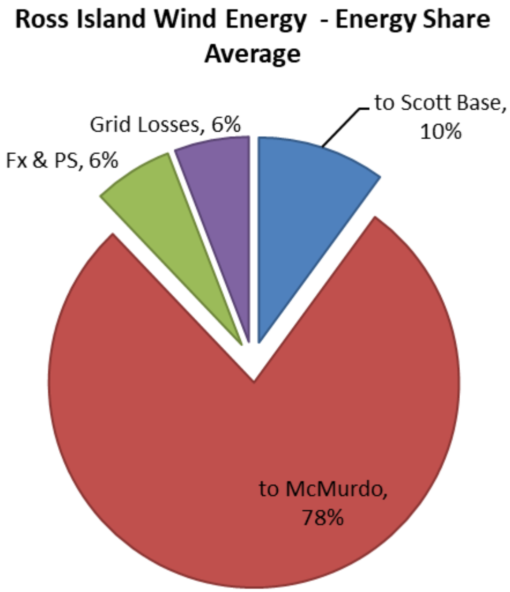

Figure 4: Crater Hill Wind Farm energy distribution. (Credit: Author)

Conclusions

International collaboration has always been the key to success in Antarctica. This remains true in the context of efforts required to operate and maintain microgrid assets in the harsh conditions of Antarctica. The experience of

Antarctica New Zealand and the USAP in operating a shared microgrid over the past 13 years will inform the design of upgraded assets as part of both programmes' infrastructure modernisation projects, presently underway. This paper has shared learnings in operation and maintenance in an effort to assist other national Antarctic programmes on a common journey to reduce carbon from Antarctic operations.

The Swiss Polar Institute Antarctic Circumnavigation Expedition[16]

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Introduction

The Antarctic Circumnavigation Expedition (ACE) stands as a remarkable example of international collaboration in Antarctic research. Initiated in 2016 and completed in 2017, ACE transcended the conventional boundaries of scientific exploration, fostering interdisciplinary endeavours across the Southern Ocean. This article examines the unique aspects of ACE, highlighting its inception, challenges faced, and the valuable lessons learned from this extraordinary journey. The importance of flexibility, effective data management, collaboration with established networks, and post-expedition support, all of which contributed to ACE's success and offer insights for future Antarctic initiatives, is also underlined in this article.

Inception of ACE

ACE's genesis was unconventional in comparison with that of traditional scientific endeavours. The idea sprouted from a collaboration between the École Polytechnique Fédérale de Lausanne (EPFL), a leading science organisation with no prior

[16] The video of this presentation is available at https://youtu.be/y7zbBNQVnAs.

polar focus, and a philanthropist offering a vessel for scientific use. The EPFL, having recently established the Swiss Polar Institute, embarked on an audacious journey to organise an international expedition.

Multidisciplinary Challenges
ACE's hallmark was its multidisciplinary approach, with 55 researchers collaborating on 22 distinct projects during each leg of the journey. This ambitious integration of various scientific domains, while fostering networking and training, presented challenges in terms of time constraints, spatial limitations, and conflicting priorities. The lesson learned here is clear – combining numerous multidisciplinary projects on a single vessel poses significant logistical and managerial difficulties.

New Institution Challenges
Being a nascent institution, the Swiss Polar Institute faced scepticism and procedural hurdles in obtaining permits for the Southern Ocean. While the lack of a national agenda granted flexibility, it also necessitated building trust within established networks. The lesson learned is twofold – the agility of a new organisation can be advantageous, yet collaboration with established entities is crucial for overcoming inherent challenges. The support of the ACE steering committee bringing leading polar institutions together was thus key.

Data Management Significance
Recognising the complexity of managing diverse datasets from multidisciplinary projects, ACE prioritised data management. Despite time constraints, hiring a dedicated

data manager proved instrumental. Post-expedition, this facilitated joint applications for funding, collaborative projects, and integration with existing data repositories. The lesson learned is unequivocal – robust data management and medium-term data curation support are fundamental for maximising the scientific output from multidisciplinary initiatives.

Open Access Policy

A significant aspect of ACE's success was its commitment to an open-access policy. Emphasising transparency and accessibility, most projects adhered to releasing data and publications openly. The enduring impact is evident, with over 75 peer-reviewed publications and more than 108 datasets accessible through international repositories. The lesson is clear – fostering open access enhances the broader impact and visibility of scientific endeavours.

Post-Expedition Support

The duration of post-expedition support for ACE exceeded the preparation lead time, extending up to four years. This support included physical reunions of principal investigators, co-ordinated presentations, and ongoing collaboration. The enduring legacy is the publication of numerous papers and the maintenance of a vibrant early-career community. The lesson learned emphasises the significance of sustained support in ensuring the long-term impact and continuity of scientific collaborations.

Conclusion

ACE, an exceptional model of international collaboration, not only ventured into uncharted scientific territories but also left behind a treasure trove of lessons. Flexibility, effective data management, collaboration with established networks, commitment to open access, and post-expedition support emerged as key pillars of ACE's success. As the scientific community contemplates future Antarctic expeditions, these lessons from ACE serve as a guiding beacon, illuminating the path toward impactful and enduring collaborations.

Team Polar: A sustainable and autonomous research rover for Antarctica[17]

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Team Polar is a student team from Eindhoven University of Technology (TU/e) in the Netherlands that was founded in 2019 as part of the Honours Academy of TU/e. Antarctica, with its challenging terrain and extreme conditions, has long captivated the scientific community as a hub for groundbreaking research. In this context, Team Polar's mission is to revolutionise Antarctic exploration through the development of a cutting-edge research vehicle. At the heart of Team Polar's mission lies a diverse and skilled group of 25 members. As a non-profit entity affiliated with the university, Team Polar relies on a dynamic financial model involving sponsorships, subsidies, and university funding. The international composition of the team, with members representing 11 different nationalities, positions it to approach challenges with a multifaceted perspective.

Objective Overview

Central to Team Polar's endeavours are three key objectives: sustainability, autonomy, and affordability (Figure 1).

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[17] The video of this presentation is available at https://youtu.be/obZKvjMlekA.

Figure 1: Polar Project objectives. (Credit: Team Polar)

Sustainability

The team's commitment to sustainability manifests in the development of an electrified vehicle powered by solar panels, emphasising the environmental consciousness embedded in the project.

Autonomous Operation

The envisioned research vehicle is designed for self-navigation through advanced sensor systems, underscoring its significance in enhancing safety and reducing human effort in the challenging Antarctic environment.

Affordability

The voluntary nature of Team Polar's engagement contributes to the affordability objective. The team's reliance on sponsorships and subsidies aims to alleviate the financial burden, making advanced research capabilities more accessible and sustainable.

Potential Activities

The sustainable and autonomous research vehicle envisioned by Team Polar holds immense potential for diverse applications in Antarctic research (Figure 2).

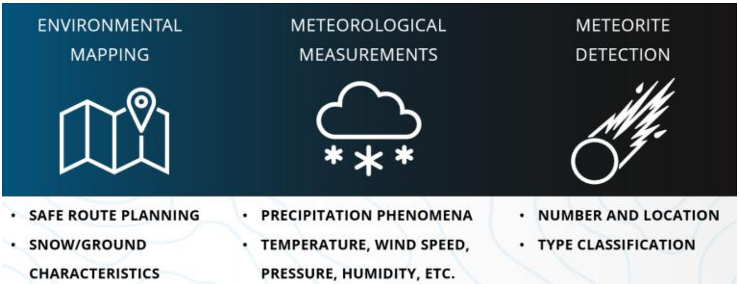

Figure 2: Polar potential activities. (Credit: Team Polar)

Environmental Mapping

The vehicle's environmental mapping capabilities allow it to play a role in planning secure routes for logistics. This application emerges as a critical component, enhancing safety and efficiency in Antarctic travel. Equipped with ground-penetrating radar, the research vehicle conducts precise measurements of snow and ground properties. This can offer valuable insights into geological features and subsurface characteristics.

Meteorological Measurements

Team Polar's research vehicle emerges as a sophisticated tool for gathering meteorological data. The meteorological data recorded by the vehicle contributes to ongoing climate research efforts in Antarctica.

Meteorite Detection

Team Polar’s vehicle can be used for the detection and classification of meteorites, potentially contributing to geological and astronomical research.

Outlook

The review of the current design process is ongoing and the team envisages the designing of a second vehicle by September, with the ultimate goal of deployment in Antarctica by 2028 (Figure 3).

Figure 3: Team Polar vehicle. (Credit: Team Polar)

Team Polar is eager to partner with research institutes and entities interested in co-developing the research vehicle since their system allows for a customised approach to meet specific design requirements. The collaborative spirit is a cornerstone of Team Polar's vision.

Conclusion

The potential of sustainable and autonomous exploration is highlighted, and the Team Polar invites interested parties to join them on this exciting journey towards advancing scientific capabilities in one of the most remote and challenging environments on Earth. The exploration provided in this article serves as a testament to Team Polar's commitment to innovation, collaboration, and addressing the unique challenges posed by Antarctica.

Implementing an Antarctic Regional Climate Centre Network[18]

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Introduction

Antarctica, with its extreme climate and unique environmental challenges, requires specialised climate monitoring and prediction services. The World Meteorological Organization (WMO) has initiated the establishment of an Antarctic Regional Climate Centre (RCC) Network to enhance collaboration and provide valuable climate-related information for Antarctic operators. This article describes the background, objectives, and potential benefits of the Antarctic RCC Network, focussing on the collaboration necessary for successful implementation.

Background and Context

The WMO, a global organisation dedicated to meteorology and hydrology, has a network of RCCs worldwide. These centres play a crucial role in developing long-term climate data sets, monitoring climate conditions, and providing predictions for their respective regions. However, the

[18] The video of this presentation is available at https://youtu.be/I1sGCY76d44.

Antarctic region's unique characteristics warrant a dedicated RCC to address its specific challenges.

The primary objectives of the Antarctic RCC Network encompass a holistic approach to climate services tailored for the Antarctic environment. RCC mandatory functions include data management services, climate monitoring, climate prediction, and training.

Data Management and Climate Monitoring

One of the key focuses of the Antarctic RCC Network is the development of comprehensive long-term climate data sets specific to the region. This involves establishing reference climatologies and undertaking diagnostics to monitor climate conditions effectively. The goal is to create a robust foundation of historical climate data, enabling informed decision-making for various activities.

Climate Prediction

Antarctic RCC Network aims to provide reliable predictions for the region, with a specific emphasis on seasonal forecasts. This process involves a consensus-based approach, interpreting and verifying predictions to ensure their relevance for the diverse range of activities taking place in Antarctica. Predictive insights into changing climate conditions are crucial for operational planning and risk management.

Training and Capacity Building

Capacity building is a central aspect of the Antarctic RCC's objectives. Training programmes will be designed to enhance the understanding and proper utilisation of RCC products and services. By empowering Antarctic operators with the knowledge to interpret and apply climate-related information, the RCC seeks to create a more resilient and informed community.

Scoping of the Antarctic RCC

The journey towards establishing the Antarctic RCC began with a comprehensive scoping process. In 2018, the WMO conducted a survey to gauge the interest and potential contributions of its member countries involved in Antarctic research. This initial survey laid the groundwork for understanding the existing capacities and interests.

Following the survey, a scoping workshop was convened in 2019, delving more deeply into the conceptualisation of the RCC. This workshop addressed crucial aspects, such as the provisional structure, governance model, and priority functions of the Antarctic RCC Network. The outcomes of this workshop were documented in a concept note, which outlined the key components of the proposed RCC.

Lessons from the Arctic RCC

Drawing valuable insights from the Arctic RCC's experience, the Antarctic initiative benefits from lessons learned in harmonisation, consistency, and effective collaboration. The Arctic RCC, being a few years ahead in its development, has successfully created a platform for all products and services. The establishment of a climate forum for regular discussions and feedback has proven instrumental in refining forecasting and data-sharing processes.

Concept Note Development

The concept note developed post-scoping outlined the provisional structure of the Antarctic RCC Network and highlighted the interests and capacities of member countries. This document served as a guide for the subsequent phases of implementation planning. It provided a blueprint for how the RCC would operate, what functions it would prioritise, and how it would engage with stakeholders.

Benefits for Antarctic Operators

The establishment of the Antarctic RCC brings forth a myriad of potential benefits for Antarctic operators, encompassing various aspects crucial for successful research and operations in the region.

One of the primary advantages for Antarctic operators lies in the improved co-ordination and sharing of climate data. The RCC's commitment to developing comprehensive data sets ensures access to accurate and up-to-date information, laying the groundwork for informed decision-making.

Additionally, Antarctic operators will benefit from specialised seasonal forecasts generated by the RCC. These predictions, tailored to the unique climate conditions of the region, provide invaluable insights for planning activities, managing resources, and mitigating potential risks associated with changing weather patterns.

Furthermore, the RCC's emphasis on training and capacity building directly empowers Antarctic operators. By participating in training programmes offered by the RCC, individuals gain a deeper understanding of climate-related information, enabling them to interpret and utilise forecasts and data effectively.

Lastly, the Antarctic RCC Network serves as a collaborative platform, fostering engagement with a global network of stakeholders. Antarctic operators have the opportunity to contribute to the development of RCC services, share their expertise, and participate in discussions that shape the future of climate services in the region.

Conclusion

The initiative to establish an Antarctic Regional Climate Centre Network marks a significant step in addressing the specific climate-related challenges faced by Antarctic operators. With a focus on collaboration, data sharing, and tailored services, the RCC aims to contribute to the sustainable and informed management of activities in the Antarctic region.

As the implementation plan progresses, stakeholder input and engagement will play a pivotal role in shaping the future of the Antarctic RCC. The benefits outlined underscore the potential positive impact on Antarctic research and operations. By fostering collaboration, harnessing data, and providing specialised services, the Antarctic RCC is poised to become a cornerstone in advancing our understanding of the Antarctic climate and supporting the diverse activities that unfold in this unique environment.

Collaborative logistics to deliver operational efficiencies[19]

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In the dynamic realm of polar operations, collaboration has emerged as a key driver of efficiency, cost-effectiveness, and environmental sustainability. This article examines the collaborative efforts between the British Antarctic Survey (BAS) and the Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research (AWI), exploring the rationale behind such partnerships, the factors contributing to their success, and the upcoming joint venture set to reshape polar logistics. The focus remains on the benefits, scoping, and objectives, shedding light on the intricate web of challenges and triumphs in the polar research landscape.

Why Collaborate in Polar Operations?

Collaboration in polar operations is not merely a strategic choice; it is a necessity driven by the unique challenges posed by the Antarctic environment. The vast expanse of the Antarctic region demands a strategic approach, where shared resources and assets enhance operational capabilities while

[19] The video of this presentation is available at https://youtu.be/6zS_RLyMU5k.

reducing costs. The geographic dispersion of research stations, illustrated by the example of the RV *Polarstern* aiding BAS in fuel delivery, highlights the logistical convenience that collaboration can offer (Figure 1).

Figure 1: RV *Polarstern* at Rothera. (Credit: Dave Wattam, BAS)

Moreover, collaboration goes beyond mere convenience; it is a means to amplify capabilities and reduce the carbon footprint. By consolidating efforts, research organisations can achieve more with fewer resources, a crucial consideration in times of budgetary constraints and environmental consciousness, while continuing to deliver science and science support.

Ingredients for a Successful Collaboration

Aligning goals and visions serves as the foundational element, where collaborative efforts are driven by a shared strategic outlook. Common values form the bedrock of collaboration, fostering a conducive environment for co-operation. Trust and respect emerge as pivotal elements, underlining the importance of open communication and honesty in navigating challenges and uncertainties.

A case in point is the crack in the Brunt Ice Shelf, posing a logistical challenge. The ability to openly discuss potential risks builds trust and enables collaborative problem-solving, essential components in the success of polar operations.

The concept of shared goals extends beyond the strategic level to tactical collaboration. The nature of collaboration introduces a spectrum of agreements, from direct exchanges of funds to more-informal barter arrangements. A successful collaboration is not only about achieving predefined objectives but also about creating value that surpasses the sum of individual contributions. This intrinsic value and overarching goal, often intangible, are the hallmark of a collaboration where both parties emerge stronger together and the total impact exceeds the sum of individual efforts.

BAS and AWI Collaboration

The plan involves sharing a charter vessel for the resupply of Neumayer and Halley research stations. The geographical proximity of loading and discharge ports in Germany and the UK underscores the efficiency of sharing a charter, reducing costs and environmental impact (Figures 2 & 3).

Figure 2: Unloading cargo. (Credit: BAS and AWI)

Figure 3: BAS and AWI air assets. (Credit: Christine Wesche, AWI)

Aligning with the previously outlined ingredients of successful collaboration, BAS and AWI share vision and values centred around delivering high-quality science. The collaboration aims to maximise capabilities, reduce costs, and minimise the carbon footprint, epitomising the essence of effective collaboration in polar research.

Conclusion

The BAS and AWI collaboration serves as a testament to the potential synergy that can be harnessed through strategic partnerships. In the ever-evolving landscape of polar research, collaboration emerges not only as a pragmatic choice but also as a catalyst for innovation, efficiency, and sustainable scientific exploration. The journey towards successful collaboration in polar operations is marked by aligned goals, trust, and a shared commitment to advancing scientific frontiers in the challenging yet rewarding polar environments.

Lessons learned from past aerogeophysical collaborations for effectively launching new pan-Antarctic RINGS surveys[20]

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This article presents an overview of the history and challenges of airborne geophysical surveys in Antarctica, emphasising the importance of addressing data gaps, particularly in coastal regions. The article introduces the pan-Antarctic RINGS initiative, which was initiated by the Scientific Committee on Antarctic Research (SCAR) with the aim of co-ordinating and enhancing geophysical surveys in the Antarctic coastal regions.

Introduction

The five-decade history of airborne geophysical surveys in Antarctica began in the 1970s. This period saw significant

[20] The video of this presentation is available at https://youtu.be/6XY-YfPLzwg.

achievements, including the bed map of the Antarctic Ice Sheet compiled digitally for the first time in 2001 and updated in 2013. However, substantial data gaps persisted, especially in two areas, known as “poles of ignorance”, which prompted collaborative projects led by various nations to address these gaps. As of 2023, we have reasonable data of the bed topography of the Antarctic Ice Sheet, but this is not yet comprehensive (Figure 1).

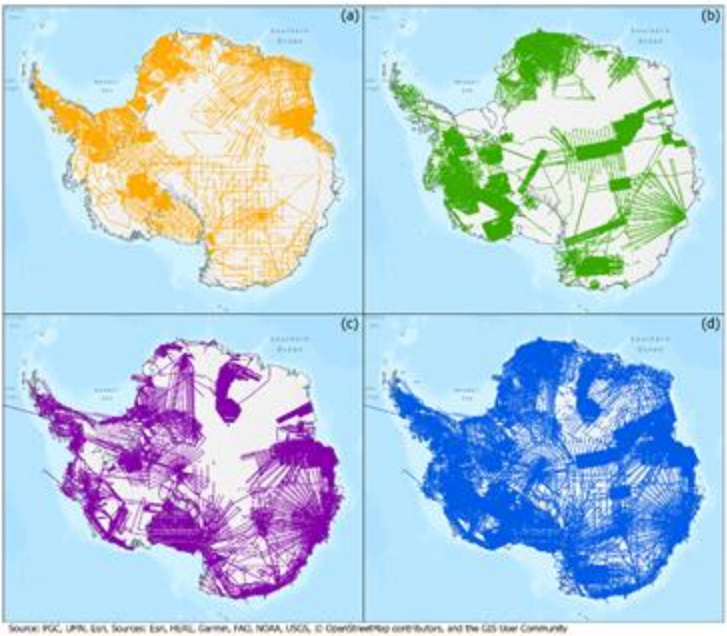

Figure 1: Radar data coverage in Antarctica (a) before 2000, (b) improvements in 2010s, (c) improvements in 2020s, and (d) as of 2023. (Credit: Fremand et al. (2023, ESSD))

Importance of Coastal Regions

Analogising the coastal regions of Antarctica as the "cork" of a wine bottle in the context of sea-level changes, whereby we pay attention to the wine, being Antarctic ice, without paying enough attention to the "cork", i.e. the ice shelves and coastal region of the ice sheet, which is in fact loose. With the bottle being upside down, we need to pay attention to how loose the cork is and how much more loose it will become in the future. Understanding these regions is crucial for comprehending Antarctic Ice Sheet dynamics and their implications for global climate change.

Data Gaps and Challenges

Analysing data availability within 100 kilometres of the grounding line – the location where the ice-sheet ice becomes afloat, i.e. becomes an ice shelf – reveals substantial gaps, notably in Enderby Land. These data gaps are due to a lack of research stations in the area and, consequently, logistical challenges for taking measurements in the area, and are not due to lack of scientific interest. In fact, the amount of ice discharged from Enderby Land is very similar to that from Amundsen Bay, including Pine Glacier and Thwaites Glacier. Only 10 per cent of the Antarctic grounding line has radar data within 1 kilometre, emphasising the challenges in making accurate elevation estimates without adequate data.

The SCAR RINGS Initiative

To address these challenges, SCAR introduced the Antarctic RINGS initiative, aiming to create three pan-Antarctic rings: primary RING, landward RING, and seaward RING. The primary RING should go to the grounding line where ice starts to afloat; the landward ring is 10 kilometres inland, where the grounding line is expected to be in the upcoming centuries; the seaward ring is over the ice shelves and the ocean to measure the seabed topography. Interpolating bed topography between these three rings is highly challenging, prompting us to conduct multiple profiles for each ring (Figure 2).

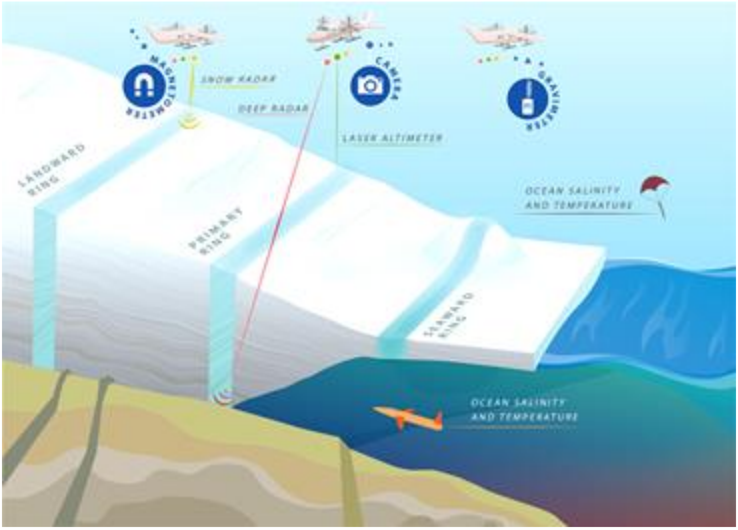

Figure 2: Three rings of observation. (Credit: Hasan Abbas (GRID-Arendal) and RINGS Action Group)

RINGS surveys can serve as multidisciplinary platforms, incorporating instruments such as deep sounding radar, gravimeters, microwave radiators, magnetometers, laser altimeters, and cameras. The RINGS project emphasises the inter-connected systems and complex processes involving the atmosphere, ocean, cryosphere, and geology.

Established in 2021, the SCAR Action Group RINGS has seen doubled membership and aims to co-ordinate surveys in advance to ensure comprehensive data coverage. Recommendations have been discussed in the ATCM meeting in Helsinki, underscoring the importance of RINGS surveys in the context of sea-level rise.

Successful Geophysical Missions and Technologies

The key factor of successful geophysical missions is international collaboration. No national Antarctic programme is capable of conducting the flights all around Antarctica alone, so the idea is to develop multiple regional projects, co-ordinating them from the outset to avoid any data gaps. One way to do this is the use of multiple research stations, which is already working properly but with challenges of different layers of communication and management between stations (Figure 3).

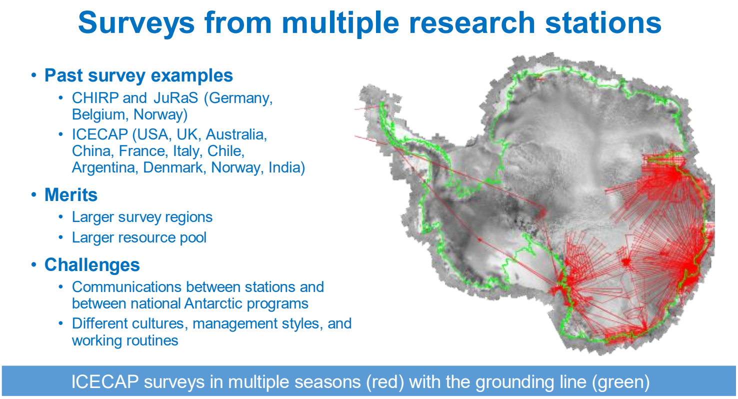

Figure 3: ICECAP survey from multiple research stations. (Credit: Authors)

Other ways are to establish remote field camps in strategic locations to reduce the "air commute", or to deploy aircraft from outside Antarctica. All the options here discussed require the use of fixed wings, but employing helicopters, even from vessels where there are no other facilities in the vicinity, and drones is very useful.

Conclusion

The RINGS goal is to co-ordinate the work and collection of data in advance rather than patching the data together afterwards.

Collaboration with COMNAP's airborne facilities and science education facilitation groups is deemed crucial for the success of the RINGS initiative.

Balloon ice caves in Antarctica[21]

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Introduction

The Italian Antarctic programme, together with other national Antarctic programme partners, such as the French programme IPEV, is planning and formulating long-term investments in logistics and infrastructure to enhance the possibilities of the scientific communities for actual and future needs. The scientific context in which the Antarctic stations managed by the Programma Nazionale di Ricerche in Antartide (PNRA) are involved, with a specific focus on Concordia station, is every year more international.

Currently, the PNRA is fully committed in exploring new ways to build new kinds of infrastructure in high-plateau sites, trying to reduce at the same time the impact of the anthropic foot-print on the continent and the costs for the materials, their transportation and installation on-site, and the potential end-of-life decommissioning.

A promising option to target the challenging points stated above is represented by the ice caves built with the

[21] The video of this presentation is available at https://youtu.be/Kd20wop7jKk.

technique of an inflated balloon buried under blown snow/ice.

Background

The construction of balloon ice caves in the polar regions is a well-known technique, mainly tested in the Arctic areas. The experience in the Arctic shows that, while on the one hand the tunnels built using the balloons are really effective, considering the need for relative cheap infrastructure to support important scientific field activities, such as deep drilling or the storage of ice cores, on the other hand a significant issue is the durability of those structures. The overall physical properties change in response to changes in the external conditions of temperature and humidity. The consequence of this effect is that the shape of the caves changes under the action of the weight of the ice on top of their roofs, with the consequent reduction of a cave's volume and the related safety concerns.

Ice Caves at Concordia Station

Concordia station is the French–Italian station located at Dome C in East Antarctica at about 3,300 metres above sea level, with average values over the year of temperature about -55 degrees Celsius, relative humidity about 50 per cent, and air pressure of about 645 hectopascals.

Because in the winter period the climatic conditions can be very harsh, with temperatures even below -75 degrees Celsius, a common request to the logistic management of the station has been the availability of facilities to protect and store scientific instrumentations and samples, and also vehicles and materials.

An idea was developed to test the construction of underground trenches caves in which balloons were inflated in trenches and then covered in blown snow/ice before being deflated after consolidation of the snow/ice. The plan was for the first cave to be a garage to store vehicles during the winter period to prevent serious damage due to the extreme cold, and then, after the validation of the effectiveness of the technique, to build up infrastructure to store scientific instruments and materials. Then, from a long-term perspective, the idea was to store the archives of ice cores from notable research drilling projects.

The first attempt was made in the course of the summer campaign 2017/2018 with the construction of a test cave with a diameter of 5 metres, a length of 15 metres, and a floor at a level of -8 metres from the ground.

The intention was to test the technique with the tools used to build up the trench and then to validate the building concept by monitoring the evolution of the ice over the years with the intention to estimate the durability of such a structure in the centre of the Antarctic continent. Considering that the external air has a variation of temperature in the year that goes from about -20 degrees Celsius to -75 degrees Celsius, the values measured in the cave indicate that the temperature is fairly constant inside, which is a promising finding in the light of potential variations of the crystallography of the ice over time.

A second cave was built at Concordia in 2019, one year after the first test cave. The section of this cave has the same diameter, 5 metres, while the main difference regards the length of the cave, which is about 35 metres, while the depth of the floor in this case is at 9 metres above the external ground level of the snow. Since its the construction, this cave has been used as a winter garage for the vehicles that cannot remain parked outside in the winter (Figure 1).

Figure 1: Internal views of the garage, with the deflated balloon still on the floor (left) and the vehicles parked in the cave for the winter (right). (Credit: ENEA/PNRA)

With regard to the monitoring protocols, focusing on the shape measurements the main difference between the second cave and the first is due to the former's use as a garage: year by year the entrance of the second cave, which is a large door of dimensions similar to the section of the trench, remains open for many days in the warmest period of the year. Also, for many hours, the cave can have people present. This difference is relevant because of the slight difference of the humidity brought inside the cave that causes the growth of ice crystals on the inside surface of the roof.

A last cave was built at Concordia in January 2023, with the same geometry and dimensions of the cave garage, but this one has been meant to be for the storage of the ice cores for the project Beyond EPICA. This means that, since the cave's construction, the ice cores collected from the drilling camp have been stored temporarily in that cave until the next processing, when sections of the ice cores will go to labs in Europe for the further analysis while the remaining parts will be stored as a permanent archive in the same cave at Concordia.

In the case of this last cave, there is no need to access it with large vehicles, therefore the main entrance is limited to a small door for people, and the phenomenon of the ice crystals on the roof is expected to be very limited compared with the case of the cave garage.

Perspectives on the Future

With the evidence that at Concordia Station the ice balloon caves could have a long-term future, the additional commitments of the PNRA are to improve the construction techniques to speed up and ease the works in the field, hence to reduce the construction and running costs.

Following the indications given in the simulation studies, the geometry of the section that guarantees a longer lifetime of the caves is the large trench in which the section of the initial trench is wider compared with the diameter of the balloon. This concept brings a stronger structure of the roof and of the walls of the cave but implies additional works to remove the snow/ice accumulating below the balloon itself during the blowing phase.

Spanish Antarctic facilities "BAES": A scientific and technical infrastructure open to international collaboration[22]

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This article explores the Spanish Antarctic facilities "Bases Antárticas Españolas" (BAES) as a part of the wider Spanish Unique Scientific and Technical Infrastructure (ICTS) network open to international collaboration. The term "ICTS" (Infraestructuras Científicas y Técnicas Singulares) refers to facilities, resources, or services partially or wholly open to competitive use by the scientific, technological, and industrial communities, both nationally and internationally.

Governed by the Ministry of Science and Innovation in Spain, ICTS BAES play a crucial role in advancing national and international research efforts. In fact, the Spanish Antarctic facilities, part of the ICTS BAES, represent a significant investment by the state and various regional governments. The two stations that, along with the supporting ICTS Fleet, form the ICTS BAES, Juan Carlos I and Gabriel Castilla, serve as essential hubs for scientific and technical exploration in Antarctica while facilitating international collaboration and

[22] The video of this presentation is available at https://youtu.be/apZhpLYBgCE.

highlighting their strategic importance in the global research landscape.

Characteristics of ICTS BAES

ICTS BAES possess three main characteristics: public ownership, competitive open access, and unique strategic importance. As publicly owned entities, these infrastructures involve substantial investments from the state and regional governments. The competitive open-access policy ensures that at least 20 per cent of the total capacity is available for use by the scientific and technological community. These infrastructures are strategically unique within their fields, contributing significantly to national research objectives.

To foster international collaboration, the Spanish Antarctic stations adhere to specific requirements, including the development of a strategic plan, the establishment of a scientific–technical advisory committee, and the implementation of appropriate management practices. An access protocol, along with an application form, serves as the gateway for international researchers seeking to conduct scientific activities at the stations.

The access protocol outlines the procedures for international researchers seeking entry to the Spanish Antarctic stations. The application form, available on the Spanish Polar Committee's website, provides a structured approach for submitting requests. The deadline for access requests is at the end of May each year, ensuring a streamlined process for international collaboration.

International Access Granted (2014–2023) and Partnerships

Analysing the period from 2014 to 2023, a total of 50 scientific projects from countries other than Spain were conducted at the Spanish Antarctic stations, with a temporary hiatus in 2020 and 2021 due to the global pandemic. Together, the stations, located in the South Shetland Islands – Juan Carlos I on Livingston Island, and Gabriel de Castilla on Deception Island – hosted research activities from 14 countries (Figure 1). The number of scientific projects conducted during this period shows the diversity and richness of international collaboration at the Spanish Antarctic stations.

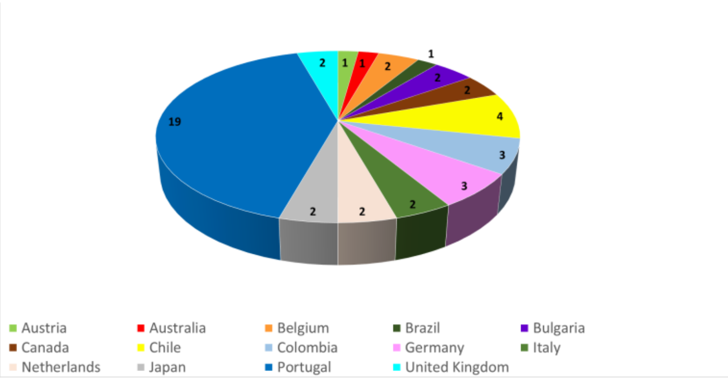

Figure 1: Research activities by country hosted at ICTS BAES. (Credit: Authors)

The scientific projects involved close to 100 researchers from different countries, emphasising the stations' attractiveness as hubs for cutting-edge research. Portugal emerged as the most frequent collaborator, followed by Chile, Germany, and Colombia, reflecting the diverse and global nature of the research conducted at ICTS BAES (Figure 2).

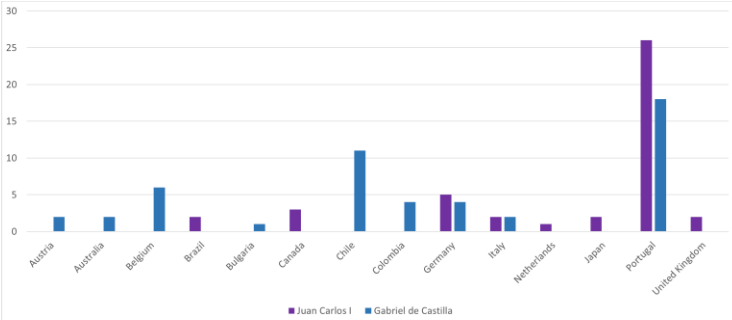

Figure 2: Scientists by nationality hosted at ICTS BAES. (Credit: Authors)

While celebrating the success of international collaboration, it is crucial to acknowledge the challenges faced. The harsh Antarctic environment poses logistical and operational difficulties. The temporary suspension of activities during the pandemic underscored the vulnerability of such remote operations. However, these challenges also present opportunities for innovation in research methodologies, data collection, and international co-operation protocols.

Advancements in survey options and technology have played a pivotal role in enhancing the scientific capabilities of the Spanish Antarctic stations. The integration of remote sensing, geophysical surveys, and state-of-the-art instrumentation has enabled researchers to delve more deeply into understanding Antarctica's unique ecosystem. Drones, gliders, and helicopters, together with fixed-wing aircraft, have become invaluable tools for collecting data, particularly in areas with complex topography.

Lessons from the Past and Future Perspectives

As ICTS BAES continue to be beacons for international collaboration, future perspectives should focus on enhancing survey options, technology, and interdisciplinary research. Encouraging a comprehensive understanding of Antarctica's role in sea-level rise remains paramount. Recommendations include encouraging parties to recognise the importance of such initiatives, actively supporting internationally co-ordinated surveys, and fostering a forum for collaboration among diverse international programmes, airborne facilities, and science education facilitation groups.

Conclusion

In conclusion, the Spanish Antarctic stations, operating within the ICTS BAES framework, stand as symbols of successful international collaboration in scientific research. The challenges encountered underscore the resilience and adaptability of researchers and institutions. The achievements in mapping Antarctica's topography and understanding its coastal dynamics emphasise the stations' pivotal role in advancing global knowledge. As the journey continues, the Spanish Antarctic stations and ICTS BAES remain steadfast in their commitment to fostering international collaboration and contributing to the collective understanding of Antarctica's profound impact on our planet.

Oral on-demand presentations

Enabling science with a subsea fibre optic cable for McMurdo Station, Antarctica[23]

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Introduction

The National Science Foundation (NSF) is investigating the implementation of a modern subsea fibre-optic telecommunications cable interconnecting the US McMurdo Station with either New Zealand or Australia to provide advanced high-speed, low-delay telecommunications (Figure 1).

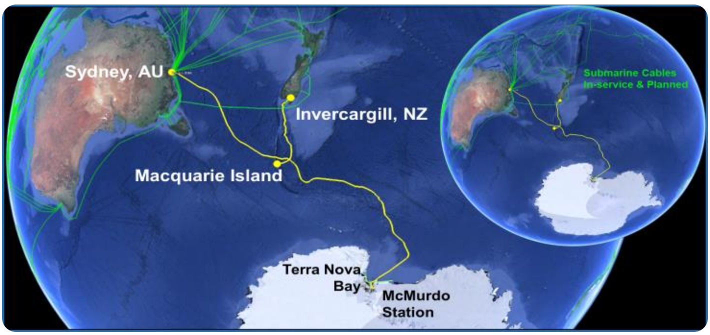

Figure 3: Proposed Antarctic subsea cable routes: McMurdo Station to either Sydney, Australia or Invercargill, New Zealand. (Credit: USAP)

[23] The video of this presentation is available at https://youtu.be/U4Bz1JN0vv0.

At present, 522 cables, installed or planned, cover all ocean regions, including the high Arctic (planned), except the Southern Ocean.

The Antarctic cable doubles as a science research sensor and platform to connect sensors by instrumenting the cable with science sensors incorporated into the cable telecommunications repeaters, providing additional fibre optic strands dedicated as a science sensor and providing connection points on the cable path for future science cabled observatories or other instruments supported by the cable’s power and telecommunications. The Science Monitoring And Reliable Telecommunications (SMART) is a concept advanced by the UN IOC/UNESCO organisation Joint Task Force on SMART for instrumenting the world’s oceans as new subsea telecommunications are deployed.

The SMART concept calls for incorporating temperature, pressure, and three-axis velocity/acceleration sensors into standard telecommunications repeaters and tapping the cable’s power and the communications compatible with the telecommunications function of the cable to approximate the 25-plus-year reliability of modern subsea telecommunications cables.

The Antarctic cable concept includes the addition of extra fibre optic strands dedicated for a sensing technique termed “Distributed Fibre Sensing” (DFS), using a shore-based laser “interrogator” transmitter, receiver, and signal processor sending pulses of light into a dedicated fibre optic strand (termed “dark fibre”) that measures return reflections from tiny reflection – or scattering – points along the length of the cable. External influences such as seismic pressure waves in the ocean (both local/regional and remote teleseisms), marine mammal sounds, and ocean water column height and temperature create small changes in the optical fibre's index of refraction, causing reflected light that can be analysed to extract information about the cause of the reflections.

Accomplishments

Science Workshop
In late June 2021, the NSF Office of Polar Programs and Office of Advanced Cyberinfrastructure jointly supported a research community-led science workshop to review the scientific benefits of a such a cable. The workshop's key findings can be summarised as two-fold: (a) a sound business case exists for the benefits to science research for both the telecommunications capacity and the inclusion of science sensors inherent in the cable design; and (b) the cable concept should be pursued.

Feasibility Study
In response to the science workshop, NSF contracted an industry-standard preliminary concept/feasibility study (known as a "Desktop Study", or "DTS"), incorporating the unique attributes of implementing a cable to Antarctica.

The study addressed two proposed routes for comparison – (a) McMurdo Station to Sydney, Australia; and (b) McMurdo Station to Invercargill, New Zealand – and included brief assessments of optional extensions from the main cable routes to Macquarie Island for potential interconnection to the Australian research station and to the Western Ross Sea Terra Nova Bay area.

Results

While both routes were considered technically feasible, the New Zealand route is favoured over the Australian route, based on these observations:

- The New Zealand route is 1,500 kilometres shorter and thus considerably more economical.
- The Australian route has additional geophysical risk to the cable, arising from a crossing of the seismically active Macquarie Ridge Complex to the north of Macquarie Island.
- The New Zealand route covers more regions of science interest, as indicated by science-researcher input to the study. Seismologist interests propose cable branching units located at 60° S and 50° S for future sea-bottom seismometer instruments tapping the cable’s power and communications.

The risk from ice scour appears reasonable, based upon detailed near-shore bathymetry – the McMurdo cable landing risk-mitigation uses standard subsea cable-landing techniques called Horizontal Directional Drilling (HDD). Environmental assessments and permitting will be a significant component of future work, as is the case with all subsea cable projects, and will include the Antarctic Treaty Committee on Environmental Protection protocols. Co-ordination with the Committee for the Conservation of Antarctic Marine Living Resources (CCAMLR) will be needed as the proposed cable route transits the CCAMLR-governed Marine Protected Areas in the Ross Sea region.

Future
In the near term, a public-release edition of the DTS is planned for completion by August 2023. This will foster a dialog with the science research community, potential subsea cable manufacturers/installers, and interested international partners.

Follow-on short-term studies include iceberg ice-scour risk, open sea-ice periods for cable ship access, market research outreach to cable industry suppliers, requirements definition for environmental reviews and permitting and a Marine Route Survey, identification of suitable hydrographic survey vessels, route and cable engineering trade-off workshops with the science research community, and a continued assessment of technology development for science sensor technology, including SMART telecom repeaters.

Conclusion

There is Strong Scientific Rationale for the Cable
Transformational telecommunications will enable innovation in science research by access to modern academic research tools, to include high-speed networks, remote data repositories, rapid transport of data from the field to the home institution, and high-performance computing supporting AI/ML.

Science research supported by the cable sensors is of societal relevance on a global scale for filling knowledge gaps of key ocean processes and trends for improved understanding and monitoring of climate change through such things as ocean heat transport, CO_2 sequestration, and sea-level rise, as well as at a regional scale for seismic monitoring and early warning of potential tsunami seismic events.

Filling the voids in the global seismic monitoring network with the ability to monitor teleseisms enables various geoscience research efforts using the data, such as subduction zone mechanisms along tectonic plate boundaries and improving the coverage of the vast Pacific Basin.

The Cable Appears Technically Feasible

Of the two feasible routes, the route to New Zealand has advantages, as described above. There are no immediate technical risks identified from the “Antarctic unique” section of the cable (such as ice scour), but more study is warranted.

The incorporation of science sensors appears viable: using dedicated fibre optic strands for established distributed fibre sensing and the incorporation of SMART telecommunications repeaters have great potential as the technology matures.

NSF will continue with additional studies to further refine understanding of potential risks and risk mitigations and prepare for the next phase of effort, which will be organising the environmental evaluation process and planning of a Marine Route Survey to examine the seabed of the cable route in detail.

Ecuadorian Antarctic Refuge: The use of eco-materials, thermal conservation, and identity[24]

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This article describes the Ecuadorian Antarctic Refuge (EAR) project, an ambitious undertaking led by architects Andres Donoso and Cesar Cornejo. Originating from the Faculty of Architecture and Design at the Universidad Católica de Santiago de Guayaquil in Ecuador, the EAR project strives to create a sheltered space for Antarctic researchers, using eco-friendly materials. The article provides an in-depth exploration of the historical background, ongoing collaboration, technological advancements, construction challenges, and future prospects that define this groundbreaking initiative.

Introduction

Antarctica, the closest continent to South America, has become a focal point for scientific exploration due to its unique environment. The EAR project, emanating from the Faculty of Architecture and Design at the Universidad Católica de Santiago de Guayaquil, introduces an innovative approach to shelter construction by incorporating eco-

[24] The video of this presentation is available at https://youtu.be/brFVVVYQE1U.

friendly materials such as bamboo, abaca, coconut tow, and rice husks. This article aims to present a comprehensive analysis of the EAR project, unravelling its historical evolution, the collaborative efforts involved, the technological innovations incorporated, and the challenges encountered during construction.

Historical Evolution of the EAR Project

The inception of the EAR project can be traced back to 2016, marked by a collaboration agreement between the Ecuadorian Antarctic Institute and the Universidad Católica de Santiago de Guayaquil. This collaboration sought to explore the thermal insulating properties of various natural fibres, often considered waste. Bamboo, banana, abaca, coconut, and rice were among the fibres tested during expeditions, with prototypes constructed on the slopes of the Chimborazo volcano. These early experiments laid the foundation for the ambitious Antarctic refuge project.

Ongoing Collaborative Endeavours

Collaboration has been a key factor of the EAR project's success, extending beyond Ecuadorian borders. The initiative's continuous evolution involves iterative adjustments based on feedback from the Instituto Antártico Ecuatoriano and other collaborative partners. The collaborative efforts go beyond design considerations, as the Chilean Navy provides crucial transportation services for the Ecuadorian Expedition members to and from Antarctica. This ongoing collaboration ensures the project's adaptability and relevance.

Technological Advancements, Challenges, and Solutions in the EAR Project

Technological innovations play a pivotal role in the EAR project's journey. The second prototype, featuring a red metal structure supporting eco-material panels, showcased advancements in design and construction. The final approved prototype, inaugurated in 2019, incorporated significant technological improvements suggested by the Ecuadorian Antarctic programme. These enhancements included additional accessories, improved anchoring mechanisms, and the integration of photovoltaic energy through solar panels. The technological prowess of the EAR project aligns with the principles of the Antarctic Treaty (Figure 1).

Figure 1: EAR project module in Antarctica. (Credit: Author)

The construction of the EAR in Antarctica presented formidable challenges that demanded adaptive solutions. The initially chosen site proved unsuitable, due to low soil resistance and the presence of lichens. The relocation to Punta Arenas became imperative, demonstrating the project team's adaptability. Challenges persisted during transportation and container unloading, necessitating manual intervention to optimise weight distribution and ensure a successful roll-out of the container onto the chosen land.

Conclusion

The EAR project, emerging from over four decades of research, stands as a testament to the feasibility of sustainable construction in the extreme Antarctic environment. The 11-day construction process in Antarctica not only highlights the efficiency of the project but also demonstrates its resilience against unforeseen challenges. As the EAR project explores the possibilities of eco-friendly materials, it sets a new paradigm for ecological construction. The potential for Antarctica to become a laboratory for weather-resistant construction materials opens avenues for sustainable solutions in the future.

Looking ahead, the EAR project prompts contemplation on whether the Antarctic continent could transform into a laboratory for testing and advancing weather-resistant construction materials. The success of the EAR project, especially in utilising bamboo, opens possibilities for shaping the identity of Antarctic shelters and influencing construction practices globally. The project's accomplishments pave the way for future initiatives that prioritise sustainability in construction and contribute to a broader understanding of resilient building materials. The success of this initiative shows the importance of interdisciplinary collaboration in advancing sustainable solutions for challenging environments.

Foraging niche divergence in a climate change sentinel from the Antarctic Peninsula: Evidence from bulk and compound-specific stable isotope analysis[25]

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COMNAP Antarctic Fellowship Awardee

This study, conducted with the support of the COMNAP Antarctic Fellowship scheme, aims to provide comprehensive insights into the multifaceted impacts of climate change on Antarctic fauna, with a specific focus on understanding the foraging ecology of Weddell seals on both the Eastern and Western Antarctic Peninsula. The Western Antarctic Peninsula, in particular, is marked by reduced sea ice extent and duration, a consequence of long-term warming trends. Understanding the implications of these changes on the Antarctic ecosystem, especially on key species such as Weddell seals, becomes crucial for predicting broader ecological responses.

Methodology

To unravel the ecological nuances and discern the impact on Weddell seals, we employed advanced stabilised isotope analysis. This encompassed the measurement of relative abundance of naturally occurring isotopes in bulk tissue, with

[25] The video of this presentation is available at https://youtu.be/nWxR6rob3Vs.

a focus on carbon and nitrogen. Additionally, a more detailed compound-specific stabilised isotope analysis of amino acids was conducted to gain a nuanced understanding of the traffic dynamics within the ecosystem.

Sampling and Analysis

Whisker samples were meticulously collected from Weddell seals inhabiting two distinct sites – the Eastern Antarctic Peninsula near Marambio Station and the Western Antarctic Peninsula near Primavera Station. Bulk tissue analysis revealed intriguing findings, with higher values observed in Weddell seals from the Eastern Peninsula, presenting anomalous carbon values compared with those of other Antarctic populations.

Amino Acid Analysis

The amino acid analysis provided a deeper insight into the diet composition and trophic dynamics of the Weddell seals. Significantly, differences emerged in both essential and non-essential amino acids, indicating a potential divergence in the dietary sources between the two populations. While traffic position similarities were observed, the proportion of prey contribution to their diets differed, unravelling subtle intricacies in their foraging behaviour.

Insights from Isotopic Niche Analysis

The application of isotopic niche analysis, a powerful tool to understand an organism's ecological role, revealed a lack of isotopic niche overlap between the two Weddell seal populations. This implies distinct ecological niches and foraging strategies, reinforcing the idea that climate-induced changes are influencing the dynamics of the Antarctic Peninsula's fauna.

Carbon Discrepancies and Environmental Influences
The unexpected carbon differences between the Eastern and Western Antarctic Peninsula, indicated by baseline isotopes, point towards a potential foraging divergence. The Eastern seals exhibited isotopic values that deviate significantly from the norm, suggesting a unique ecological context, possibly driven by variations in sea ice conditions and associated phytoplankton dynamics.

Resilience of Western Antarctic Peninsula Seals
Contrary to the heightened sensitivity observed in the Eastern seals, those from the Western Antarctic Peninsula demonstrated a remarkable resilience. Their isotopic compositions mirrored those of other populations, indicating a level of dietary plasticity and adaptability in response to environmental shifts. This adaptability is of paramount importance for the survival of species in the face of ongoing climate change.

Unravelling the Enigma of Eastern Peninsula Isotopic Values
The distinctive isotopic values observed in the Eastern Antarctic Peninsula Weddell seals present an intriguing enigma that warrants further exploration. Uncovering the sources of the enriched values in this region requires dedicated research initiatives and technological advancements. Tools such as animal-borne instruments or dedicated ship services could enable a deeper investigation into the biological and physical features influencing the Weddell seals' foraging habits.

Broader Implications and Conservation Relevance

The ecological divergence observed in Weddell seals serves as a crucial indicator of how climate change can manifest in the Antarctic ecosystem. These sentinel species provide a unique lens through which we can comprehend shifts in energy sources and assess the overall resilience of the ecosystem. This knowledge is instrumental in formulating effective conservation management strategies, especially in the context of ongoing climate change.

The Role of the COMNAP Antarctic Fellowship

I extend my sincere gratitude to COMNAP for facilitating this research endeavour. The COMNAP Antarctic Fellowship not only provided financial support but also enabled collaboration with esteemed researchers, Dr Seth Newsome and Dr Nico Lübcker, at the University of New Mexico. This collaboration has been pivotal in expanding my knowledge in the field of stabilised isotope analysis and contributing to my professional growth.

The significance of this fellowship extends beyond individual research projects. For scientists from developing countries who have limited access to cutting-edge technology, the fellowship plays a crucial role in fostering expertise in new areas of study. This, in turn, contributes to the overall development of polar scientists who can address the unique challenges posed by climate change in their respective regions.

Conclusion

In conclusion, the ecological divergence observed in Antarctic Weddell seals underscores the intricate ways in which climate change is reshaping the Antarctic Peninsula. As we unravel the mysteries of isotopic compositions and foraging behaviours, we gain valuable insights into the resilience and adaptability of Antarctic fauna. This research not only expands our understanding of climate change impacts but also emphasises the urgent need for collaborative, interdisciplinary efforts to ensure the conservation of this pristine ecosystem.

Poster presentations[26]

[26] Posters are available at https://www.comnap.aq/20th-comnap-symposium.

Decarbonising Antarctica Discussion Forum: An example of idea sharing to overcome a common challenge

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The 2015 Paris Agreement and relevant national commitments to reduce carbon emissions highlight an urgency to phase out fossil fuels and decarbonise activities globally. Decarbonising Antarctic operations is therefore a challenge many national Antarctic programmes are either actively or conceptually investigating. In line with COMNAP's purpose, "to develop and promote best practice in managing the support of scientific research in Antarctica" a Decarbonising Antarctica Discussion Forum was established in 2022 by Antarctica New Zealand and the British Antarctic Survey, who recognised a shared challenge of trying meet domestic net zero emissions.

The Decarbonising Antarctica Discussion Forum is an informal virtual discussion forum to support shared learnings between national Antarctic programmes. The Decarbonising Antarctica Discussion Forum has met four times, approximately every two months. The forum operates under Chatham House rules. Meeting participants are free to use information shared from the discussion, but minutes are not recorded. This creates an open discussion forum environment.

The success of the forum is seen in an increase in the number of participants and a growing community of practice.

Suggestions of topics for future meetings, especially national Antarctic programmes' experiences with investigating and using renewable energy technologies in Antarctica and wider approaches to decarbonising Antarctic activities, are welcome and participation is encouraged.

Energy efficiency considerations for McMurdo Station lodging facility

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Existing facilities at McMurdo Station are legacies of the original station developed by the US Military in an era when the cost of energy was extremely low, and the resources to support the military presence operating the station were seemingly unlimited. The station development at that time was predicated upon quickly accommodating a large human footprint required to launch and support a growing population of both support staff and scientists. The need for expediency drove planning efforts, and available non-site-specific materials were incorporated into designs that eventually were realised, with little or no consideration for energy or operational efficiency. Those early plans and designs resulted in buildings and facilities that were energy inefficient, necessitating large amounts of fuel to be continually shipped to Antarctica to heat and power them.

At the time of original development of McMurdo Station, the cost of a barrel of fuel was inconsequential, and shipping that fuel to Antarctica was supported by the US military. After the many decades that the US Navy operated McMurdo, the US National Science Foundation assumed operations of the station, and, in the process, inherited a portfolio of facilities, utilities, and infrastructure that had either outlived their useful lives or were approaching the ends of their useful lives.

Over time, the cost of fuel increased, as did the maintenance and repair costs, which translated into more and more of the Program's operating budget to be directed to these requirements, when it could have been directed to supporting other priorities, including additional science.

This poster demonstrates the study used to determine energy efficient approaches that could be used to diminish the energy requirements in replacement facilities, in particular, the lodging facility that will become part of a larger rebuild programme at McMurdo. The lodging facility is a single building that includes rooms for singles as well as rooms for couples. The facility has an energy efficient building envelope that will be "stick built" on-site rather than built modularly, using a design/build approach. The poster also discusses lessons learned in the overall design effort.

Antarctic Infrastructure Renewal Program: Drivers and strategies

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The Australian Antarctic Division (AAD) is planning to renew aging infrastructure and progress planning for new state-of-the-art facilities that, once delivered, will enhance the AAD's ability to deliver world-class science and environmental stewardship across East Antarctica. The work is being delivered within the Antarctic Infrastructure Renewal Program. The majority of the Program's works will be delivered under a programme alliance delivery model (Programme Alliance).

The poster highlights why a Programme Alliance has been selected as the preferred delivery model, and the environmental and operational drivers of the design and how they will support greater efficiency in future station operations.

The Program will aim to deliver on key objectives that include safety, environment and sustainability, partnership, culture and workforce, stakeholders, innovation, disruption, and cost and value. The Initial Works Packages comprise:

- Aviation facilities renewal to improve services for summer operating aircraft crews and provide greater safety for expeditioners and crew; and
- Priority infrastructure renewal at Davis Station to reduce safety risks to expeditioners and improve station operations and capability.

Silver Arctic: A new platform for supply and research in the Southern Ocean

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Every year, equipment and supplies are transported to the coast of Antarctica to operate the Norwegian year-round station Troll in Dronning Maud Land. The transport is carried out under the auspices of the Norwegian Polar Institute (NPI) using a modern ice-going vessel, MV *Silver Arctic*. NPI integrates supply cruises with research activities on the annual cruise between South Africa and Antarctica.

Development of a man-portable Hybrid Autonomous Underwater Vehicle for Antarctic deep-seabed exploration

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In Ecuador, underwater sites with high scientific interest, such as the Galapagos Islands hydrothermal vents, are poorly explored because of the lack of local underwater robots technology for deep-sea exploration (> 4,000 metres). The last time deep-sea exploration at the Galapagos hydrothermal vents was in 2015 by “Nautilus Live”. The Antarctic Peninsula area has a high scientific value, especially the Drake Passage. However, the seabed of the Drake Passage is largely unexplored due to the climate conditions. Deploying work-class Remotely Operated Vehicles (ROVs) for deep-seabed exploration from an oceanographic vessel is a very risky operation in the Drake Passage, where usual conditions are 8 metre waves and 60 knot winds that can cause the umbilical cable to break and the consequent loss of a million-dollar ROV. A limitation is the deployment of an Autonomous Underwater Vehicle during the narrow window of good-weather conditions to explore the seabed, minimising the risks. These are the key reasons to develop a new kind of deep-sea underwater robotic technology to explore the South America and Antarctica seabed environments based on open hardware and software platforms. The goal of the HadalBotics Startup is to provide the scientific community with the first human-portable low-cost Hybrid Autonomous Underwater Vehicle (HAUV) for routine and long-term access to the deep seabed, with an endurance of up to 8,000 metres and 8 hours. The proposed vehicle has a length of less than 2 metres and a weight of 40 kilograms; it performs some ROV tasks fully autonomously, such as getting close images of sites with high scientific interest and sampling specimens from the seabed with a robotic arm. This technology allows the usage of sailing ships for deep-sea exploration instead of costly oceanographic vessels, lowering the exploration cost from USD 50,000 per day to USD 800 per day. The HAUV can also operate as a classic ROV. In the ROV-mode commands, telemetry and 4K video signals are sent through a lightweight, bare fibre-optic cable using a similar approach as for the Woods Hole hybrid underwater vehicle *Nereus*. Since a sailing yacht cannot maintain a stable position against surface currents and winds to perform deep-sea ROV operations, the tether will be deployed from an Unmanned Surface Vehicle (USV) that co-ordinates its movements with the HAUV. Simultaneous deployment of several HAUV working as Autonomous Underwater Vehicles (AUV) from the same mother ship is possible to cover more seabed. The vehicle employs an open-source hardware–software platform to support routines of inertial guidance, computer vision, and artificial intelligence, running on ARM CPU, FPGA, and TPU. A strategic capability of an AUV is the position estimation accuracy. Typically, an

AUV for deep-sea exploration has a tactical grade Inertial Navigation System (INS) complemented by another navigation aid, for example a Doppler velocity log. This kind of INS employs three-axis fibre-optic gyroscopes or ring laser gyroscopes with a bias stability of less than 0.001 degrees per hour. An INS for the HAUV is being developed as an organic component, partially based on gyroless INS technology in order to avoid expensive gyroscope technology and a strong foreign technological dependency. The basic INS architecture optimised for underwater navigation application includes low-cost MEMS accelerometers and gyros and one Fibre Optic Gyro (FOG) for heading. The novel mathematics for this approach, MEMS/FOG technology, is based on unscented Kalman filter with sigma points, Lie algebra groups, and stochastic differential equations with partial Brownian motion. The INS algorithms are coded by C++/VHDL routines running on an FPGA. The batteries and electronics system are contained in a pressurised vessel made of aluminium alloy 6061 T6 and titanium grade 5. The basic HAUV payload is cameras for photogrammetric surveys and a robotic arm to collect samples on the seabed. A prototype with 400-metre depth capability to serve as a technology demonstrator and software validation platform has been completed successfully and will monitor and explore Ecuadorian continental Marine Protected Areas. Another prototype with 6,000-metre depth capability is under development, and key mechanical systems such as locally made pressurised housings have been tested at sea, to a depth of 2,200 metres near the Ecuadorian coast. After software validations on the first prototype and getting the necessary funding a more capable 6,000-metre HAUV for Antarctic exploration will be available.

The USAP Antarctic Research Vessel (ARV) project

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In early 2023, the United States Antarctic Program completed the second of three formal design reviews for its next-generation ice-breaking Antarctic Research Vessel (ARV). This represents a significant milestone, advancing the project towards its final design review and the start of construction, pending full funding by the US Congress. The ARV will serve as the replacement to the current USAP ice-breaking research vessel, *Nathaniel B. Palmer*.

The design of the ARV has advanced significantly over the preceding two-plus years of effort, culminating in a vessel that will have an endurance of 90 days unreplenished, be able to accommodate at least 55 researchers and technical personnel, and be rated as a Polar Class (PC) 3 vessel, capable of independently operating in ice up to 1.4 metres thick with an additional 30 centimetres of snow at a continuous 3 knots. With a dedicated UAS/drone deck and hangar, advanced acoustic sonar suite, motion compensated CTD launch and recovery system, the ability to launch and recover 40–50 metre-long cores, as well as more than 400 square metres of lab space and 670 square metres of deck space, the ARV will represent a dramatic increase in capabilities for researchers in the Antarctic.

Construction is anticipated to start in 2027 and complete in 2030, with the vessel fully ready for science in 2031. More information can be found at https://future.usap.gov/arv.

Introduction of the RRS *Sir David Attenborough*: Two years on

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It is now over two years since the British Antarctic Survey (BAS) was handed the keys to the RRS *Sir David Attenborough*. The aim of this presentation is to share progress of our path to delivery of marine science, and some of the challenges and unexpected opportunities along the way.

Using innovation to prevent the need for Search and Rescue in the Australian Antarctic Program

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The Australian Antarctic Program (AAD) is currently going through a step change in operational support. The Field Operations section is due to expand and with this change comes innovation. From a field operational context, the prevention of the need for Search and Rescue (SAR) is the highest priority; but how do we prevent it?

The poster provides an overview of our current AAD field safety systems, highlighting the emerging technology related to field operations, and it shows how this technology will help prevent the need for SAR in the future. The poster covers the existing and planned AAD field operational practices:

- Communication systems including TAC, Shout Nano, and tracking.
- Practices such as the Operating Conditions Matrix, Comms emergency PACE procedure, and Take 5 planning.
- Policy such as field manual, SOPs, guidelines, and forms.
- Training such as pre-departure, survival, travel, and SAR.
- Clothing and field equipment improvements.
- Incident management system.

- Future direction.
- Collaboration with other nations; how to share knowledge on prevention of the need for SAR.

Monitoring of natural hazardous objects of Antarctic oases: Key results of the programme implemented at the Larsemann Hills

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Operating close to Antarctic oases often involves risks associated with hazardous natural objects and processes. Depending on the degree of danger, they can cause significant damage to the infrastructure of polar stations, seriously complicate logistical operations, or threaten the lives of people working in the field. One of the priority tasks of the Russian Antarctic Expedition (RAE) in recent years is a programme of study and comprehensive monitoring of natural hazards. Such a programme was launched in 2017 in the area of the Russian Antarctic Progress Station (Larsemann Hills, East Antarctica).

Among the objects that pose a risk to transport operations, glacial crevasses can be mentioned first. In addition, the Larsemann Hills is characterised by another source of natural hazards – a wide range of dangerous hydrological objects and phenomena. These include hidden intra-glacial reservoirs: temporary seasonal watercourses and lakes characterised by periodic flooding.

The best way to deal with hazardous natural objects and processes is a technique that involves: (a) establishing their presence; (b) establishing trends and mechanisms of their development; (c) long-term monitoring and timely identification of critical situations when it is impossible to transfer activities from a site exposed to hazardous processes. The working methods of the programme are a function of the nature of the objects and processes under study. For example, in the case of glacial crevasses, the main work is carried out using ground-penetrating radar (GPR). This makes it possible to determine the presence and geometric characteristics of crevasses and to assess their degree of danger. Furthermore, glaciological polygons are organised at all infrastructure on the glacier. Regular monitoring of glacier dynamics is used to determine how objects move towards dangerous areas. Outburst reservoirs are mainly monitored using terrestrial hydrology methods, in particular long-term water level monitoring. In addition, GPR is used to detect the presence of hidden watercourses in the body of the glacier or snowfield. All types of surveys are complemented by aerial photography using unmanned aerial vehicles.

To date, the main result of the programme has been the completion of an inventory of natural hazard sources within all the infrastructure facilities that are part of the RAE. Lakes have been identified and described in detail, the catastrophic outburst floods of which can affect the successful implementation of logistics operations, and monitoring activities are being carried out on them. Crevasse zones have been identified within existing routes. The capacity of snow bridges and the level of danger in a given field season are assessed annually. The design of new infrastructure facilities is carried out taking into account the results of a comprehensive survey, and, as far as possible, directly in areas that are not affected by hazardous natural objects and processes.

Expose to treat: The standardisation of cold casualty care for Antarctica

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One of the greatest challenges in providing medical care to the deployed population is preventing additional injury from the environment. Managing a casualty in the field poses risks to the individual but also to the caregiver/rescuer, theoretically meaning that those trying to help can very quickly become casualties themselves. How to we mitigate this risk? How do we prevent the rescuer needing to be rescued?

In this submission, we are keen to discuss our vision for "expose to treat" – the standardisation of immediate delivery of cold casualty care to protect from the environment both the casualty and those providing the immediate care. To this end, we are keen to discuss the following position statements:

- The use of central, sternal access as the default for immediate treatment in the field environment.
- The approach to the polar primary survey and how to offer optimal information yield without injury to the assessor.
- Future research requirements for care delivery (including thermal loss, secondary harm to providers, and equipment adaptation).

This submission draws from current experience in trying to adapt equipment and training to standardise the deployed medical capability. This work is running in parallel with projects looking at the remote support to medical care – using standardised equipment models that can be discussed from two parties operating at reach but having a shared understanding of its content.

The submission also discusses the future role of these capabilities: augmented reality technologies and immersive training.

Leveraging the pandemic: How advancements in technology and telemedicine can improve the health and well-being of the Antarctic deployer

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Prior to the pandemic, telemedicine was met with scrutiny and hesitation. Telemedicine was not well-studied and not widely adopted. However, the pandemic bore at least one positive outcome: the increased use of telemedicine that resulted in new research and innovation. Promising findings emerged, suggesting that telemedicine is noninferior to in-person care for health outcomes in certain conditions. Simultaneously, digital health technologies (i.e. remote patient monitoring devices and sensors) improved, expanding the possibilities of continuous monitoring and early interventions.

As we emerge from a period that dedicated the Antarctic medical community's efforts primarily to COVID-19 mitigation and control strategies, we are at the doorstep of new healthcare opportunities. There are myriad benefits to telemedicine and digital health technologies to bolster the health of the Antarctic deployer. As internet access improves, so does our opportunity to create a more robust healthcare ecosystem.

This presentation discusses new advancements in the fields of telemedicine and digital health technologies. The presenter provides approaches that can improve health outcomes, potentially allowing deployers to remain deployed. The presentation describes how leveraging telemedicine and biological monitoring may improve diversity through the inclusion of communities that experience greater health disparities. Ultimately, the presenter discusses avenues for agility as health needs change in this dynamic Antarctic environment.

Remote medical support to polar operations: The effect of "reach back" on clinical care delivery

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The provision of remote medical support to the Antarctic and sub-Antarctic space can be challenging – especially when additional support is required, or advice needed. How can we best support our deployed medical personnel from the headquarters of national programmes? Does the access to senior clinicians or specialists mitigate the need for evacuation or enable care to be delivered at reach for longer?

As part of the pre-deployment training for any British Antarctic Survey Medical Unit (BASMU) clinician, additional time will be spent seconded to secondary and tertiary specialty clinics to enhance understanding and increase diagnostic/treatment confidence whilst deployed. However, if there are concerns whilst deployed, BASMU clinicians can "reach-back" to UK resources through several means and modalities. In this poster, we explore the various methods utilised over the previous seasons and the impact on patient care delivery as well as support to those patients requiring evacuation.

The poster looks to discuss the following:

- The use of videoconferencing for support to practical procedures.
- The use of digital x-ray and ECG for easier/rapid review.
- The use of videoconferencing for tertiary specialist opinion (from multiple specialties).
- The use of data forms for case discussion and record-holding.
- The future use of augmented/virtual reality technologies to support training and clinical care.

The poster also looks to assess the current limitations and challenges to implementation, most notably around technological infrastructure.

DROMLAN (Dronning Maud Land Air Network): 20 years of international collaboration – Establishing an efficient air network in Dronning Maud Land

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In 2002, at the COMNAP meeting in Shanghai, DROMLAN – Dronning Maud Land Air Network – was formed as an international co-operative project by the national research programmes from Belgium, Finland, Germany, India, Japan, the Netherlands, Norway, Russia, South Africa, Sweden, and the United Kingdom, all conducting research in Dronning Maud Land. The aim was to establish an air network to Dronning Maud Land and provide its members with a more economic, efficient, and flexible way to access Antarctica, creating an air network. In 2020, Belarus joined the collaboration.

From the beginning, there were only one intercontinental airfield and one air operator available, but over the years these have grown to four intercontinental airfields and several air operators for intercontinental and intracontinental flights. By being able to share logistical resources and infrastructure, DROMLAN has grown to a successful international collaboration, giving researchers easy access to Antarctica. The collaboration is governed by a steering committee, with one representative from each member country, which meets twice a year in post-season and pre-season meetings. These meetings are chaired by two co-chairs, who are replaced every two years, and the positions are rotated among the member countries.

In addition to the actual air network, DROMLAN and the different air operators have taken upon themselves the improvement of the safety of air transport and Search and Rescue (SAR) arrangements for its members.

- ADS-B receivers are installed at all the major airfields and stations in the area.
- A communications list is compiled and updated each season.
- Various email lists are established and updated each season to ensure that the information flow within the collaboration reaches the right persons.
- Flight notifications and information emails are sent for all flight movements as a way of updating each other.
- A DROMLAN Weather Service provides flight-specific weather forecasts as well as general forecasts for all members.
- With several air operators and airfields, SAR and medevac capability is high.

An added benefit from the logistic collaboration has been that several international science projects have grown out of, and taken advantage of, the already-existing and well-functioning logistical collaboration.

Improving the co-ordination of Antarctic aviation has positive safety benefits

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Worldwide, there is a continuing demand and increase in aviation activities – the COVID-19 pandemic only caused a transient pause in this trend. The Antarctic Continent is following this trend, which includes an increase in the use of Remotely Piloted Aerial Systems (RPAS). The need for co-ordination of activities has, in the past, often been driven by the need to make things more efficient. However, this need is starting to be driven by the desire by all nations to improve the safety of the aviation environment in the Antarctic. COMNAP has played a significant role in the improvement of Antarctic flight safety, with the introduction of many initiatives, including the *Antarctic Flight Information Manual* (AFIM), the Asset Tracking System (CATS), the Communications Database, and continent-wide planning maps for aviation among the highlights.

The increase in complexity, including increasing use of RPAS, often with "Beyond Line of Sight" capabilities, makes co-ordination and communication between all the operators and programmes even more important in keeping aviation as safe as reasonably possible. The COMNAP Air Operations Working Group will discuss, among other topics, the benefits of a forum for sharing safety information, RPAS integration, a centralised Notice to Air Missions (NOTAM) system, and the more recent technical developments with benefits to safety, such as ADS-B and other traffic awareness/surveillance systems.

Integrating Remotely Piloted Aerial Systems (RPAS) into air operations

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Globally, there have been an increased use, plans to use, and availability of Remotely Piloted Aerial Systems (RPAS) to deliver civil airborne tasks. The use of smaller RPAS in Antarctica has increased over the last decade to become routine for Visual Line of Sight (VLOS), and larger Beyond Visual Line Of Sight (BVLOS) RPAS are being deployed. This season, the British Antarctic Survey (BAS) deployed and piloted a 3-metre-wingspan PRION3 with a potential range of 1,000 kilometres to conduct airspace integration at Rothera. Next season, a 10-metre- wingspan Ultra capable of 100 kilogram payload/1,000 kilometres-plus range will be flown by commercial operators at Rothera.

Use of RPAS, particularly BVLOS, to improve science mission availability year-round, achieve fuel savings, improve utilisation of manned aircraft, and reach NetZero means RPAS will become routine. Therefore, RPAS need suitable Concepts of Operations (CONOPS) to allow safe and responsible use of RPAS in the Antarctic airspace and on the ground that are compatible with manned aviation. A combination of CONOPS and technology, such as ADS-B, air traffic awareness, Notices to Air Missions (NOTAM), and emerging detect-and-avoid technology is needed to maintain RPAS and manned aviation separation and interoperability. Antarctica has a vastly different and challenging environment to where manufacturers of RPAS would normally fly and test their RPAS. Including Antarctica's sparse or limited infrastructure and data creates potentially added operational risks or system limitations for RPAS to overcome.

The poster presents BAS RPAS operations experiences of the PRION3 and proposed CONOPS for Ultra operations and the operations environment, and it examines best practices and regulations being developed by regulators. Preparation for the increased use of RPAS is essential to allow national programmes to choose and operate the most suited RPAS or piloted platform to deliver science and operations missions to meet NetZero goals and programme delivery.

Korea's international air network collaboration for the past 35 years

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The Korean Antarctic Research Programme started in 1988 with the inauguration of King Sejong Station on King George Island, Antarctica. From the early stage of King Sejong Station operation, there was much robust and active co-operation and collaboration among Korea and other countries, such as Brazil, Chile, and Uruguay, in the field of logistics operation by sharing each country's air force air network. This has continued over the past 35 years. Korea has been expanding its scope and range of international co-operation and collaboration from the government-to-government level to the level of each Antarctic research programme.

This context of international co-operation and collaboration provides the Korean Antarctic Research Programme with opportunities to initiate new collaboration with other Antarctic research programmes, including newly established Antarctic research programmes. The Korean Antarctic Research Programme is going to share experience and lessons learned in the air network co-operation and collaboration from the past 35 years.

COVID-19: A review of the impact of COVID-19 on operations in the British Antarctic stations

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The impact of the COVID-19 pandemic has been felt throughout the Antarctic medical community, with lasting effect. The aim of this presentation is to deliver a thematic analysis of the issues/events faced during the initial phases of the pandemic through to current management stratagems for those deploying to British Antarctic stations. Key areas of discussion include:

- The screening of the pre-deployed population for risk of severe COVID-19 and modified risk assessment for the deployed working.
- The management of the transiting population, including pre-deployment quarantine.
- The comparison of maritime versus land-based deployed populations and how risk mitigation was delivered.

Beyond the technical challenges of both managing COVID-19 and preventing outbreak amongst the population should be consideration of the psychological impact of COVID-19. This area of discussion is likely to have significant overlap with other Antarctic nations and is a critical area of understanding to ensure optimal psychological safety for our personnel.

To complement the above retrospective, additional discussion focusses on the lasting impact of COVID-19 and how management has changed in relation to UK/national policy. This aspect includes an exploration into where there is variation with reference to clinical risk management.

Significant aspects of this session are taken from the work compiled by the COVID-19 JEGHBM working group that contributed to the COVID-19 guidelines for operations.

COVID-19 protocol in Punta Arenas as a gateway city

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The Covid-19 pandemic in Antarctica will have had effects that are difficult to measure in the mid-term. At the onset of the pandemic, several Antarctic programmes suspended theiractivities. Hughes and Convey (2020) have already drawn the attention to the effects of the Covid-19 pandemic on scientific activity and logistics in Antarctica. A similar situation occurred in the Arctic, with the cancellation and postponement of field campaigns in Svalbard amongst other places (Duveau 2021).

Countries and national Antarctic programmes had to take extreme preventive measures to avoid the spread of the coronavirus. From the beginning of the pandemic, one of the main concerns of the Chilean programme was the need to co-ordinate all actors involved in the national Antarctic activity to prevent the entry of the SARS-CoV-2 virus to the continent. These efforts have always been carried out while trying not to affect the national and international scientific activity.. Punta Arenas city is one of the main gateways to the White Continent, and many of the national Antarctic programmes started their operations in Antarctica from Punta Arenas. For this reason, it was imperative to develop an appropriate response, aligned with a national commitment as a last port and gateway to Antarctica. In early March 2020, preventive measures were taken to isolate the Chilean Antarctic stations and scientific activities were cancelled. Subsequently, the authorities of the Magallanes Region of Chile, national Antarctic operators, and private actors were summoned to participate in various co-ordination meetings in which the scientific background known to date was presented. As a result of these efforts, in June 2020, the *Covid-19 Protocol for the Control and Monitoring of Passengers and Cargo Transit Between Punta Arenas and the Antarctic Peninsul*a was presented, which made it possible to regulate Antarctic activity through Chile. This protocol was one of the first of its kind among the countries considered as gateways to Antarctica, setting a benchmark for the efforts to be developed by other states.

The design of the protocol was based on the epidemiological control documentation prepared by the Chilean Ministry of Health. The objective of the COVID-19 control work was to provide guidelines for the control and monitoring of national Antarctic programmes' personnel and cargo during their transit through Punta Arenas to and from Antarctica, in order to: (a) prevent the spread of COVID-19 in the Antarctic Peninsula; (b) prevent the entry of the virus from other countries to the Magallanes Region; and (c) not jeopardise the regional health care system's capacity to provide care. This protocol was applied to researchers, logistic personnel, and cargo of the national Antarctic programmes and to all Chilean Antarctic operators using Punta Arenas as a gateway to Antarctica. All scientific and logistical personnel had to undergo the Chilean disease detection and monitoring system by registering prior to travel and to undertake a quarantine period in a quarantine hotel. In addition to undergoing mandatory testing prior to arrival in Chile and at the border, they were required to present a certificate documenting a negative SARS-CoV-2 test result prior to departure from Punta Arenas to Antarctica. As the vaccination process progressed in the different countries, the protocols changed. In the case of Chile, preventive isolation and PCR or antigen tests are currently recommended before travelling to Antarctica. The efforts made have proven to be successful, since several national Antarctic programmes have developed their activities normally. Thanks to these efforts, beyond the contingency, a significant number of them have confirmed the continuity of their Antarctic operations from Chile, in spite of the restrictions and controls requested.

Currently, the main concern remains the early detection of the virus prior to travel to Antarctica. In addition, we advocate for the use of guidelines to reduce the risk of reverse zoonotic transmission of the virus from humans to Antarctic wildlife.

US Antarctic Program COVID-19 posture and collaboration

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In advance of the 2022/23 austral summer season in Antarctica, the US Antarctic Program (USAP) made the decision to begin transitioning our approach to managing COVID-19 as the virus outbreak evolved from pandemic to endemic. While extreme testing and quarantine postures were effective at keeping COVID-19 out of USAP stations in the previous two seasons, they were challenging for our deploying populations and for our mission execution.

The goal of the National Science Foundation (NSF) this season was to minimise bad outcomes of the virus in our deploying population. This included (among other actions) maintaining heightened physical qualifications, increasing medical support at our gateways and stations, and ensuring our capability for reliable medical evacuation throughout the summer season. Ultimately, flexibility was important as on-station mitigations varied by location and spread of the virus in our population. Communication of the USAP COVID-19 posture and infection rates was key as we worked closely with many international partners and, most importantly, our nearest neighbours on Ross Island at Scott Base.

This presentation discusses the 2022/23 USAP season as well as the proposed modifications in 2023/24.

Korea's collaboration for COVID-19 preparedness and response amid the COVID-19 pandemic

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For the past three years, the COVID-19 pandemic has been a key issue and a big challenge for all managers of national Antarctic programmes. COVID-19 brought the managers an opportunity to go over the past and to prepare for the unforeseen but predictable and to swiftly respond to rapidly changing situations.

The Korean Antarctic Research Programme has been actively co-operating with government and related organisations for preparedness and response to the COVID-19 pandemic as well as collaborating with other managers of national Antarctic programmes and related key international organisations.

The Korean Antarctic Research Programme shares its experience and lessons learned in COVID-19 preparedness and response, and its related co-operation and collaboration.

Breaking the ice: Communications for the Scott Base Redevelopment

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Scott Base is Aotearoa New Zealand's home on the Ice. While only a small percentage of the population has ever travelled to Antarctica, many Kiwis feel a strong and intimate connection to Scott Base and are proud of New Zealand's long and enduring history there.

Antarctica New Zealand is mandated by the Minister of Foreign Affairs to raise awareness of Antarctica and of New Zealand's activities and scientific research programme. The redevelopment of Scott Base is the largest project Antarctica New Zealand has ever embarked upon and has thus become a core focus of our communications activities. The Scott Base Redevelopment will see the aging infrastructure replaced with a safe, fit-for-purpose, and sustainable research facility that will support New Zealand's presence in the Ross Sea region of Antarctica for the next 50 years.

This presentation explores Antarctica New Zealand's efforts to raise awareness of the Scott Base Redevelopment and to build a connection between the New Zealand public and the new base. Below is an overview of the areas the presentation covers:

- "Colour our place, Scott Base" public engagement campaign, where New Zealanders were asked to vote on the colour of the new base.
- *Capturing the Story of Scott Base*, a documentary being made on the redevelopment project.
- Bringing our people on the journey of the rebuild: stakeholder engagement for the design of the new base, including user experience through cardboard mock-ups.
- Collaboration efforts with Antarctic partners: a DUPLO® exhibit for kids at the Antarctic attraction in the gateway city of Christchurch.
- Community engagement in Timaru, the regional town where the new Scott Base will be constructed.
- Community-born initiatives: an initiative of local students to virtually create the new base in Minecraft.

Modernising care delivery: the impact of modular training and equipment structures for Antarctica

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When considering polar operations, a key facet or consideration of part of the operational planning is the medical risk. Operating at significant reach with limited resource can generate an imbalance between the risk itself and the level of mitigation available.

In order to optimise medical risk mitigation (MRM), deploying individuals should receive training to support the deployed medical asset or to provide immediate medical care to those they are deployed with. To effect optimal MRM, training must be consistent with clearly defined learning objectives/outcomes that are drawn from the reality of operating at extreme reach in adverse conditions. All individuals who deploy as part of the British Antarctic Survey will have undergone mandatory “first aid” training to enable them to support with the care of a casualty or, if first on scene at a medical incident, to provide immediate aid. As an organisation delivering this training, we at the British Antarctic Survey Medical Unit (BASMU) have developed an extensive programme designed to enable any individual, regardless of trade or role, to be able to help their deployed colleague.

The key aspects of this session/discussion centre on the following:

- The structure of modular training and its delivery.
- Key learning outcomes for ensuring optimal MRM.
- The utilisation of the multidisciplinary team in constructing modular training.

In addition, this session also discusses the re-design of equipment structures to suit both modular training delivery and immediate utilisation by individuals, depending on their training level.

Antarctic School Fair: 20 years of collaborative science at the secondary school level

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Understanding Antarctica as a continent of the future means not only accepting its potential to transform and determine the future of the planet, but also the challenge of communicating this relevance to those who will be responsible for its protection: our future generations. For this reason, the challenge of stimulating motivation and interest in understanding and protecting this territory among young people from an early age has been an objective that the Chilean Antarctic Institute has systematically addressed. The most consistent effort has been the Antarctic School Fair, which for 20 years has led thousands of high school students to ask questions about Antarctica and to seek science-based answers with the help of their teachers.

According to Oppliger et al. (2019), "Science fairs increase motivation for science, interest in pursuing a scientific career, and decrease perceptions of scientific complexity in high school students, regardless of gender and socio-economic level." In addition, several pedagogical methodologies state that learning based on experience and project development emotionally engages young people in the learning process and enhances collaboration, critical thinking, and communication (Villanueva et al. 2022), essential transversal skills for the new generations.

The difference between the Fair and others that exist in Chile and elsewhere the world, besides this fair’s theme focussed on the White Continent, is that the Fair opens the possibility of two spaces that are inaccessible under normal conditions for a Chilean high school student: the winners have the opportunity to travel to Antarctica and to have a first-hand experience of the scientific work of real researchers.

The international co-operation inherent in Antarctic activity has also been a protagonist in the development of the Fair during its 20 years, being one of the elements that enrich the experience.

Gender lens in Chilean scientific Antarctic expeditions

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The Chilean Antarctic Institute (INACH) is implementing a gender perspective across its entire institutional body, including its employees and the scientific and logistic community involved in Antarctic expeditions. One of its main goals is to create safe spaces and promote gender equality, particularly during its Antarctic Scientific Expedition. INACH has made several changes, such as recruiting a gender-balanced logistic personnel, updating its code of conduct, and establishing protocols to prevent and address mistreatment, sexual harassment, and workplace harassment. During the last expedition, all participants received talks on how to treat each other respectfully and how to identify and report inappropriate behaviours. These actions demonstrate INACH's commitment to advancing gender equality and expected behaviour. As a result, people have been utilising formal communication channels more frequently when facing any inappropriate behaviour, report responses have been expedited, and work environments have been recreated in a more optimal way. This work is part of the Chilean Antarctic Institute Gender Agenda (2023–2026).

Eradication of non-native winter crane fly, *Trichocera maculipennis*, introduced to maritime Antarctica

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Here we describe our recent efforts to eradicate a non-native insect, the winter crane fly (WCF), *Trichocera maculipennis* (Diptera: Trichoceridae), from the King Sejong Station on King George Island. WCF was introduced onto King George Island, spreading over several research stations across the island. WCF is cold-tolerant in its native range, and the presence of WCF has been consistent in its invasive habitats over a decade on King George Island, despite some eradication attempts. At the King Sejong Station, systematic efforts have been made to obtain information on WCF's biology in its invasive range and to develop an eradication protocol. We have found that embryonic and postembryonic developments of WCF can be successful at least in part under the outdoor conditions on King George Island. We have also found that ultraviolet (UV) light and some habitat-related odorants are attractive to WCF adults. We have been closely monitoring the WCF population at the King Sejong Station by using traps over the last ten years or so. It appears that WCF is now being eradicated from the King Sejong Station, although the options that can be applied in the Antarctic environment are limited. Through the combination of delimitation of the presence of WCF, elimination of WCF adults from its habitats, management of its main habitats, and prevention of its re-entry, the number of WCF adults, monitored by UV trap captures and visual inspection, has been consistently decreased over the last few years. Now, no WCF adults have been captured or detected from the King Sejong Station since July 2022, and we will be able to declare a successful eradication of WCF from the King Sejong Station if no further WCF is detected there for one more year.

Understanding future sea-level change around Antarctica

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As the Antarctic Ice Sheet melts, coastlines near to melting ice may see overall sea-level fall due to gravitational effects. A sea level fingerprint for Antarctic modelled using 3-D Earth structure derived from seismic imaging shows that if West Antarctic ice melted at a rate that raised global sea levels by 1 millimetre per year on average, sea-level around all of West Antarctica and the Antarctic Peninsula would fall by several millimetres per year, whereas most of the East Antarctic coast would have greater rise than the global mean (Hay et al. 2017). Vertical land motion driven by ice mass loss, glacial isostatic adjustment (GIA), also strongly influences local sea level around Antarctic coastlines. New, more comprehensive constraints on the direction and magnitude of vertical land motion are being derived for coastal locations where GNSS measurements have been compiled as part of the collaborative SCAR GIANT-REGAIN project. Rapid uplift is taking place where ice mass is being lost near the Amundsen Embayment and the Antarctic Peninsula. Due to complexities in Earth structure and tectonic influences, some coastal sectors in these regions are moving downward. Similar variation in uplift or subsidence of coastlines occurs around the coast of East Antarctica, but at lower rates.

Future sea-level change around Antarctica's coastlines will impact infrastructure, heritage sites, ecosystems, and operations. Currently, however, no robust and spatially comprehensive projections of sea level exist for Antarctic coasts. The latest IPCC AR6 (Fox-Kemper et al. 2021) contains global, state-of-the-art sea-level projections to 2100 and beyond, but these were computed for only two locations along Antarctica's coastline, both within the northern Antarctic Peninsula (https://sealevel.nasa.gov/ipcc-ar6-sea-level-projection-tool), due to lack of *in situ* tide gauge observations in Antarctica.

Our collaborative effort aims to substantially improve sea-level projections for Antarctic coastlines by incorporating GNSS crustal deformation measurements, which will greatly augment the very sparse tide-gauge records and provide more vertical land-motion records. We have also identified many locations of COMNAP-Member facilities, penguin rookeries, Antarctic Specially Protected Areas, and Historic Sites and Monuments that are without sufficiently nearby, long-running GNSS instruments. These gaps can be filled if national programmes establish an enlarged network of observations of vertical land motion (GNSS) and sea level (tide gauges) and maintain them for many years – a goal of the SCAR INSTANT programme.

The practice of using scientific instruments of a new generation at the Belarusian Antarctic station for remote sensing of the natural environment of the Antarctic

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Remotely controlled and autonomous technologies have been identified in the SCAR Horizon Scan project and in the COMNAP Antarctic Roadmap Challenges (ARC) project as critical and priority for achieving scientific results in all disciplines.

At the Belarusian Antarctic Research Station (BARS), in order to support priority research and achieve the set scientific goals, instruments and instrumental complexes of a new generation for remote sensing of the natural environment of the Antarctic are being widely introduced.

This poster highlights the use of selected next-generation remotely operated and autonomous technologies at BARS to generate knowledge on priority scientific issues and areas of global concern, such as: an automatic meteorological station with a satellite communication channel for year-round (autonomous) transmission of measured meteorological parameters to a database on the mainland; autonomous systems for year-round temperature monitoring of the upper layers of soil, rocks, and snow and ice cover; an automatic seismic monitoring station; unmanned remotely controlled aircraft and underwater vehicles for performing multiple tasks in the interests of glaciological, biological, geological, and geophysical research and Search and Rescue operations; autonomous and automated instrumented systems for radiometric and lidar monitoring of atmospheric aerosols, and for spectrometric measurements of the reflection spectra of the underlying surface, as well as for monitoring the parameters of the atmosphere, ozonosphere, and ultraviolet radiation in air and water.

Science automation at Halley Research Station

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The British Antarctic Survey (BAS) introduced an automated power system to Halley Research Station to support winter-over science following a decision to cease wintering due to the discovery of an active chasm on the Brunt Ice shelf that threatened to calve (and subsequently did calve, in February 2023). This innovative, multi-year, project has delivered a micro-turbine power supply and datalink to a suite of autonomous scientific instrumentation around the Halley VI Research Station and on the Brunt Ice Shelf. This system enables data collection throughout the Antarctic winter when the station may be unoccupied.

The formal project is now coming to an end, having fully transitioned into an operational capability, with a focus now on developing resilience for the system.

UK–US International Thwaites Glacier Collaboration: Plans and challenges

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The 1st SCAR Antarctic and Southern Ocean Science Horizon Scan identified questions of Antarctic Ice Sheet mass balance and potential input to sea-level rise as critical research priorities. The US National Science Foundation (NSF) and the UK Natural Environment Research Council (NERC) funded the International Thwaites Glacier Collaboration to address these pressing questions through a large-scale field programme supported by the US Antarctic Program (USAP) and the British Antarctic Survey (BAS). The British Rothera Station and the US McMurdo Station sit at opposite edges of the West Antarctic Ice Sheet and are well-positioned to undertake this investigation. The goal of the logistics collaboration is to support a field effort larger than what either programme can support independently, by combining complementary logistics capabilities. BAS and USAP have contributed resources comprising research and operational vessels, aircraft, over-snow traverse, field equipment, and staffing. Since the first field activities in 2018, the collaboration has experienced challenges and delays associated with the COVID-19 pandemic, ship construction, and aging equipment, along with routine Antarctic

uncertainties such as poor weather. This poster summarises the original logistics plans, anticipated risks, and how USAP and BAS have been able to fill in resources when the other programme experienced unexpected setbacks.

International Cold Exposure Database (Drugs) (ICED(D)): A novel resource for the circumpolar community

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The handling of pharmaceuticals whilst operating at extreme reach and in extreme temperatures can be challenging. Maintaining medical stores at appropriate temperatures whilst working in deep field conditions adds an additional layer of complexity to operational planning to ensure that, if needed, emergency drugs are not frozen and are suitable for use. But what if there were agents that were able to be stored as depots in the deep field? What if there were agents that could undergo multiple freeze–thaw cycles and still be safe for use?

It is our intention to propose a novel, international, collaborative project looking at the effect of the polar environment on pharmaceutical agents (including their storage and delivery systems) to better inform those operating and providing remote support in extreme cold and at extreme reach.

The International Cold Exposure Database (Drugs) or ICED(D) is proposed as the first in a series of international collaborative projects looking to enhance the medical capability across the continent. The aim of the project would be to review multiple agent exposure to sub-zero temperatures and repeated freeze–thaw cycles to review for the following:

- Possible increasing cryo-concentration after freeze/thaw solute loss.
- Viable isomer formation or maintenance of existing drug molecular structure.
- Absolute freezing point/lowest operational temperature.
- Modification to dosing regimens/schedules if undergoing freeze–thaw cycles.

Although the above represents a sample of the possible aims for this project, it is hoped that when considered in conjunction with other workstreams, the impact of any outcomes will be far greater. When considering enhanced telemedicine or reach-back capabilities, the ability to store medications for longer and outside of traditional hard standing infrastructure may enhance the delivery of medical care.

The ICED(D) would be a truly collaborative project, utilising the currently available literature to guide all interested nations in working towards the shared aim. The ability to support remote operations without a strict warm chain and to utilise medications that have undergone freeze–thaw cycles may have direct benefit for safety assurance and patient care, and potential environmental impact from reduced freight transfer and temperature maintenance.

Standardisation across the Continent: The challenge of universal resources for Search and Rescue in the sub-Antarctic and Antarctic environment

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Search and Rescue (SAR) in the Antarctic is a concept delivered in practice by people who are usually not professionals within this specialism. It is undertaken with equipment that may be historic and highly variable in terms of function and location and that may be used by non-specialists. This leads to risk to rescuer(s) and patient(s), which can and should be mitigated against as much as possible. Standardising and modernising the training and equipment have become a key priority within the Antarctic and sub-Antarctic theatres.
This has entailed the following, which is ongoing:

- Assessment of current training and mapping of resources.
- Understanding the requirements (location, resources).
- Development of combined interdisciplinary training packages that include field guides, medical assistants, and physicians learning, under arduous conditions in multi-day events, SAR and medical-care techniques from multidisciplinary professionals who work and deliver SAR in hazardous environments.

- Specific examination of cold-water, shore-side and small-island rescue, utilising knowledge from UK sea- and water-rescue professionals.
- Rationalisation of medical and SAR equipment – modularised, simplified, and standardised.
- Electronic mapping of SAR and medical resources, with prompts for equipment checks, use guides, etc.
- Development and review of standard operating procedures for SAR to support high-risk decision-making and support personnel both in remote-site and parent-nation headquarters.
- Refinement and modernisation of SAR practice/moulage in location.
- Refinement and modernisation of nation headquarters table-top exercises.
- Learning and refinement of process through debrief and PDSA cycles.

Appendices

Appendix A: List of Keynote Speakers

COMNAP Symposium 2023
26 June 2023

Theme	**Title**/Presenter/Organisation
a	**COMNAPs proactive development and response to the SARS CoV-2 pandemic**, Tim Heitland, Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research (Germany)
b	**SCAR – Serving for over 60 years to facilitate international scientific collaboration in the Antarctic and Southern Ocean**, Deneb Karentz, University of San Francisco (United States of America) and the Scientific Committee on Antarctic Research (SCAR) Vice President for Science

Appendix B: List of oral in-person presentations

COMNAP Symposium 2023

26 June 2023

Theme	**Title**/Presenter/Organisation
a	**Transforming Antarctic Operations - management of change and modernisation of operations at BAS**, Amie Jackson, British Antarctic Survey (United Kingdom)
a	**An Introduction to the research on Co-operative mobile Robot System Technology for Polar Region Development and Exploration**, Dong-Jing Yoon, Korea Polar Research Institute (Republic of Korea)
b	**Concordia solar array and solar energy potential on Dome C site,** Emilie Perrott, IPEV (France)
b	**The Energetic Modernisation of Neumayer Station III,** Uwe Nixdorf, AWI (Germany)
b	**Energy Efficiency: New Antarctic scientific stations projects,** Ricardo Faundez, INACH (Chile)
b	**Innovation developments in JARE activities by NIPR for its 50 years commitments,** Takuji Nakamura, NIPR (Japan)
e	**Safety in Ship-Based Polar Expeditions: An Example of Turkish Polar Program,** Doğaç Baybars Isiler, Turkish Polar Program (Türkiye)
g	**Multinational Collaboration to Overcome Airlift Challenges in the 22/23 Season,** Stuart Gregory, USAP (United States of America)
g	**Snow runway for Ilyushin heavy aircraft in the Larsemann Hills (East Antarctica): renovation,**

	statistics for the first season and future prospects, Svetlana Grigoreva, Russian Antarctic Expedition (Russia)
g	**Air operations in the polar depths; public-private cooperation and the use of natural blue ice runways,** Miguel Figueroa, Chile
j	**Logistical challenges on future upgrades of Syowa Station,** Gen Hashida, NIPR (Japan)
j	**Argentina and Australia collaboration on environmental biotechnology,** Tim Spedding, (Australia)
j	**Success Through International Collaboration in Microgrid Operation on Ross Island,** Maria Fernando, Antarctica New Zealand (New Zealand)
k	**The Swiss Polar Institute Antarctic Circumnavigation Expedition,** Danièle Rod, Swiss Polar Institute (Switzerland)
k	**Team Polar – A sustainable & autonomous research rover for Antarctica,** Laurenz Edelmann, Netherlands Polar Programme (Netherlands)
k	**Implementing an Antarctic Regional Climate Centre Network,** Robert Argent, Bureau of Meteorology (Australia)
k	**Collaborative logistics to deliver operational efficiencies,** Dave Wattam & Christine Wesche, BAS (United Kingdom) & AWI (Germany)
k	**Lessons learned from past aerogeophysical collaborations for effectively launching new pan-Antarctic RINGS surveys,** Kenichi Matsuoka, NPI (Norway)
k	**Balloon Ice caves in Antarctica,** Rocco Ascione, PNRA (Italy)

k	**Spanish Antarctic Facilities "BAES": A Scientific and Technical Infrastructure open to international collaboration,** Sonia Ramos, CPE (Spain)

Appendix C: List of oral on-demand presentations

COMNAP Symposium 2023
26 June 2023

Theme	**Title**/Presenter/Organisation
a	**Enabling Science with a Subsea Fibre Optic cable for McMurdo Station, Antarctica**, Patrick Duncan Smith, USAP (United States of America)
b	**Ecuadorian Antarctic Refuge: The use of eco-materials, thermal conservation, and identity**, Carlos Alberto Andrés Donoso Paulson, Universidad Catolica de Santiago de Guayaquil (Ecuador)
k	**Foraging niche divergence in a climate change sentinel from the Antarctic Peninsula: evidence from bulk and compound-specific stable isotope analysis**, Renan Costa de Lima, COMNAP Antarctic Fellowship Awardee

Appendix D: List of posters

COMNAP Symposium 2023
26 June 2023

Theme	**Title**/Main Author/Organisation
b	**Decarbonising Antarctica Discussion Forum: An example of idea sharing to overcome a common challenge**, Sophia White, Antarctica New Zealand (New Zealand)
b	**Energy efficiency considerations for McMurdo Station Lodging facility,** Ben Roth, USAP (Unites States of America)
b	**Antarctic Infrastructure Renewal Program: Drivers and Strategies**, Matthew Wuersching, AAD (Australia)
d	**Silver Arctic - A new platform for supply and research in the Southern Ocean**, Stig Flått, Norwegian Polar Institute (Norway)
d	**Development of a Man-Portable Hybrid Autonomous Underwater Vehicle for Antarctic Deep Seabed Exploration**, Arturo Cadena Torres, (Ecuador)
d	**The USAP Antarctic Research Vessel (ARV) Project**, Timothy M. McGovern, USAP (United States of America)
d	**Introduction of the RRS Sir David Attenborough – 2 years on**, Richard Warren, BAS (United Kingdom)
e	**Using innovation to prevent Search and Rescue in the Australian Antarctic Program**, Chris Gallagher, AAD (Australia)
e	**Monitoring of natural hazardous objects of Antarctic oases: key results of the programme implemented at**

	the Larsemann Hills, Svetlana Grigoreva, Russian Antarctic Expedition (Russia)
e	**Expose to Treat – the Standardisation of Cold Casualty Care for Antarctica**, Jonathon Lowe, British Antarctic Survey Medical Unit (United Kingdom)
f	**Leveraging the Pandemic: How Advancements in Technology and Telemedicine Can Improve the Health and Well-Being of the Antarctic Deployer**, Elicia Liles, USAP (United States of America)
f	**Remote Medical Support to Polar Operations – The Effect of 'Reach Back' on Clinical Care Delivery**, Jonathon Lowe, British Antarctic Survey Medical Unit, (United Kingdom)
f	**DROMLAN (Dronning Maud Land Air Network) – 20 years of international collaboration - Establishing an efficient Air Network in Dronning Maud Land,** Sven Lidström, Norwegian Polar Institute (Norway)
g	**Improving the Co-ordination of Antarctic Aviation Has Positive Safety Benefits**, Rod Arnold, BAS (United Kingdom)
g	**Integrating RPAS into air operations**, Carl Robinson, BAS (United Kingdom)
g	**Korea's International Air Network Collaboration for the past 35 years**, Mingu Kang, Korea Polar Research Institute (Republic of Korea)
h	**COVID-19 – A review of the Impact of COVID-19 on Operations in the British Antarctic stations**, Jonathon Lowe, British Antarctic Survey Medical Unit (United Kingdom)
h	**COVID-19 protocol in Punta Arenas as a gateway city,** Marcelo Leppe, INACH (Chile)
h	**U.S. Antarctic Program COVID Posture and Collaboration**, Margaret Knuth, USAP (United States of America)

h	**Korea's Collaboration for COVID-19 Preparedness and Response amid COVID-19 Pandemic**, Sunhwi Kim, Korea Polar Research Institute (Republic of Korea)
i	**Breaking the ice: Communications for the Scott Base Redevelopment**, Samantha Chapman, Antarctica New Zealand (New Zealand)
i	**Modernising care delivery – the Impact of Modular Training and Equipment Structures for Antarctica**, Jonathon Lowe, British Antarctic Survey Medical Unit (United Kingdom)
i	**Antarctic School Fair: 20 years of collaborative science at the secondary school level**, Marcelo Leppe, INACH (Chile)
i	**Gender Lens in Chilean Scientific Antarctic Expeditions**, Geraldine Asencio Subiabre, INACH (Chile)
j	**Eradication of non-native winter crane fly, Trichocera maculipennis, introduced to maritime Antarctica**, Ji Hee Kim, Korea Polar Research Institute (Republic of Korea)
j	**Understanding future sea-level change around Antarctica**, Matt King, University of Tasmania (Australia)
k	**The practice of using scientific instruments of a new generation at the Belarusian Antarctic Station for remote sensing of the natural environment of the Antarctic**, Aleksei Gaidashov, (Republic of Belarus)
k	**Science automation at Halley Research Station**, Thomas Barningham, BAS (United Kingdom)
k	**UK-US International Thwaites Glacier Collaboration: Plans and Challenges**, Jessie Crain, USAP (Unites States of America)
k	**International Cold Exposure Database (Drugs) (ICED(D)) – A Novel Resource for the Circumpolar**

	Community, Jonathon Lowe, British Antarctic Survey Medical Unit (United Kingdom)
l	**Standardisation Across the Continent – The Challenge of Universal Resources for Search and Rescue in the Sub-Antarctic and Antarctic Environment**, Matt Warner, British Antarctic Survey Medical Unit (United Kingdom)

Appendix E: Oral presentations – Schedule 26 June 2023 – Hobart, Hotel Grand Chancellor, 11:00 – 19:00

Session 1 Themes: Antarctic Roadmap Challenges (ARC) Outcomes, Building and Energy Efficiencies and Safety Chairs: Patricia Ortúzar and Christine Wesche		
Time	**Presenters**	**Presentation Title**
11:00 – 13:00	Amie Jackson, British Antarctic Survey (United Kingdom)	**Transforming Antarctic Operations - management of change and modernisation of operations at BAS**
	Dong-Jing Yoon, Korea Polar Research Institute (Republic of Korea)	**An Introduction to the research on Co-operative mobile Robot System Technology for Polar Region Development and Exploration**
	Emilie Perrott, IPEV (France)	**Concordia solar array and solar energy potential on Dome C site**
	Uwe Nixdorf, AWI (Germany)	**The Energetic Modernisation of Neumayer Station III**
	Ricardo Faundez, INACH (Chile)	**Energy Efficiency: New Antarctic scientific stations projects**
	Takuji Nakamura, NIPR (Japan)	**Innovation developments in JARE activities by NIPR for its 50 years commitments**
	Doğaç Baybars Isiler, Turkish Polar Program (Türkiye)	**Safety in Ship-based Polar Expeditions: An example of Turkish Polar Program**
Session 2 Themes: Air Network & Environmental Chair: Christine Wesche and Miki Ojeda		
Time	**Presenters**	**Presentation Title**
13:30 – 15:30	Stuart Gregory, USAP (United States of America)	**Multinational collaboration to overcome airlift challenges in the 22/23 season**
	Svetlana Grigoreva, Russian Antarctic Expedition (Russia)	**Snow runway for Ilyushin heavy aircraft in the Larsemann Hills (East Antarctica): renovation, statistics for the first season and future prospects**

	Miguel Figueroa, Chile	**Air operations in the polar depths; public-private cooperation and the use of natural blue ice runways**
	Gen Hashida, NIPR (Japan)	**Logistical challenges on future upgrades of Syowa Station**
	Tim Speeding, (Australia)	**Argentina and Australia collaboration on environmental biotechnology**
	Maria Fernando, Antarctica New Zealand (New Zealand)	**Success Through International Collaboration in Microgrid Operation on Ross Island**
Session 3 Theme: Science and Science Facilitation Chairs: Patricia Ortúzar and Gen Hashida		
Time	**Presenters**	**Presentation Title**
16:00 – 18:00	Danièle Rod, Swiss Polar Institute (Switzerland)	**The Swiss Polar Institute Antarctic Circumnavigation Expedition**
	Laurenz Edelmann, Netherlands Polar Programme (Netherlands)	**Team Polar – A sustainable & autonomous research rover for Antarctica**
	Robert Argent, Bureau of Meteorology (Australia)	**Implementing an Antarctic Regional Climate Centre Network**
	Dave Wattam BAS (United Kingdom)	**Collaborative logistics to deliver operational efficiencies**
	Kenichi Matsuoka, NPI (Norway)	**Lessons learned from past aerogeophysical collaborations for effectively launching new pan-Antarctic RINGS surveys**
	Rocco Ascione, PNRA (Italy)	**Balloon Ice caves in Antarctica**
	Sonia Ramos, CPE (Spain)	**Spanish Antarctic Facilities "BAES": A Scientific and Technical Infrastructure open to international collaboration**
18:00 – 19:00	Opportunity to view the Symposium posters, network with exhibitors.	