PROCEEDINGS OF THE COMNAP SYMPOSIUM 2020

Future-proofing Infrastructure to Support Research and to Reduce Environmental Impact

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ANTARCTIC STATION MODERNISATION: FUTURE-PROOFING INFRASTRUCTURE TO SUPPORT RESEARCH AND TO REDUCE ENVIRONMENTAL IMPACT

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THE COUNCIL OF MANAGERS OF NATIONAL ANTARCTIC PROGRAMS

THE COUNCIL OF MANAGERS OF
NATIONAL ANTARCTIC PROGRAMS

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Foreword

In December 2018, COMNAP published the Proceedings of the COMNAP Symposium 2018 “Facilitation of Internationally Collaborative Antarctic Science”, which included a foreword much like this one you are reading right now. The 2018 Proceedings, however, contained prescient thoughts from the COMNAP Chair Dr Kelly K. Falkner that are worthy of recalling now. In 2018, Kelly wrote:

> *“Facilitation is the act of helping others achieve their goals. In the case of national Antarctic programmes, facilitation entails sharing of specialised knowledge and skills in order to achieve long-term planning, dependable logistics chains, and implementation of the plans and policies to ensure scientists arrive where and when their research objectives demand. It also includes, among other things, technologies to appropriately collect, transit, and store data and samples. On top of all that, there is always a need for “Plan B”.”*

The Chair then closed her remarks with, *“...we all look forward to continuing to work together to tackle both the well-known and the new challenges...”* on our horizon.

It seems almost surreal looking back to December 2018, and without knowing it then, the national Antarctic programmes and the world were less than a year away from the beginnings of a global pandemic, the ultimate new challenge, requiring international co-operation, preparedness, and the need for a “Plan B”.

From a practical perspective, the restrictions on global travel and the need for countries to close borders and isolate populations in an effort to slow down the virus spread meant that COMNAP, and the host of our annual meetings, the Australian Antarctic Division, made an early decision to cancel all in-person meetings for 2020. This included the cancellation of the 19th COMNAP Symposium scheduled to take place in Hobart, Tasmania, Australia on 2 August 2020. With that early decision to cancel the in-person meetings, COMNAP quickly moved to ensure the COMNAP Symposium 2020 went ahead, albeit in an online virtual format.

Not only are these Proceedings a record of the particulars of the presentations, but they will also serve to remind us of our need to change our plans, to adapt to complex challenges, and to implement our "Plan B" when required. The Proceedings are a showcase for the complex tasks that many national Antarctic programmes are only just beginning to undertake in regard to their Antarctic station modernisations. The Proceedings will support the recorded, virtual Symposium presentations that were ultimately delivered by way of the COMNAP YouTube Channel. The welcome video by COMNAP Symposium Convener Charlton Clark was made live on 10 August 2020. At the time of the writing of these Proceedings, there had been 187 individual views of the welcome video and over 2,000 individual views of the 15 Symposium presentations. The COMNAP YouTube Channel is assisting us to reach a much wider audience than ever before and the community is watching and paying attention. Congratulations go to Charlton, who became a YouTube star overnight.

While the platform for the Symposium has moved online, the purpose, as found in the Symposium First Circular, remains the same:

> *". . . support COMNAP Member national Antarctic programs in their role as facilitators of Antarctic research . . . provide a forum to aid the conversations between engineers, technologists, health and safety managers, scientists, environmental managers and the range of people involved in the Antarctic facilities' modernisation projects."*

Modernisation of Antarctic infrastructure is critical and addresses facilities that are past their "use by date". Modernisation also provides the opportunity to include innovative technologies and services that are sustainable and that reduce direct environmental impact, and technologies that support modern research requirements. A commitment to modernisation requires significant contributions by governments of funds, resources, and people over the course of many years. It requires solid planning and decision-making and the need to understand Antarctic conditions now and for the next 50 years – the anticipated life expectancy of much of the Antarctic infrastructure currently under development.

If we cannot see a global challenge on our horizon only a few months away, how do we contemplate the range of possibilities and challenges that we might face in the next 50 years in Antarctica?

The COMNAP Antarctic Roadmap Challenges (ARC) project went some way to addressing future challenges, therefore frequent referral to the project outcomes will certainly continue to assist national Antarctic programmes in the planning of their infrastructures. Having, collectively, the greatest first-hand knowledge of the Antarctic region living within the national Antarctic programme teams also provides us with an advantage. Those programmes have been the witnesses to change, and to consistency, in the Antarctic region for over 60 years now.

The Symposium is but only one forum where, through COMNAP, national Antarctic programmes can come together, learn from each other, and address challenges. Together, we can work to support our Plans A and B, and even a Plan C when required.

As the COMNAP Chair Dr Kelly K. Falkner said two years ago, together we can tackle both well-known and new challenges. Truer words have never been spoken and may never be more relevant than they are today. We hope that the global COVID-19 pandemic is brought under control for our whole COMNAP Antarctic family and for all countries of the world, and that it soon allows us to lift restrictions related to social distancing. We look forward to being together once again, if not for the COMNAP Symposium 2020, then hopefully at some point in the near future. Virtually or in person, through COMNAP, we will continue to share information amongst the entire COMNAP community and we stand ready to address together challenges that arise.

Agnieszka Kruszewska
COMNAP Vice Chair
EXCOM Officer, Symposium

Acknowledgements

These Proceedings are a record of the 19th COMNAP Symposium on “modernisation” with a goal to “future-proof” our infrastructure in order to meet, or exceed, environmental protection obligations and to support the range of globally important Antarctic research.

Our Antarctic buildings literally have stood the test of time and the elements; going beyond what many thought would be a reasonable life expectancy. I would like to think that this could be due, at least in some small way, to the discussions and presentations shared at the very first Symposium on Antarctic Logistics held in 1962. That first Symposium, held five years on from the International Geophysical Year (IGY), looked at the “symbiosis” of operations, logistics, and science and had its largest session on the topic of “buildings”. Presenters shared their plans for building designs, incineration latrines, fire-fighting, freshwater production, and sewage disposal, and the behaviour of basic materials at low temperatures. One of three speakers on “site selection and installation development” from that first Symposium, presenter Paul Siple, said, “A new station is like that of an infant that it is bound to grow in size. Each new generation of occupants provides the requirements and nourishment.” Well, our infants have grown into old age and each generation has left its mark on those structures.

Our generation has an opportunity to ensure we incorporate innovative technologies that support environmental protection, continue high-quality support to research, and effectively integrate health and safety standards to best serve Antarctic expeditioners now and into the future. The

sharing of information and ideas as part of the Symposium is one way to ensure we achieve these lofty goals.

This year's Symposium would not have been possible without the efforts of the presenters, all of who had to become comfortable with recording of their presentations; and so, special acknowledgement goes to all presenters for embracing the use of virtual technologies to bring their Symposium message to the community. As Convener, I would like to thank the other Symposium Review Committee members – Simon Garrod (United Kingdom), Stephanie Short (USA), Bo Sun (China), and Safety Expert Group Leader Simon Trotter (New Zealand) – who all played a key role to review the abstracts received and to select a broad range for inclusion in this year's Symposium. Former EXCOM Vice Chair Sergio Gago Guida (Brazil) and Vice Chair Agnieszka Kruszewska (Poland) are each thanked for providing EXCOM oversight of the Symposium project, Sergio to 1 April 2020 and Agnieszka thereafter. Special thanks go to Symposium Project Manager, Andrea Colombo, COMNAP Research and Project Development Manager, who ensured the Symposium was ready to be launched from the COMNAP YouTube Channel during the week of the COMNAP AGM XXXII (2020) and for his efforts to ensure these Proceedings were brought together and published. His work has been outstanding. Additionally, I would like to acknowledge the work of Rob Wooding, former EXCOM Vice Chair and Symposium Convener (to December 2019) for the active role he played within COMNAP until his move to a new position within the Australian Antarctic Division.

It was my pleasure to take on the role of Convener in late 2019 and to work with everyone within COMNAP to deliver the virtual event and to see the publication of these Proceedings as a record of the 19th COMNAP Symposium.

Charlton Clark
COMNAP Symposium Convener

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Oral Presentations

HOW FUTURE-FOCUSSED LOGISTICS AND INFRASTRUCTURE WILL ENHANCE ANTARCTIC SCIENCE[1]

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Introduction

The Australian Antarctic Division (AAD) is shaping the future of the Australian Antarctic Program and formulating long-term logistics and infrastructure works to enhance the ability of scientists to answer questions of global significance.

The AAD is in the early stages of developing a master plan for Davis research station that will incorporate new and emerging technologies to improve efficiency in water and energy systems and to improve waste-handling streams, thereby reducing the station's per capita environmental and operating demands.

The AAD is also continuing to progress plans for an aerodrome capable of supporting year-round access to East Antarctica, subject to environmental and other government approvals. If approved to proceed, the Davis aerodrome would be East Antarctica's premier aviation hub, with year-round flights to

[1] The video of this presentation is available at https://youtu.be/1VmQ8Zav0ZA.

the continent departing from the Antarctic gateway city of Hobart, Australia.

It is envisaged that expeditioners landing at the aerodrome would be taken to Davis station, or transported to field camps and stations further afield through a network of intracontinental flights operated by Australia and other nations.

Background

The *Australian Antarctic Strategy and 20 Year Action Plan* sets out Australia's national Antarctic interests and vision for future engagement with the continent.

Since the release of the strategy and action plan in 2016, the Government has invested significant funding to ensure Australia can continue its strong support for the Antarctic Treaty System, run Australia's Antarctic operations safely and efficiently, and deliver world-class science.

It also recognises Hobart's role as an important Antarctica gateway and the most common departure point for expeditions to East Antarctica – by both Australian and international parties.

Establishing year-round access to Antarctica is a key component of Australia's new era of Antarctic endeavour, and, if approved to proceed, it will underpin engagement with the continent for decades to come.

The proposed Davis aerodrome is being assessed under the Antarctic Treaty (Environment Protection) Act 1980 (ATEP

Act), which implements the Protocol on Environmental Protection to the Antarctic Treaty, and also under the Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act).

The Scientific Committee on Antarctic Research (SCAR) *Antarctic & Southern Ocean Science Horizon Scan* (2014) notes that future research on the continent will require expanded year-round access. The *Antarctic Roadmap Challenges* (ARC) published by COMNAP in 2016 also outlines the multiple benefits of expanded, year-round access to the continent and access to deep-field sites within the continent. If approved, the Davis aerodrome will enable exactly this – overcoming one of the most significant barriers facing the Antarctic community and enabling Antarctic scientists to focus on answering critical questions of global significance.

A Modern Davis Research Station

While developing the Davis research station master plan, the AAD is considering the future requirements of Davis station both with and without the proposed Davis aerodrome.

Six key principles underpin the development of a master plan, which comprise the following:

- Enhance health, safety, and well-being
- Promote and facilitate world-leading science
- Represent Australia in Antarctica
- Lead environmental protection
- Showcase holistic sustainability

- Provide future flexibility

Initial work to stabilise current Davis station infrastructure is underway to address the ageing station and sustainably support a station capacity to accommodate maintenance and works crews as well as teams undertaking site assessments for the aerodrome. These works are envisaged to require seven years to be completed.

Shaping the future of AAD’s station infrastructure, the final master plan station (Figure 1) provides a long-term vision for station facilities that support a wide range of activities in East Antarctica. Davis station would continue to be a major logistics and research hub in East Antarctica and provide accommodation, transport, and logistics opportunities to scientists, including those who will transit via Davis to other stations and deep-field camps.

If the aerodrome project is approved, the final construction of a modernised Davis station will follow the construction of the aerodrome. If the aerodrome project is not approved, the delivery of a new modernised station will be earlier.

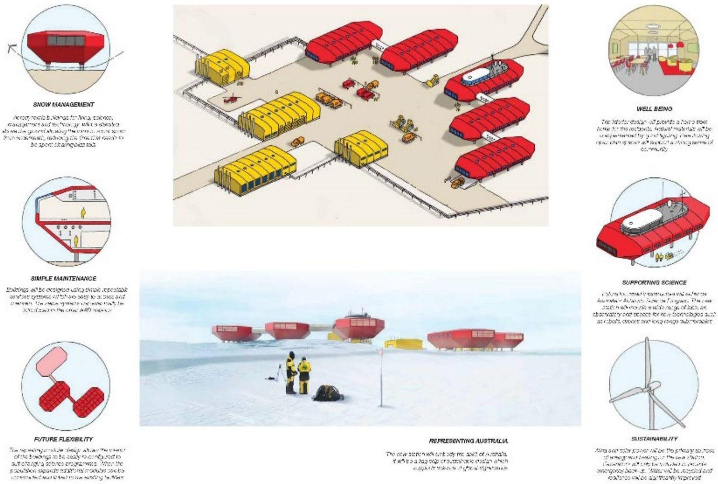

Figure 1: Illustration of the Davis station modernisation master plan. (Credit: AAD)

Davis Aerodrome Project

After three field seasons of geotechnical and environmental investigations, the AAD has identified a suitable site for the runway in the Vestfold Hills region, East Antarctica, approximately 6 kilometres from Davis station. The Vestfold Hills is a triangular area of rounded rocky hills that are predominantly ice-free and cover an area of approximately 410 square kilometres. The proposed aerodrome footprint would be approximately 2 square kilometres (Figure 2).

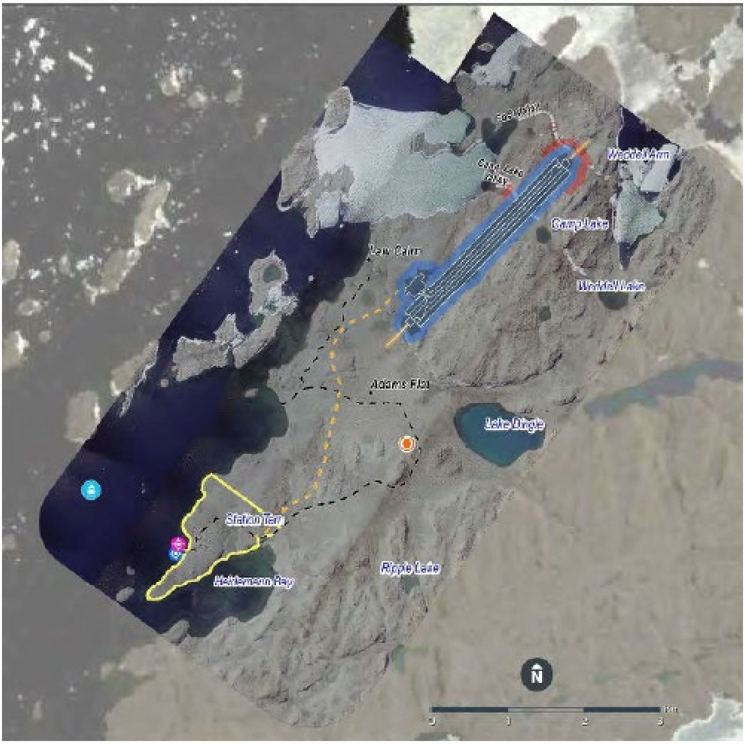

Figure 2: Aerial view of the site of the proposed Davis aerodrome. (Credit: AAD)

The project proposes a 2,700-metre paved Code 4E runway suitable to accommodate all existing and future large aircraft capable of return flights from Australia without refuelling at the aerodrome. It is envisaged that the runway would be constructed from precast concrete pavers manufactured in Australia and shipped to Antarctica where they would be assembled on-site. These pavers would measure approximately 5 by 3 metres and would be around 250 millimetres thick. Transporting 11,500 panels, weighing up to 10 tonnes each by way of ship would be a significant undertaking, as would be transporting the construction workforce and equipment. Modular and prefabricated techniques would be used to minimise *in situ* constructions.

Aviation infrastructure, including a taxiway, aircraft apron, runway lighting, intracontinental aircraft hangars, expeditioner processing facility, storage shed, fuel storage, and Aerodrome Rescue and Fire Fighting Services (ARFFS) station and air traffic services (ATS) centre would also be constructed as part of the project.

A 4.5 kilometre unsealed road connecting the station to the aerodrome would be built to allow the construction works to get to the aerodrome and would then be used to transport cargo and expeditioners between the station and aerodrome. A new wharf would be built to support the delivery of construction materials required during the construction.

It is anticipated the construction process would take 10 years to complete and the aerodrome would start its operation in 2040. The aerodrome would be located at approximately six to seven flight hours' time from Hobart and it would become the Australian Antarctic Program's primary inter- and intracontinental aviation hub (Figure 3).

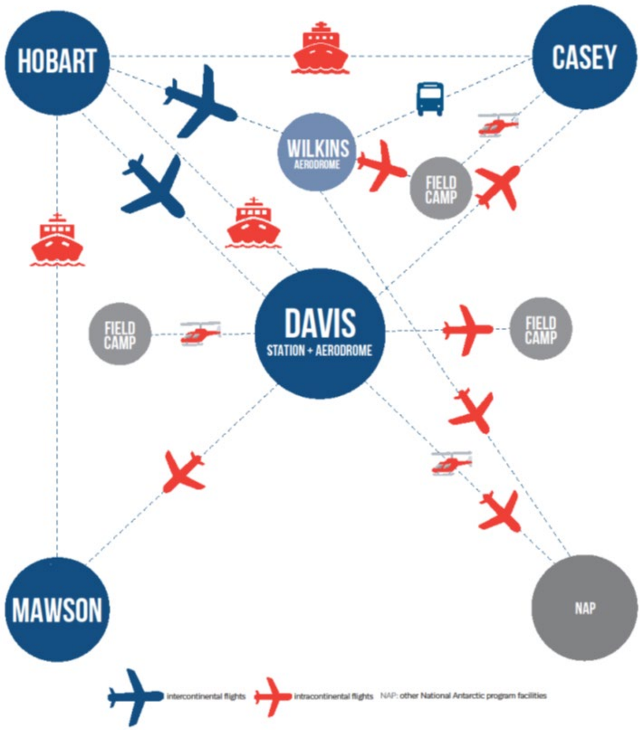

Figure 3: Schematic of the proposed Davis aerodrome operations. (Credit: AAD)

The Davis aerodrome could be used for aircraft from Australia and these would be conducted under the charter of the AAD or by the Australian Government. Australia would offer available capacity for cargo and passenger on chartered aircraft to support ongoing collaborative arrangements with other national Antarctic programmes. While the Davis aerodrome would not accept intercontinental flights from other nations, it would offer support to intracontinental flights. Wilkins Aerodrome would continue to support Casey research station during the summer season. To meet the forecast demand for personnel transport, it is anticipated there would be three intercontinental flights per month between October and May to Davis. During the winter there would be one flight per month. Up to 10 heavy-lift cargo flights are also anticipated each year. During the winter months the Davis aerodrome would also provide support to helicopters and fixed-wing aircraft for intracontinental flights in support of year-round science.

In March 2020, the AAD hosted a series of workshops to understand how enhanced logistics could help scientists answer questions of global significance. The outcomes of the workshops were published in the *Future Science Opportunity Synthesis Report*.

Antarctic scientists outlined the benefits for Antarctic research that could be unlocked by more regular and reliable access to the icy continent, including access during the cold, dark winter months.

An ambitious agenda for future Antarctic research enabled by year-round access was discussed, including the following:

- Higher-resolution models for weather forecasts and climate projections
- More-detailed understanding of the southern hemisphere's climate

- Improved understanding of Antarctica's contribution to global sea level
- Use of oceanographic sampling devices on seabirds and seals to capture winter oceanographic data
- Monitoring of marine resources across all seasons, and enhancing sustainable management of fisheries populations, including krill – the keystone species of Antarctica

Scientists also highlighted opportunities for increased innovation, large-scale and multidisciplinary science campaigns across multiple regions of Antarctica, rapid responses to important observational events, and improved safety and efficiency.

The AAD is currently preparing an environmental assessment, which will be released for public comment in Australia and internationally and presented to the Antarctic Treaty nations.

THE BELARUSIAN ANTARCTIC STATION: THE COMPLEX APPROACH TO CREATION, CONSTRUCTION, AND RENOVATION[2]

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Background

In December 2015, with the transport and logistics assistance of the Russian Federation, the Republic of Belarus began to create the infrastructure of the Belarusian scientific station "BAS" in Enderby Land in East Antarctica, on Mount Vechernyaya of the Thala Hills. The presentation provides an update on the construction, which is making good progress.

The Belarusian Scientific Station "BAS"

The Republic of Belarus began to create the infrastructure of the BAS in East Antarctica in 2015 at the location of 67^{o} 40' S, 46^{o} 09$'$ E. The modules were built off-site, external to Antarctica, and were then transported by ship to the site, ready for placement and finishing.

The infrastructure is composed of two separate structures occupying separate platforms. The first object installed was a three-section module for control, communications, and navigation on platform one (Figure 1).

[2] The video of this presentation is available at https://youtu.be/pL8iRh3hcIw.

Figure 1: Control, communications, and navigation module installed during Belarusian Antarctic Expedition (BAE) VIII. (Credit: BAE)

Through the period for Belarusian Antarctic Expedition (BAE) IX to BAE XI, a second platform and five sectional laboratory and residential modules were installed (Figure 2).


Figure 2: Installation of modules during BAE X. (Credit: BAE)

In BAE XII, three more sections were added to the second platform, and, in April 2020, the modular structure of the second platform was combined into a single base of eight sectional laboratories, services, and residential modules (Figure 3).

This brings a total of 11 functional modules installed and ready for use. (Figure 4).

Figure 3: The second platform consisting of eight sectional modules. (Credit: BAE)

Figure 4: Completed construction: first site (right view), second site (left view). (Photo: BAE)

In addition, during BAE IX to BAE XI, four new technological objects were put in place. Those are a diesel power plant complex (Figure 5), a refrigerated container (Figure 6), a garage box (Figure 7), and a VISAT satellite communication antenna (Figure 8).

Figure 5: Diesel power plant complex. (Credit: BAE)

Figure 6: Refrigerated container. (Credit: BAE)

Figure 7: Garage box. (Credit: BAE)

Figure 8: VISAT satellite communication antenna. (Credit: BAE)

When carrying out work on the creation of BAS, an integrated approach is used to simultaneously work on the installation of new infrastructure, to remove or repurpose (utilisation) the old materials, and to reconstruct or modernise the buildings from the period 1980–91 that have been preserved in a satisfactory condition and will remain on-site. These older buildings are from the activities of the Soviet Antarctic Expeditions (Figures 9 and 10).

Figure 9: An example of one of the old Soviet Antarctic Expedition buildings: converted to a new biological laboratory during the modernisation process. (Credit: BAE)

Figure 10: Second example of one of the old Soviet Antarctic Expedition buildings: converted into new living quarters. (Credit: BAE)

Conclusion

A multi-year programme of works is underway, with the Republic of Belarus progressively implementing the plan for the creation of a modern research station in Antarctica. The modernised station will provide the necessary conditions for scientific activities and seasonal and year-round accommodation for up to 16 people by the end of the 2020/21 Antarctic season.

The construction of BAS facilities is carried out in strict accordance with the Final Comprehensive Environmental Evaluation Assessment submitted by the Republic of Belarus at ATCM XXXVIII / CEP XVIII (Sofia, Bulgaria), IP39 *Construction and operation of the Belarussian Antarctic Station on Mount Vechernyaya, Enderby Land – The Final Comprehensive Environmental Assessment.*

ARCHITECTURE AND CONSTRUCTION OF THE NEW MAIN BUILDING OF THE ARCTOWSKI STATION[3]

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Kuryłowicz & Associates Architecture Studio

Introduction

Poland is in the planning phase for the comprehensive conversion of the Henryk Arctowski Polish Antarctic station located in Admiralty Bay, King George Island.

The scope of works includes the construction of a new main residential building, two new warehouses that are inclusive of a garage for mobile equipment with an evacuation shelter and a garage for vessel equipment, and the modernisation of all existing infrastructures. These existing infrastructures include the power plant, the main fuel depot, the two warehouses, several residential buildings, a lighthouse, and all service networks (power, water, and sewage).

This Symposium paper focusses on the main building planning, design, and proposed construction, since it is the most complex portion of the scope of works for the modernisation.

[3] The video of this presentation is available at https://youtu.be/pL8iRh3hcIw.

Current and Proposed Locations

The Henryk Arctowski Polish Antarctic station consists of several buildings that need to be renovated or replaced. Because of the station's location on the coast, for some of the buildings replacement is required, due to the rising level of the ocean. Figure 1 shows an aerial view of the current facility and the proximity of some the buildings to the shore.

Figure 1: Henryk Arctowski station aerial view. (Credit: Kuryłowicz & Associates Architecture Studio)

The location of the new main building has been chosen to be well above sea level and to minimise impact on the environment (Figure 2). The station will be raised approximately 3 metres above the ground, using a steel sub-structure, which allows the flow of wind and snow under the building. The shape of the station, its location, and the raised structure are designed to address the specific extreme climatic conditions of the location, which are characterised by powerful winds and significant annual snowfall.

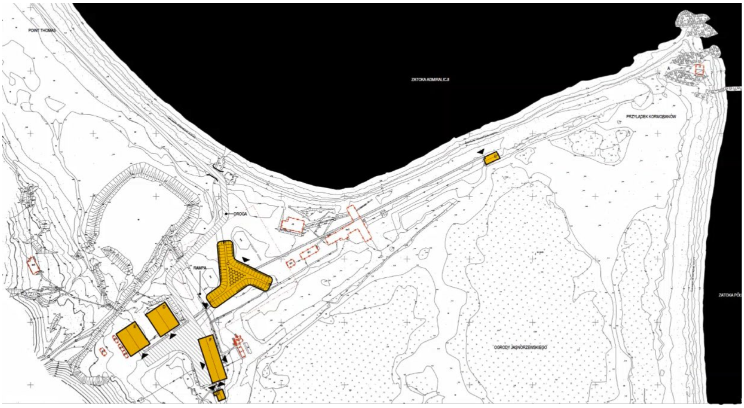

Figure 2: Proposed location for the modernised Henryk Arctowski station. (Credit: Kuryłowicz & Associates Architecture Studio)

Building Shape

The building shape was designed in a special way to mitigate the wind load on structural elements and to prevent snow accumulation around the structure and at the entryway. The building will be situated in accordance to the main wind direction, which is the south-west. At the beginning of the design process, multiple models trialling a range of shapes and layouts were drafted and each model underwent rigorous testing in wind conditions that simulated the extreme Antarctic winds at the site. The chosen design performed the best in regard to aerodynamic profile, meaning the chosen shape produced the largest downward pressure.

The design also incorporates functionality, employs a modular strategy, and takes into account exposure to and availability of sunlight hours to obtain the maximum light hours year-round. This is especially important for the winter-over station and wintering team.

The Structure

The main building structure will consist of a precast timber frame with sandwich panels as cladding. The outer layer is to be made of a special alloy of aluminium with copper. This material provides sufficient stiffness and is resistant to mechanical grinding caused by particles carried by wind. With environmental sustainability in mind, the building was designed to utilise as much natural light as possible. Necessary power will be partially provided by renewable energy sources (photovoltaics).

The entrance hall to the station will be located on the ground floor, referred to as level 0. The entrance itself is hidden in a niche, which is protected from the prevailing weather conditions. In addition, in order to prevent snow accumulation at the entrance, the main building is to be elevated on a steel truss, which is to be set on a precast concrete foundation.

The building will have three wings. Wing one will host laboratories and a library on level 1 (Figure 3), and living quarters on level 2. Wing two will contain the medical room on level 1 and guest rooms on level 2. Wing three will be used for food and general-use storage. The central area connecting the three wings will be the common area. Each space has been designed in sectional modules that could be repurposed for specific needs.

Level 1 will be the central multi-function section of the station, hosting meeting and lecture rooms, the dining room, and the kitchen.

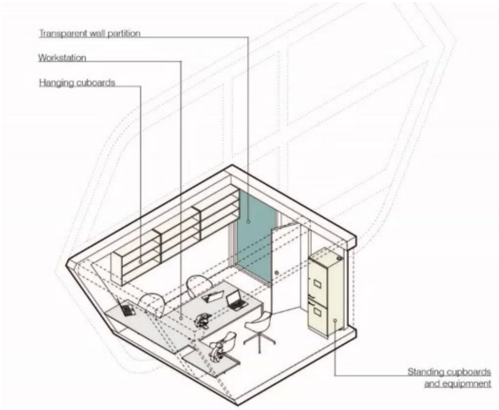

Figure 3: Graphic showing an example of the modular laboratory and library rooms. (Credit: Kuryłowicz & Associates Architecture Studio)

Level 2 will host the living quarters. This area will be protected by glass walls to assure privacy and to reduce noise levels. One of the wings will contain rooms for the visitors; the rest of the space, including a gym and hydroponics facility, will be used for recreational activities. The living quarters have been designed as modular single rooms that will contain a folding internal fit-out making it possible to achieve a sense of space despite the limited dimensions (Figure 4). There will be rooms for visitors, and also double rooms and rooms for up to four occupants. These larger rooms have been designed with the use of the bigger span of the module and are adaptable to specific requirements.

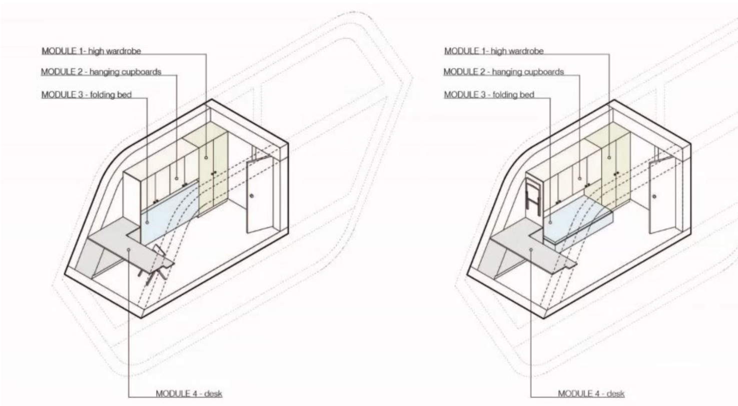

Figure 4: Graphic showing an example of a modular single room and the flexibility provided by the incorporated folding fit-out. (Credit: Kuryłowicz & Associates Architecture Studio)

Challenges

Building anything in the Antarctic is challenging. Moving materials from Poland to the Antarctic presents logistics challenges as well. The modernisation plan calls for the entire structure of the station to be prefabricated in Poland and built on a test site there before it is dismantled and systematically fitted into containers, ready for transport to Antarctica.

Transport from Europe to Antarctica will be by sea. It is estimated that the delivery of all the prefabricated elements, including foundations, external walls, and slabs would require 113 standard-sized containers. Each container must be carefully filled, and so planning includes working out which sections will fit into a container together in order to guarantee that none of the containers is too heavy for loading and offloading and transport to Antarctica.

The main building will have a usable area of approximately 1,500 square metres. The structure will use steel and wood to provide maximum modularity. Concrete will be used as the foundation for the station, on which a steel frame tubular profile will be placed to form the base of the building.

On top of this base, a light structure of prefabricated laminated wood, characterised by its resistance to weather conditions, will be built. The roof structure and slabs will be made of wood beams. The station shell will be made of prefabricated timber and layers of acoustic and thermal insulation, protected by a robust skin of copper and aluminium sheets (Figure 5).

Figure 5: An illustration of the proposed main building of the new Henryk Arctowski station. (Credit: Kuryłowicz & Associates Architecture Studio)

Construction will be carried out only during the four summer months, between December and March.

Conclusion

The new station is designed to reach a high standard of safety and well-being of the station crew and has a focus on environmental protection and long-term support to Antarctic research.

Structural components and other required materials will be transported by sea in standard shipping containers after trial assembly and disassembly at the manufacturing site.

The modular, prefabricated design allows for off-site preparatory works to be carried out any time of year, while construction works on-site will be undertaken during Antarctic summer seasons.

DESIGNING AND VALIDATING A SUSTAINABLE ANTARCTIC STATION[4]

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Introduction

The Scott Base Redevelopment Project is a multi-year project that will see the replacement of New Zealand's Scott Base and the upgrade of the Ross Island Wind Energy wind farm. Antarctica New Zealand set environmental and sustainability requirements as a key part of the design for the project, including the requirement for independent accreditation of the sustainable design of a building in Antarctica.

The Scott Base Redevelopment Project will integrate innovative architectural elements, energy efficiency, and

[4] The video of this presentation is available at https://youtu.be/_A-l0Zy3De0.

occupant health and well-being, and will demonstrate leadership in the design and construction of a sustainable building for Antarctica. Antarctica New Zealand is currently working through the design and analysing options for logistics and construction methodologies, ranging from a traditional build on-site, to a full build off-continent and a large ship delivering the pre-assembled station to Antarctica.

Independent accreditation of the sustainable design of a building in Antarctica required a sustainability accreditation tool that is both robust and specific for the Antarctic built environment. As no known accreditation tool existed for Antarctica, one was developed in collaboration with the New Zealand Green Building Council, and a bespoke Green Star Custom Tool for the design and as-built building was created.

The Green Star Custom Tool encourages practices that reduce the project's contribution to climate change, enhance the health and well-being of inhabitants, ensure high performance of buildings, and contribute to market transformation (being an innovator of new sustainable technology to support market exposure).

Sustainability Requirements

Two key strategic objectives of the Scott Base Redevelopment Project that are central to this theme are: to protect the Antarctic environment, and to provide an environment that keeps people safe and healthy. These two overarching project objectives led to the development of principal environmental and sustainability requirements, including

- compliance with the Antarctic Treaty;
- reduction in fossil fuel consumption;
- minimisation of waste production; and
- improvement in the quality of wastewater discharge.

These objectives and requirements are also aligned with the requirements needed to achieve Green Star accreditation for sustainable design.

Sustainable design attempts to reduce environmental impacts during the production of a building's components and the construction process, as well as for the whole life cycle of the building. However, a sustainable design is broader than environmental aspects alone. In fact, sustainable design covers social sustainability, health and well-being of occupants, material and product responsibility, and transparency.

Various sustainable design accreditation schemes have been developed worldwide, many of which are administrated by the World Green Building Council. Antarctica New Zealand chose to collaborate with the New Zealand Green Building Council due to local knowledge and the close collaboration required for the development of a custom tool. Green Star is New Zealand's only comprehensive Green Building rating scheme.

The remote Antarctic location, the extreme weather conditions, and the mixed-use functionality of the proposed facilities have presented challenges related to the application of standard accreditation tools. For this reason, Antarctica New Zealand, in collaboration with design consultants and the Australian and New Zealand Green Building councils, developed a custom Green Star tool to be used on the Scott Base Redevelopment Project.

Custom Green Star Accreditation Tool

The Green Star Antarctic custom tool was based on the existing Green Star accreditation tool, with categories on energy and carbon management and life-cycle assessment for material impacts remaining largely unchanged. Non-applicable categories were excluded, and other categories were modified to ensure their suitability for encouraging sustainability in the Antarctic context. These modified categories focussed on indoor environment quality to enhance occupant health and well-being, emphasising operational policy development, and environmental protection based on the Protocol on Environmental Protection to the Antarctic Treaty. The following sections provide an overview of the various categories that form this custom tool.

Management

Management in Green Star is a commitment to performance and environmental targets, and the setting of policies to operate the building sustainably. This includes the commissioning and tuning of the building, adaptation and resilience, providing building information, and monitoring the organisation's commitment to performance. The management category also covers responsible construction practices and accounting for effective site planning and layout.

Occupant health and well-being

The occupant health and well-being category focusses on the interaction between people and the building. Modules include the provision of amenities enhancing the occupants' well-being, indoor air quality, including elimination of pollutants, acoustic comfort, lighting comfort and control, thermal and visual comfort, providing sensory variability, and the provision of universal design. Additionally, this category covers the organisation's emergency preparedness and emergency facilities.

Energy and water

Energy and water form a large component of Green Star, accounting for 40% of the points in the custom tool. This category focusses around efficiency of energy and water use, and provision of renewable energy sources. The category is heavily focussed on reducing the building's contribution towards climate change.

Materials

The materials category focusses on modelling the life cycle impacts of the design, where embodied and operational environmental impacts of materials are assessed. The materials category also accounts for responsible materials and sustainable products selection.

Environmental and wildlife protection

The Protocol on Environmental Protection to the Antarctic Treaty is central to this category. This section has been heavily modified for the Antarctic context and focusses on biodiversity, site remediation, and the elimination of pollutant impacts, including from wastewater and refrigerants.

Conclusion

The development of the Green Star Antarctic custom tool drives inclusion of multiple facets of sustainability during the design process. The Green Star custom tool will be used to independently validate sustainability, where Antarctica New Zealand hopes to achieve five stars out of a possible six. A significant aspect of implementing Green Star is continually driving for innovation, market transformation, and iterative improvements in design. Areas of innovation explored in the design of the Scott Base Redevelopment Project include the following:

- Removable pile foundations
- Full build in New Zealand and delivery of large building modules
- Commissioning off-site and adopting the soft landings framework
- Maximising renewable energy penetration
- Minimising wastewater impacts
- Integrated Building Information Modelling (BIM) for design efficiencies
- Te Aranga Māori Design Principles

The next step for Antarctica New Zealand is the independent review of the Scott Base Redevelopment design in June 2021. Following the design review, Antarctica New Zealand will share with COMNAP lessons identified and our experience in implementing this tool.

ENERGY SUPPLY STRATEGIES FOR SPANISH ANTARCTIC STATIONS: LOOKING FOR SUSTAINABILITY[5]

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Introduction

The Spanish Antarctic stations Gabriel de Castilla and Juan Carlos I are located in the South Shetland Islands. Despite being summer-only stations, in operation each year from mid-November to the end of March, both maintain scientific equipment that acquires data also during the eight months of winter station closure. The continuity in the data acquisition is crucial for long-term monitoring that is part of Spain's commitment to several projects and programmes.

Continuous data acquisition and the objective of minimising the environmental impact of both stations has led to different strategies in order to provide, without direct oversight, the energy supply required both in summer, when the stations are open and fully operational, and in winter. This paper discusses those strategies.

[5] The video of this presentation is available at https://youtu.be/4hevCq50Ncg.

Operation During Summer Months

In both of Spain's stations, power generation during the summer months is based on diesel generators. Juan Carlos I station is run by three diesel generators of 130 kilovolt-amperes each and the station has a storage capacity of 72,000 litres of diesel. To take advantage of the heat produced by the generators, during the rebuild of the facility a few years ago a cogeneration system was added to these generators (Figure 1). The heat generated by the diesel generators could be used for conditioning the station's domestic and system hot water, stored in a 2,400 litre tank.

The cogeneration system is fully incorporated into operations and is considered a basic element in the daily energy management of the station. The modular configuration of the station adds a higher level of complexity to the cogeneration system, requiring special pipes and conduction networks. This was taken into consideration during the design phase and so heat lost through the piping system is not significant. The addition of the cogeneration system coupled with improved station design has resulted in a substantial saving in fuel consumption.

An autonomous cogeneration generator project has been developed at the Gabriel de Castilla station, which allows for a relatively small generator to operate with an integrated cogeneration system to support station energy needs. This prototype includes a 50 kilovolt-ampere generator and the heat recovery unit. The residual heat of the engine is used to heat a 500 litre tank of water used for sanitary and heating purposes.

Figure 1: Cogeneration system and pipes at Juan Carlos I station. (Credit: UTM-CSIC)

Operation During Winter Months

The winter energy supply strategy is entirely based on the use of renewable energy, both wind and solar. In the 2000s, wind turbines and some photovoltaic panels were introduced, powering specific equipment during the winter.

After 15 years of experience and data analysis, Juan Carlos I station has a wind farm consisting of three wind turbines, producing up to 9,000 watts, and two photovoltaic fields, producing a total of 6,000 watts. The energy is accumulated in 24 large batteries, and a communication system allows the energy system to be monitored from Spain during the winter, where the state and quality of the energy supplied can be controlled. The communication system also identifies and communicates possible problems in the powered equipment.

The batteries can accumulate up to 100,000 watt-hours, giving an autonomy of 10 days if, at any time, there is no wind. However, during the winter in the most recent season there was an extended period of no wind that was longer than the 10 days autonomy period, causing the collapse of the system. To address this, there are plans in place, from the 2020/21 season, to double the power generation capacity with the installation of three new wind turbines, and to double the storage capacity (Figure 2). This new capacity would ensure the system remains functional through periods without the wind required for longer than the 10-day window. The new system will be able to be monitored and controlled from Spain via satellite communication.

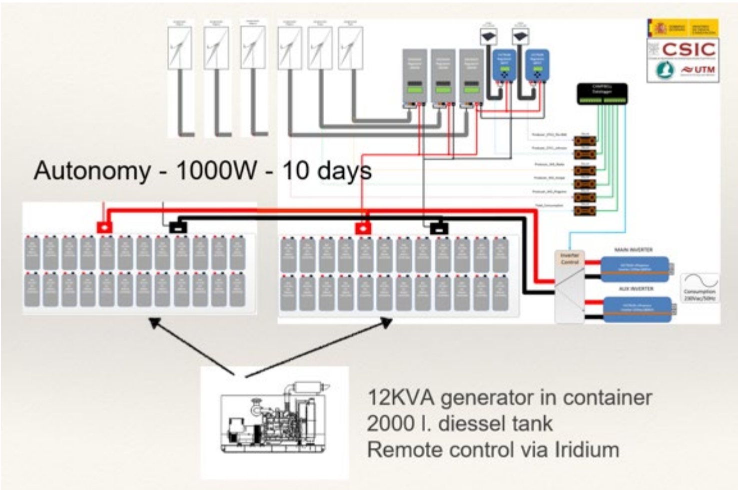

Figure 2: Graphic illustrating additional components of the renewable energy system needed to ensure power requirements are met during winter months at Juan Carlos I station. (Credit: UTM-CSIC)

In Gabriel de Castilla station a different approach is being used. There, a 3,000 watt wind turbine has been installed and a prototype of a methanol battery is being worked on to supply energy to scientific equipment during the winter. This energy source is based on two 125-watt methanol cells working in parallel, charging a batteries bank at 24 volts (Figure 3).

Figure 3: Methanol battery power system at Gabriel de Castilla station. (Credit: Spanish Army)

In addition to this prototype system, a diesel generator is installed as a contingency. The whole system is located in an isolated container.

Trialling this technology at the station has three main purposes:

- Demonstrate the feasibility of its use for small requirements at the station
- Confirm the safety of the use of such an unattended energy source for 270 days' duration
- Consider feasibility of expanding such containerised power-generation systems to develop a distributed generation system for the whole station (provide each building with its own renewable generation equipment based on this technology)

The trial is ongoing.

Conclusion

Despite the approaches at each of the Spanish Antarctic stations being different, both pursue the same final objective: reduce and optimise the use of fossil fuels. Diesel consumption is now around 500 litres per day, significantly less than was predicted during the modernisation planning for Juan Carlos I station. The intention is to maximise the use of alternative energies and provide a reliable energy source for the automatic unattended scientific instruments working throughout the winter. At stations where no winter-over personnel are on-site, it is critical to have reliable power, to have the ability to remotely monitor and make adjustments to the system, and to be able to implement contingencies in case of a failure in the battery or power system.

TESTING A METHODOLOGY TO QUANTIFY CARBON FOOTPRINT AT THE FRENCH POLAR INSTITUTE, AND FIRST RESULTS[6]

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Introduction

The French Polar Institute (IPEV) proposed at the last COMNAP Annual General Meeting (AGM) in Plovdiv, Bulgaria, in 2019 to be a "beta tester" for the quantification of national Antarctic programmes' carbon footprint. In order to have an exhaustive approach in quantifying the footprint, we consider the full parameters of IPEV activities, in 2019, including its headquarters, the Arctic, sub-Antarctic islands, and Antarctica. A French method/tool, developed mainly for corporations, called Bilan Carbone®, has been used to conduct this trial. Sources of carbon are divided into categories (i.e. transport energy, purchases, services, etc.) and the data collected is organised in a database. The database is published by the French energy agency (Agence de l'Environnement et de la Maîtrise de l'Energie (ADEME)). The CO_2 emission factors from the Bilan Carbone® databases are automatically calculated per unit; however, direct measurement of petrol consumption, for example, can be introduced.

[6] The video of this presentation is available at https://youtu.be/zzu77YRM6cI.

IPEV Activities
The IPEV has its headquarters located in Plouzané, Brest, France. It implements its activities in three geographical areas:

- The Arctic, mainly through renting facilities from Kings Bay AS, a private Norwegian company located in Ny-Ålesund, Svalbard, while running its own station called Corbel
- The sub-Antarctic islands in the Indian Ocean, in close partnership with the French Austral and Antarctic Territories (TAAF)
- The Antarctic, with Dumont d'Urville station on the coast and Concordia station (shared with Italy) on the East Antarctic plateau. Also in Antarctica, IPEV operates the polar class ship *L'Astrolabe* for cargo and passenger transfer.

The three geographical areas and the IPEV headquarters have been considered independently from each other for the carbon budget.

Methodology
Sources of carbon are distributed in different categories: energy, refrigerant, goods and services, packaging, professional services, freight from Europe to station, freight from station to Europe, and waste. All these categories are linked to a database, updated every year, which provides standardised carbon emissions. The database expresses a CO_2 equivalent emission in tons (tCO_2eq) per unit of the corresponding category. For example, it provides weight-

times-kilometre for road, marine, and air transportations of goods, or fuel and gas consumption for energy production.

Collection of data is based on invoices and the detailed descriptions of goods within purchase orders (weights and type of materials), type of refrigerant used in cooling systems, gas and fuel consumption, and number of passengers being transported as well as their transport means (flights, train, helicopter hours, internal Antarctic aeroplane flights). The source of the data collected and attributed to the carbon footprint of the IPEV is defined based on financial documents: if a service is paid for, it will be charged into the carbon budget.

Main Difficulties Encountered

There is a huge amount of work to collect the data required for robust quantification. Looking for information that can be translated into carbon impact means getting all the dimensions of the activities: transportation, freight, all the purchases of equipment, invoices of services, types of material used for infrastructure and buildings, and fixed-assets depreciation. Several lessons learned are shared in this section.

Partnerships

Partnerships refers to instances when management is done jointly or costs are shared with others. Quantifying data from partnerships proved to be the source of the biggest inaccuracies. When the management of a site is shared with other programmes or involves private companies’ services, the information on carbon footprint becomes difficult to obtain unless the partners also have the same methodology or maintain records to the same measurements and level of detail. Often it was found that the only way was to consider the financial component, for example the rent costs, and to associate those with approximate carbon-footprint quantitative appreciation.

Accuracy quantification

Most of the partners are considered as manufacturers, leading to transferring their invoices (in euros) in tCO_2eq. In our own accounting system, the level of detail on purchases may be a limiting factor. For example, quantities of purchased material such as wood or steel must be approximated through loading plans of the cargo.

Depreciation of assets

Major purchases such as vehicles, sledges, or building infrastructures are subject to depreciation through time. Inventories and common rules have to be set between sites, and those shared with partners for a proper attribution of a corresponding carbon budget.

Data collection

In order to establish a carbon footprint every year and to follow the resulting improvement in our practices, data collection should be done in a manner that is more efficient than from scratch as we did through this first approach. An efficient information system for the IPEV is currently being developed, and it will take the carbon budget into account.

Results

We established a first carbon budget of the IPEV by considering the calendar year 2019. During that year, the Institute implemented a total of 74 research projects deployed, through 108 different field projects. More than

320 scientists were accompanied in our polar districts. When adding the technical staff, IPEV deployed in the field more than 36,000 person days. The corresponding overall carbon footprint of the IPEV for this level of scientific support amounts to about 12,270 tCO_2eq, with an error estimation of 6%.

The majority is attributed to Antarctica (~80%), as the Institute handles there all the activities related to freight, transportation, and infrastructures. In the Arctic and Sub-Antarctic Islands, the carbon footprint is mostly associated with the services paid to partners, and is not counted against the IPEV. The real footprint of the Institute might be significantly under-evaluated under such conditions (Figure 1).

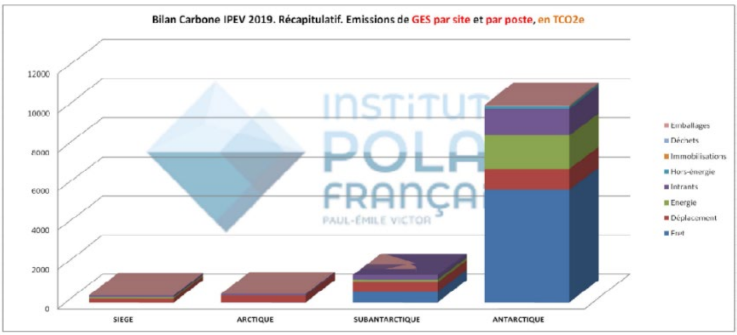

Figure 1: Graph showing IPEV carbon footprint in 2019 divided by location. (Credit: IPEV)

Transportation of cargo in and out of Antarctica (Figure 2) represents by far the largest contribution to our carbon budget, being more than three times larger than the carbon emitted by the energy consumption of our Antarctic research stations.

Figure 2: Fuel transfer on sea ice from *L'Astrolabe* located 40 kilometres away from Dumont d'Urville station in Antarctica (2017/18 season). (Credit: Patrice Bretel, IPEV)

The Choice of a Relevant Metric: Absolute Value Versus Ratios

The absolute values of tCO_2eq are meaningful only when internally compared on a yearly basis. Any comparison with other national Antarctic programmes would be very tricky, as the activity, the context, and the capacities of the stations largely differ from programme to programme and take place in different areas.

An interesting metric that might be used would be "ratios". The tCO_2eq can be expressed relative to a number of persons or scientists being deployed, with an average carbon footprint of 0.340 tons/person/day, or as a number of person-days in the field, or as a number of scientific projects being implemented. Internal consideration must be given as to the rule to establish such metrics, allowing to target an improved strategy for each national Antarctic programme when it comes to its carbon footprint.

Reducing Carbon Footprint: Targets and Recommendations

International reports, as well as Conference of the Parties (COP) initiatives, provide general objectives to be reached in order to avoid climate change consequences. Based on these reports, the IPEV targets a mean yearly reduction of 4% of its carbon footprint until 2050 to reach the "Factor 4" as established by the Paris Agreement.

The main recommendations deriving from this one-year exercise on carbon budget conducted at IPEV are as follows:

- Improving freight handling and the logistical chain to reduce the main source relative to the Hobart gateway to/from Antarctica by ship.
- Reducing whenever possible air travel and air transportation.
- Improving energy management on the station and introducing more alternative energy sources.

Conclusion

Transport and freight are the categories with the highest carbon footprint impact for the IPEV, far ahead of the stations themselves – despite the stations being situated in extreme environments. Optimising transport by fully utilising the capacities of the vectors (vessels and aircraft) each journey is a first major step.

Seasonal set-up should include buffer times to guarantee the success of operations and to avoid any carbon emission from operations with a low success rate. Whenever possible, adding scientific activities to existing logistical activity is a good way to optimise the carbon footprint component that can hardly be reduced otherwise.

Finally, the metrics used to measure the improvement of our practice and its accuracy are critical for a proper evaluation of politics aiming at reducing the absolute carbon footprint of our activities.

FROM LOGISTICAL HUB TO KEY SCIENCE AND OBSERVING STATION: UPSCALING SCIENCE AND ENVIRONMENTAL PERFORMANCE AT THE NORWEGIAN RESEARCH STATION TROLL[7]

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[a]Norwegian Polar Institute
[b]Statsbygg (Norwegian Directorate of Public Construction and Property)

Introduction

The Norwegian research station Troll was established as a small seasonal field station in 1989, mainly to support remote fieldwork in an extensive area of Dronning Maud Land, Antarctica. The upgrading to a year-round station in 2005 included efforts to increase the science capabilities. However, Troll station's primary role has continued to be to support and provide service to remote and large-scale fieldwork.

Troll and the operations at the station comply with the legal environmental framework for activities in Antarctica. Over the years, the nature of the development of the station has meant that there has been little room to move from good environmental compliance to more-extensive environmental innovation.

[7] The video of this presentation is available at https://youtu.be/zzu77YRM6cI.

Developments over the last decades, and an increased willingness and interest in providing for more science activities at the station itself, have led to a continuous need to expand facilities, adding new elements onto the existing structures. The core structure at Troll station is now no longer able to support and facilitate further energy-efficient, environmentally sensitive expansion. The Norwegian national Antarctic programme therefore finds itself at a crossroads with regard to decisions about the future status of and capabilities at Troll. This paper presents some of the current thinking regarding upscaling science and environmental performance at the station.

Norwegian Contribution in Antarctic Science

Antarctic research is pivotal for understanding not only Antarctica but also the whole earth system. Norway's objective is to continue and to improve on its efforts to address gaps in knowledge in regard to the Antarctic region.

One of the keys to the future Norwegian contribution relies on the dedicated effort to expand the air observation capacity at Troll station and the surrounding area. In order to do that, efforts are currently underway to find means to fund the establishment of Troll Observing Network (TONe) which will transform Troll station to a state-of-the-art observatory for comprehensive long-term observation of the earth and monitoring of atmospheric, terrestrial, and marine realms (Figure 1).

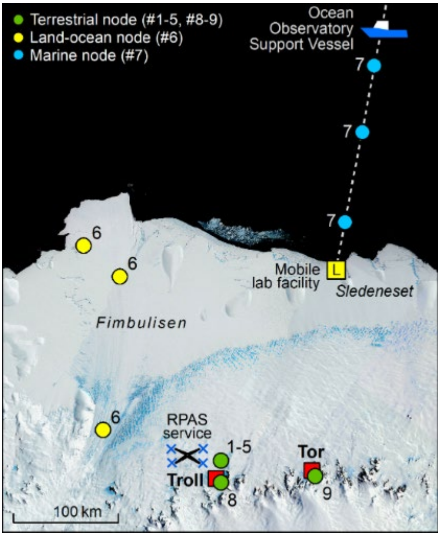


Figure 1: Graphic representation of the proposed Troll Observing Network (TONe). (Credit: Norwegian Polar Institute)

In January 2020, a group of deputy ministers from four key Norwegian government ministries visited Troll station, with the aim of understanding the role the station plays in Norwegian research and to discuss future international collaboration. The discussions led to a clear understanding of the station's importance for Antarctic research, and established broader political support for initiatives related to future upgrading.

Norwegian Infrastructures in Antarctica

Troll station is Norway's only permanent research infrastructure in Antarctica, located in Dronning Maud Land, on the snow-free slope in the break between the low-line coastal ice sheets and the high-altitude inland plateau. The Norwegian Polar Institute (NPI) is responsible for operating the station on behalf of the entire nation. In 1989, Norway established Troll, as summer-only station with accommodation for up to eight people. The station primarily supported deep-field research.

In 2003, it was decided that Troll station would become a year-round facility, motivated by the desire to increase Norway's contribution to the Antarctic scientific knowledge. The new Troll station was officially opened in February 2005. A new main building was established and the old building was incorporated into the new one (Figure 2). The upgrade also included a new generator building, an emergency station, a garage, provisions, and fuel and equipment containers.

Figure 2: Troll station in January 2020. (Credit: Norwegian Polar Institute)

While the refurbishment of the station paved the way for *in situ* scientific observations, Troll station continued to have a key role in supporting remote and large-scale fieldwork.

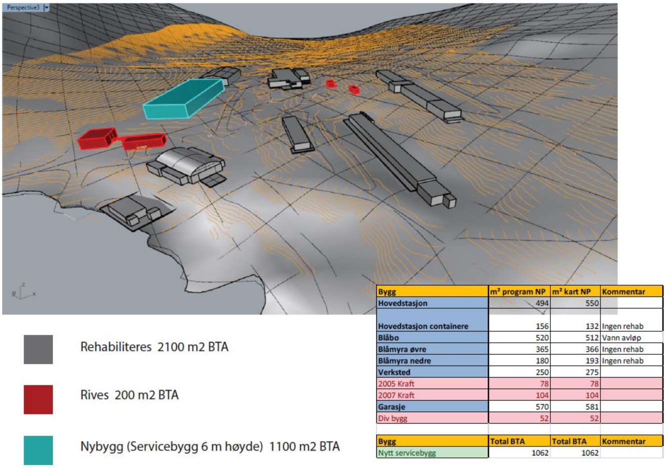
In February 2020, the NPI invited Statsbygg, the Norwegian government's key advisor in construction and property affairs, building commissioner, property manager, and property developer, to visit Troll station in order to get its professional assessment as to the state of the infrastructure. Statsbygg concluded that Troll station has more or less out lived its useful lifespan. This left the NPI to question how it could ensure that Troll station continues to serve as an innovative and robust platform for Norwegian Antarctic research plans.

The Future for Norwegian Activities

A stepwise approach has been initiated to assess future needs and potential directions, and to establish a roadmap for government planning and purchasing. In doing so, goals and indicators have been established in relation to research functionality, logistical efficiency, and safe and green energy production. In addition, a number of requirements that will frame a modernisation project have been identified. The project team has also identified some gaps where the current Troll station does not fulfil the aims and goals identified, and these are related to research, sanitary and service facilities, and green and energy efficiency solutions.

In framing the research facility needs, the NPI has looked to the capacities and capabilities at other Antarctic facilities and has also conducted a survey within the Norwegian scientific community to assess needs.

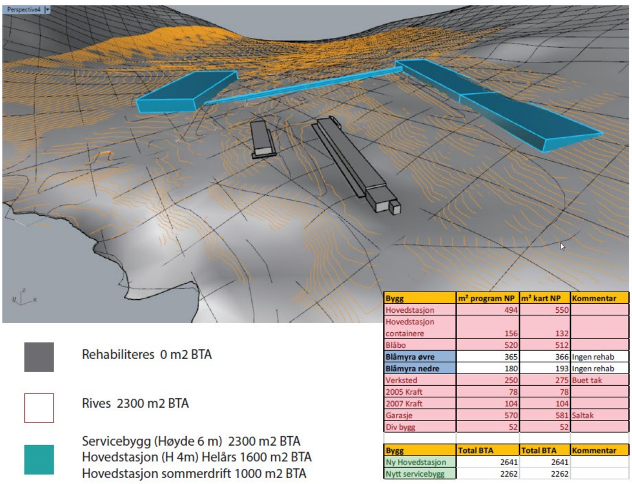
At present, Statsbygg has consolidated all the information received and has proposed three different alternative approaches. Alternative 1 (Figure 3) would see the use of most of the existing infrastructures, with some refurbishments required, and the construction of a new service building, including a garage, laboratories, and workshops. Alterative 3 (Figure 4) suggests the construction of an almost completely new station. Alternative 2 would be in between the two above-mentioned concepts.



Bygg	m² program NP	m² kart NP	Kommentar
Hovedstasjon	494	550	
Hovedstasjon containere	156	132	Ingen rehab
Blåbo	520	512	Vann avløp
Blåmyra øvre	365	366	Ingen rehab
Blåmyra nedre	180	193	Ingen rehab
Verksted	250	275	
2005 Kraft	78	78	
2007 Kraft	104	104	
Garasje	570	581	
Div bygg	52	52	

Bygg	Total BTA	Total BTA	Kommentar
Nytt servicebygg	1062	1062	

Figure 3: Visualisation of Troll station as envisioned under Alternative 1. (Credit: Statsbygg)



Bygg	m² program NP	m² kart NP	Kommentar
Hovedstasjon	494	550	
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Verksted	250	275	Buet tak
2005 Kraft	78	78	
2007 Kraft	104	104	
Garasje	570	581	Saltak
Div bygg	52	52	

Bygg	Total BTA	Total BTA	Kommentar
Ny Hovedstasjon	2641	2641	
Nytt servicebygg	2262	2262	

Figure 4: Visualisation of Troll station as envisioned under Alternative 3. (Credit: Statsbygg)

In each case, whatever alternative is ultimately chosen, the strengthening of the environmental performance of the station is paramount. This is especially true in regard to the energy requirements, which have a large cost associated with them in addition to environmental considerations. Drawing on the current status of technologies and previous work, solar and wind power production will be considered as well as biofuel and fuel cell technology and also alternatives for power storage.

The process provided a unique opportunity to consider a wide array of options, which will lead to decreasing our impact in Antarctica while continuing to deliver and support critical Antarctic data and research outcomes.

SCOTT BASE REDEVELOPMENT PROJECT[8]

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[b] Hugh Broughton Architects, London, United Kingdom

Introduction

The Scott Base Redevelopment Project is the largest project ever undertaken by Antarctica New Zealand. It aims to provide a fit-for-purpose Antarctic facility that meets the project objectives:

- Maintain a continuous presence in the Ross Sea Region
- Protect the Antarctic environment
- Provide working conditions that keeps people safe and healthy
- Enable logistics to support high-quality science
- Maintain New Zealand's credibility amongst Antarctic Treaty Parties

The Scott Base Redevelopment Project is in the third of four stages of design before construction, which is due to commence in the 2022/23 season.

[8] The video of this presentation is available at https://youtu.be/Rqgge35Q6B8.

The design fuses pragmatism with the desire to create a home away from home for the residents, and a building that captures the spirit of New Zealand.

Background

New Zealand's current Antarctic research station, Scott Base, is located on Pram Point, Ross Island, and comprises 12 interconnected buildings, which were commissioned in the mid-1980s. The current station can accommodate up to 86 people.

This station is the second facility at Pram Point; the first station was established in 1957 for the Commonwealth Trans-Antarctic Expedition. Pram Point is approximately 4 kilometres from McMurdo station (United States of America). Due to this proximity McMurdo station and Scott Base operate on a shared energy grid that utilises renewable energy from three wind turbines.

While the current New Zealand base has served the national Antarctic programme known as Antarctica New Zealand very well, it is deteriorating and it is no longer fit for purpose.

The Scott Base Redevelopment Project was initiated in 2016 to respond to problems of running the ageing infrastructure. There are several issues that determined the case of need for changing the current station. These include the need to improve access, that the basic engineering and life support systems are now operated well beyond their intended design life, and that the accommodation quarters are no longer fit for purpose. This final point refers to present issues where housing people in basic shared facilities with noise transfer between hallway and rooms make sleeping difficult and the need to accommodate people in external modified shipping containers at the peak of the season. Due to the long lead time to address all these issues, it is critical to develop a suitable redevelopment plan.

Detailed Design

In 2017, Antarctica New Zealand formed an international project team, with expertise in polar environments, to deliver the Scott Base Redevelopment Project. Currently, the project is approaching the final step, called detailed design, where the details will be confirmed and will ensure that the design is fit for purpose and is able to be assembled in Antarctica.

While starting to draw designs in 2017, one idea emerged as the optimal solution, being three buildings of matching width and shape stepping down the hill at Pram Point. The buildings are connected by link bridges to ensure that the lower level of the top building connects to the upper level of the middle building and the lower level of middle building connects to the upper level of the lower building (Figure 1).

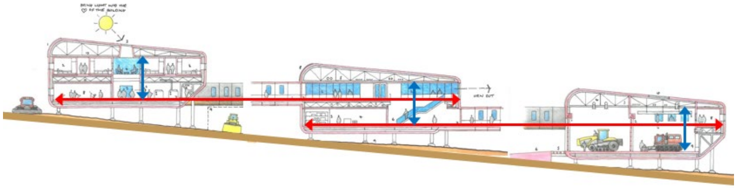

Figure 1: Illustration of the proposed Scott Base Redevelopment interconnected design. (Credit: Hugh Broughton Architects; Antarctica New Zealand)

The top building is the main accommodation block, containing bedrooms, dining and recreation areas, and the main entrance. The middle building is the science staging building, containing laboratories, offices, and administration functions. The third and lower building contains engineering, workshops, and the warehouse. The layout has been designed to minimise the environmental impact (Figure 2).

Figure 2: Aerial view of the proposed new Scott Base project. (Credit: Hugh Broughton Architects; Antarctica New Zealand)

The positioning of the station has taken into consideration several factors, including the position of the road to/from the US McMurdo station, the distance from the coastline, the location of the long-term science instruments, rare flora that grows on a hillside in the vicinity, and the irregular sloping topography of the site.

The design will provide linked, communal, and collaborative spaces to support people's well-being, and it endeavours to make people feel culturally connected to Antarctica and to New Zealand.

The new station will be efficient, safe to operate, resilient, and highly sustainable, making best use of wind energy to reduce the use of fossil fuel, and it will provide facilities to support world-class science.

Each of the building modules will have the same cross-section. Each will be steel framed and zones have been created to facilitate service distributions and ease of maintenance. The buildings will have monopitch roofs and leading edges to reduce wind drag. They will be elevated above the ice surface on legs, at least 1 metre above the ground, so that the winds can cross underneath, preventing snow from accumulating under the building or in the immediate vicinity. Models of the current and proposed station have been tested using water flumes and fine sand to simulate the snowdrift in order to have a benchmark representing the weather conditions at Scott Base.

Interior Design

The interior of the space has been given considerable thought. The main entrance will be welcoming, with views into "Building A" (Figure 3). The entry will welcome people in a dedicated lounge space where expeditioners can receive their inductions with scenic views of the surroundings. The main entrance corridor will include displays to explain the history of Scott Base and of New Zealand Antarctic explorers.

Figure 3: Illustration of proposed main entrance to Scott Base Building A. (Credit: Hugh Broughton Architects; Antarctica New Zealand)

The dining rooms will be located on the upper level, guaranteeing views, through a panoramic window, to the pressure ridges of Ross Ice Shelf and Mount Erebus. A library will be located at the far end of the accommodation building, with views over Mount Discovery. While long-term residents will have single bedrooms with views into the landscape, storage space, and blinds and lighting to support the circadian cycle, short-term visitors will be accommodated in twin or pod-style rooms. Great emphasis has been made on ensuring acoustic comfort for the residents, which has been designed using a laboratory process simulating the likely level of noise transmission from one space to another.

“Building B” is dedicated to science activities, with a large science cargo-handling area allowing expeditioners to organise and gather their instruments before departing for field campaigns. The area will provide clean rooms, allowing scientists to prepare or calibrate electronic equipment. The upper level will host offices for managers, field operatives, and visitors, as well as rooms for training, meeting, and communication. The offices have been designed as open plan to foster collaboration and in close proximity to laboratories that have been developed to support various scientific research.

The lower of the three buildings, “Building C’”, will contain workshops, warehousing, and the main services spaces, including the wastewater treatment plant. Generators, boilers, and water production will be split between this building and the accommodation building to maximise the resilience of the base.

Structure and Construction

The structure will be made of steel, at the same standard as that of a public hospital in New Zealand, utilising a regular and repeatable frame. The cladding will use metal composite panels for the main body of the building and composite glass fibre panels for the areas with more complex geometries:

those that need to be curved to minimise the impact of the wind on the structure and snow deposition.

Various ways in which the new base could be built have been investigated, ranging from prefabricated components transported in shipping containers through to moving the whole building in one go. At present, the proposal is to have a fully commissioned station built in New Zealand and transported by ship to Antarctica in large modular sections using specialist equipment.

ROTHERA REDEVELOPMENT AND THE CHALLENGES OF MANAGING A "CONSTRUCTION SITE"[9]

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British Antarctic Survey

Introduction

The British Antarctic Survey (BAS) is undertaking extensive redevelopment at Rothera research station, Adelaide Island, Antarctica, as part of its modernisation programme. The first phase involved replacing the existing wharf with a deeper version to allow the new BAS research vessel, the RRS *Sir David Attenborough*, to resupply the station. The wharf project has now been completed successfully, and, perhaps most importantly of all, safely. As major construction activity was undertaken whilst maintaining normal station operations, safety and risk management were an overarching theme and required a joined-up approach between construction partners and BAS. From the outset, the project philosophy was to deliver the modernisation programme as a partnership, rather than as a separate construction team working independently of BAS. Achieving this level of integration began well before construction started on-site. This joined-up approach has been integral to the overall success of the projects delivered

[9] The video of this presentation is available at https://youtu.be/Rqgge35Q6B8.

and was a key element in managing a construction site at a research station.

Construction Projects

The first construction project that BAS undertook at Rothera station was on the wharf infrastructure. The construction of a new wharf, replacing the previous one that has been in service for more than 25 years, has been made necessary by the upcoming entrance into service of the RRS *Sir David Attenborough*, which requires a bigger wharf in deeper water (Figure 1).

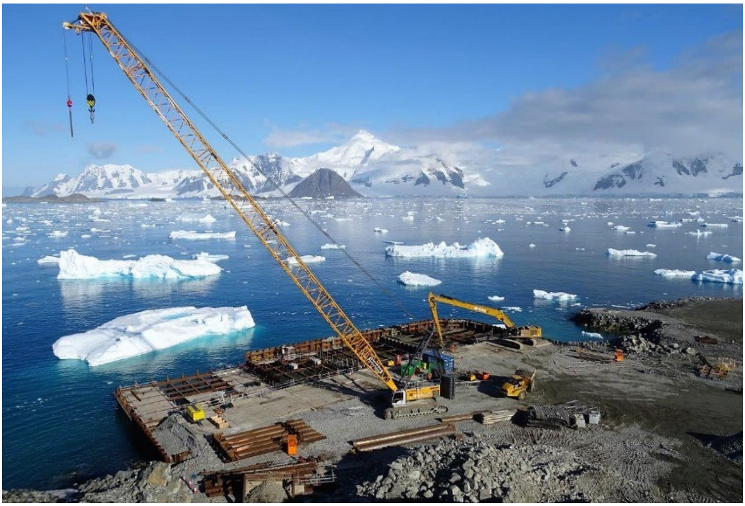

Figure 1: New Rothera station wharf under construction. (Credit: Billy Thursfield)

Rothera station is also undergoing a modernisation project on the buildings and infrastructure. The current buildings are dated and BAS is undertaking this project to replace them with more-modern efficient buildings and services. The first phase of the modernisation project started with a new science and operation building, where small individual buildings will be replaced with a larger multi-functional building. Construction works started in January 2020 (Figure 2).

Figure 2: Graphic envisioning the new Rothera station science and operation building. (Credit: British Antarctic Survey)

At the time the groundworks for the science and operations building were started, the two-year wharf project was in the final stages of construction, finishing in April 2020.

Modernisation project on the building infrastructure

This construction projects brought significant challenges with them, due to the scale of the activity and the relatively limited space available for machinery operations, quarrying and stockpiling of rock, and building the new steel frames, workshops, and temporary accommodations. A further challenge was presented in regard to the active runway at Rothera station. BAS and other national Antarctic programmes use Rothera runway as a transiting point in order to fly further into the continent. Making sure construction activity did not adversely interfere with the safety requirements of an active runway was vital to the success of the project.

Over the period that the new wharf was being constructed, there was no wharf available, but nevertheless ships were still resupplying the station with fuel, food, and goods. This too had to be accommodated in the plan.

The proximity of construction activities to the station created further challenges. Construction was undertaken near the accommodation and dining building. The area that was used to construct the wharf is adjacent to the Bonner Marine Laboratory (Figure 3), which was open and utilised during the whole construction phase, thanks to the implementations of new safety protocols and excellent site management.

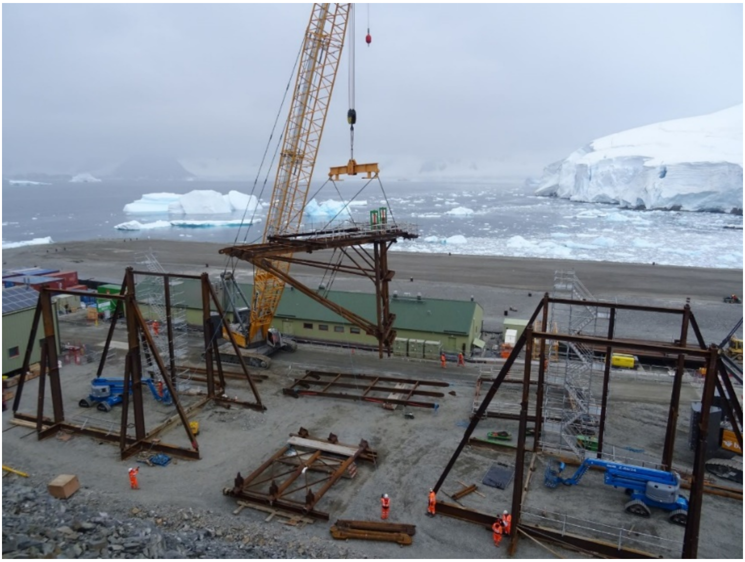

Figure 3: Wharf frame building area with Bonner Marine Laboratory (green building) behind. (Credit: Billy Thursfield)

The projects are multi-year, meaning they require activity over multiple Antarctic research seasons. It is therefore vital to ensure continuity of research activities, especially those that are part of long-term observation and monitoring projects.

Scientific activities conducted at Rothera station are both terrestrial and marine, with a focus on diving and water sampling. Rothera station is also supporting major field programmes, the biggest of these being the International Thwaites Glacier Collaboration.

During this period, it was very important to balance the construction teams’ numbers against science, operations, and support numbers to allow for both effective construction and maintenance of science outputs.

Ways to be Successful

One of the biggest factors that contributed to the successful completion of the first project was to have a "one team" approach. "One team" meant that all BAS personnel worked in partnership with contractors. There was joint planning, sharing knowledge and working together. This proved to be key, and was especially important given that Antarctica was a new area of operation for the contractors. In preparation, a selected pool of people from the contracting company visited Rothera station the season before starting the *in situ* works. This gave them a first-hand understanding of the weather, short day-lengths, and other environmental conditions; it also gave them an understanding of the end of the supply chain.

Site supervision, management, and safety have been important elements to consider. The construction supervisor, technical advisor, and station leader all worked together as a team to guarantee that Rothera station would remain a safe place to work. Site tours were organised to allow station occupants to gain a better understanding of the risks related to the movement of heavy machinery within a constrained shared working space. During these site tours, personnel also had the opportunity to sit in the heavy vehicle cabs to appreciate how the visibility from the driver perspective is limited, and that helped in rising awareness between all the parties. During construction, site segregation and effective radio communication were critical to maintenance of safety.

The human factor is also something that required a huge management effort, due to extensively different backgrounds and roles of the people living at Rothera station. The long seasons and sustained workloads prompted a proactive approach to management of fatigue and mental health.

To ensure positive outcomes, a social and sporting calendar was developed that allowed for joint events where all Rothera station personnel and contractors could come together and relax. With contractors on-site, there was a higher than usual number of people on-station. Extra chefs were employed and mealtimes were extended to reduce pressure on the dining areas. Additional accommodation facilities were built and some areas were repurposed to create new socialising environments. Communication with family members and friends at home is always important. With extra people at the station, to guarantee to everyone the possibility to communicate with those at home, internet bandwidth was increased.

Finally, to ensure ongoing support to major field science campaigns, the support staff at Rothera station was increased to ensure that active flying and field science programmes could be maintained. To decrease the pressure on Rothera station the season length was extended. To further relieve the pressure of personnel movements through Rothera some staff deploying to West Antarctica field camps routed via McMurdo station and staff deploying to Halley VI station routed using the Dronning Maud Land Air Network (DROMLAN).

Conclusion

The integration of all the teams since the start of the wharf project and the “one team” approach that BAS employed have been pivotal to the success of this project. An important part of the “one team” approach is establishing and maintaining an effective joint site supervision and management.

The creation of temporary infrastructures and the re-purposing of some buildings proved extremely important, not only to accommodate a higher population, but also to guarantee the well-being of everyone living at the station.

Poster Presentations

CHILEAN ANTARCTIC INFRASTRUCTURE TO 2030[10]

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This programme started in 2019 and it has the purpose of modernising three Chilean Antarctic stations, which are:

- Professor Julio Escudero station, King George Island, Fildes Bay
- Yelcho station, Doumer Island, South Bay
- Carvajal station, Adelaide Island, Marguerite Bay.

We estimate an investment of 70 million USD to complete this project in a period of not less than eight years. The project requires co-ordinated work with other public and Antarctic actors, for the development of the project and logistical support.

During 2019 and 2020, we have done studies on soil mechanics and on topo-bathimetry associated with port facilities to define the type of foundations and constructive modalities, stages of construction, and initial models for the stations' operation, projected for a future horizon of 30 years. These will be our inputs to obtain the definitive preliminary

[10] The video of this presentation is available at https://youtu.be/NHZ2yeOYPiw.

project to tender the detailed design and construction of each of these stations.

With all the aforementioned input, we are in the process for bidding for the preliminary projects for the Yelcho and Carvajal stations.

In this poster we will present the conceptual design models of these two stations, based on the study of the lines of research that are developed in the Antarctic Peninsula and the logistical requirement for the infrastructure and science to carry out the different expeditions linked to each area.

NEW FIRE EXTINGUISHING SYSTEM IN JUAN CARLOS I STATION[11]

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One of the main characteristics of the Spanish Antarctic station Juan Carlos I is its modular design. This design implies some special characteristics regarding general services, such as energy, communications, and protection systems, to mention a few.

One of the innovative systems at the station is its fire extinguishing system, closely related to the fire detection system. The combination of both makes the base safer and better protected against one of the greatest dangers an Antarctic base can face: a fire. A water mist system is installed: this converts water into a fine mist at a pressure of 120 bar when it is activated and remains pressurised to 18 bar the rest of the time. These systems are not only 100% environmentally friendly, but are also often more effective than conventional gas or water fire-fighting equipment.

One of the added advantages is that the system is kept charged year-round with a liquid called "Temper S", a saline solution that to -40°C does not freeze, with minimal maintenance.

[11] The video of this presentation is available at https://youtu.be/VsCbF4zCPKQ.

In addition, the protection is increased with the additional fixed hose reels and extinguishers that allow access to places where the sprinklers of the nebulised system cannot reach. Fire detection is carried out in all the modules by means of a wide range of detectors (smoke, temperature, flame) that are installed depending on the uses of the rooms. Fire containment is also important during the base design stage. At Juan Carlos I, containment features include doors with different radio frequency (RF) alarms and specially protected areas where all walls have a RF120 rating: the kitchen, the pump room, and the control room for the extinguishing system.

Finally, not only the systems, but also the personnel, who must have the appropriate training, can guarantee the quality of a system so important to the life of the base.

IMPROVING INSULATION CAPABILITIES AT GABRIEL DE CASTILLA STATION FOR A BETTER ENERGY-EFFICENCY[12]

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Energy efficiency and renewable energy are pivotal to reducing energy consumption and to achieving greater energy independence. Proper identification and the evaluation of design parameters for living zones will contribute to more energy-efficient stations, leading to obvious economic savings, and, even more importantly, will guarantee less environmental impact in the area.

This presentation aims to carry out an analysis of the optimal parameters to comply with the NZEB concept. We will focus on three factors:

- Current status of the insulation of the Spanish Antarctic station Gabriel de Castilla and the influence of thermal bridges on energy behaviour
- Infrastructure's thermal transmission coefficients
- Thermal behaviour influence on the soil under the Gabriel de Castilla station.

This study then proposes improvements to reduce energy consumption by up to 85% and to increase environmental

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

comfort, implementing clean energies to supply the station. These components must be transportable to Deception Island and built without auxiliary elements that are not available in the Antarctic. Additionally, they must require minimum maintenance and withstand the climatic characteristics of the area, with such characteristics affecting their durability. Our proposal suggests the use of materials that favour an adequate life cycle, reducing the ecological footprint.

SCIENCE MUST GO ON: RUNNING RESEARCH WHILE JUAN CARLOS I STATION WAS REBUILT[13]

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The Spanish Antarctic station Juan Carlos I, located on the Hurd Peninsula, Livingston Island (62° 39′ 46″ S, 60° 23' 20'' W), has been in operation, with interrupted periods, since its establishment in January 1988. Even though it is a summer-only station, staffed from mid-November to early March, automated instruments are maintained year-round.

A rebuilding process started in 2004, when there was official acceptance that the station's original facilities and services needed a refurbishment. In 2008, the tender winner started the work for manufacturing the new modules. The 2017/18 Antarctic campaign was the first in which the renewed base operated at its full capacity. In February 2019, the renovated facilities were officially inaugurated.

During the renovation years, a large population of workers and technicians, dedicated to the refurbishment, coexisted with a reduced number of researchers conducting scientific projects in order not to paralyse scientific activities. One of the main scientific goals during the rebuild period was to continue to

[13] The video of this presentation is available at https://youtu.be/kdjWMup-NZI.

maintain the historical data series, which had been recorded since the establishment of the station.

The combination of both activities represented a challenge for planning, logistics, and co-ordination of field activities because the refurbishment affected all the station spaces and vital systems – obliging people to work and live, for a long time, in provisional facilities with a high occupancy density.

This presentation shows the timeline from the start of the refurbishment activities, with its milestones and construction phases, the scientific activities carried out, and steps implemented to co-ordinate and enable both activities simultaneously.

ENVIRONMENTAL IMPACT RELATED TO THE MODERNISATION OF THE ARCTOWSKI STATION (LEGAL BASIS, ASSESSMENT METHODOLOGY, MITIGATION ACTIONS GUIDELINE)[14]

Bartosz Marciniak, Monika Piątkiewicz, and Dariusz Puczko
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Project Management (Poland)

The aim of this presentation is to assess the environmental impact in relation to the modernisation of the Henryk Arctowski Polish Antarctic station.

In order to assess the modernisation's environmental impact, Bartosz Marciniak and Monika Piątkiewicz touch upon the legal basis for the environmental impact assessments (EIAs), including also the Polish domestic regulations. Those domestic regulations include the Act of 3 October 2008 on the Provision of Information on the Environment and its Protection, Public Participation in Environmental Protection and Environmental Impact Assessments consolidated text Journal of Laws of 2020, item 283 as amended.

We will discuss the environmental impact assessment, the methodology used to identify the zones of direct and indirect impact, and the identification of environmental threats. We

[14] The video of this presentation is available at https://youtu.be/posEzFBc8c0.

will also present the results of the environmental impact assessment.

We will discuss the proposed mitigation actions, including rules for conducting construction works in areas with special environmental conditions, and cumulative impact, both in the context of other activities implemented in the region and in the context of subsequent stages of the station modernisation. The station modernisation has been divided into stages to mitigate the cumulative impact, and monitoring guidelines have been followed and implemented.

CREATING AN OPTIMAL WORK/LIVING SPACE FOR RESEARCHERS: DESIGNING INTERIORS FOCUSSING ON PEOPLE'S NEEDS IN EXTREME ANTARCTIC ISOLATION[15]

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Demiurg Project (Poland)

Demiurg Project is tasked to design the new Polish Antarctic station. Previous strategies for designing spaces located in extreme environments hardly ever took into account the needs of their habitants. The main focus was on their functional and technical purpose.

Marginalisation of the psychological needs of people living and working in isolation for months is surprising, since the results of the scientific research, to a large degree, depend on the psychological condition of the researchers.

The idea behind the designing of the new Henryk Arctowski station's interiors is based on the identification of the needs of people who will work and live in long-term isolation. In our presentation, we will explain why it is important and pragmatic to adopt this particular approach in designing Antarctic stations' interiors.

[15] The video of this presentation is available at https://youtu.be/HdI29tXGz4E.

Appendices

Appendix A:

COMNAP Symposium 2020

Antarctic Station Modernisation: Future-proofing Infrastructure to Support Research and to Reduce Environmental Impact

List of oral presentations

Title/ Presenter/ Organisation
How future-focussed logistics and infrastructure will enhance Antarctic science, Stuart Gibson, Australian Antarctic Division (Australia)
The Belarusian Antarctic station: The complex approach to creation, construction, and renovation, Aleksei Gaidashou, Republican Centre for Polar Research (Republic of Belarus)
Architecture and construction of the new main building of the Arctowski station, Piotr Kuczyński, Kurylowicz & Associates (Poland)
Designing and validating a sustainable Antarctic station, Peter Taylor, Antarctica New Zealand (New Zealand)
Energy supply strategies for Spanish Antarctic stations: Looking for sustainability, Joaquim Nunez, Spanish Army (Spain)
Testing a methodology to quantify carbon footprint at the French Polar Institute, and first results, Patrice Bretel, French Polar Institute (IPEV) (France)
From logistical hub to key science and observing station: Upscaling science and environmental performance at the Norwegian research station Troll, Birgit Njaastad, Norwegian Polar Institute (Norway)
Scott Base Redevelopment Project, Simon Shelton, Antarctica New Zealand (New Zealand)
Rothera redevelopment and the challenges of managing a “construction site”, Simon Garrod, British Antarctic Survey (United Kingdom)

Appendix B:

COMNAP Symposium 2020

Antarctic Station Modernisation: Future-proofing Infrastructure to Support Research and to Reduce Environmental Impact

List of poster presentations

Title/ Presenter/ Organisation
Chilean Antarctic infrastructure to 2030, Marcelo Leppe, Chilean Antarctic Institute (INACH) (Chile)
New fire extinguishing system in Juan Carlos I station, Joan Riba, Marine Technology Unit – Spanish National Research Council (Spain)
Improving insulation capabilities at Gabriel de Castilla station for a better energy-efficiency, Mario Garzón Juan, Spanish Army – Ministry of Defence (Spain)
Science must go on: Running research while Juan Carlos I station was rebuilt, Joan Riba, Marine Technology Unit – Spanish National Research Council (Spain)
Environmental impact related to the modernisation of the Arctowski station (legal basis, assessment methodology, mitigation actions guideline), Bartosz Marciniak, Project Management (Poland)
Creating an optimal work/living space for researchers: Designing interiors focussing on people's needs in extreme Antarctic isolation, Hubert Maciejewski, Demiurg Project (Poland)

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