Proceedings of the COMNAP Symposium 2012
Sustainable Solutions to Antarctic Challenges

Portland, Oregon, USA
15 July 2012

The Council of Managers of National Antarctic Programs
ISBN 978-0-473-23259-7

COMNAP SPECIAL PUBLICATION
COMNAP Secretariat
Private Bag 4800
Christchurch, New Zealand
www.comnap.aq

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ISBN 978-0-473-23259-7

First published 2012

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PHOTOGRAPHER: EDMUND STUMP (2010)

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Acknowledgements

The COMNAP Symposium was made possible by support from the United States National Science Foundation Office of Polar Programs. Special thanks go to that organisation and to the local Symposium organising committee head, Serin Bussell.

The COMNAP Symposium would not have been possible without the work of the Symposium Review Committee which consisted of Lou Sanson (Symposium Review Committee Chair and Co-Convener), David Blake (British Antarctic Survey), Iain Miller (Antarctica New Zealand and Co-Convener), Kazuyuki Shiraishi (Japan's National Institute of Polar Research) and Brian Stone (United States National Science Foundation) who was the COMNAP Vice Chair with oversite responsibility for the COMNAP Symposium.

We are also grateful for those who participated in the Symposium by making an oral presentation or by submitting a poster.

Our thanks go to editor, Janet Bray, for her efforts on these Proceedings.

Foreword

The 2012 COMNAP Symposium was held in the Portland State University Hotel and Conference Center, Portland, Oregon, USA, on 15 September 2012. The theme of the event was “Sustainable Solutions to Antarctic Challenges”. As national Antarctic programmes, we have always faced challenges in the Antarctic and we have become experts at responding to them. The extreme conditions and remote location make supporting science in such a place very challenging, but worthwhile for what we have learned. However, it seems that, more and more, our challenges are coming not only from the Antarctic itself, but also from “external” sources. In particular, the global financial situation is forcing us as managers to take a further look at ways we can support and sustain our research excellence within ever-decreasing budgets.

Sustainability means different things to different people. In the context of the Symposium, it was a theme that allowed participants to consider how we can find long-lasting and robust solutions to challenges, and how we can collaboratively share any that are successful with other national Antarctic programmes that are likely to be also looking for solutions to similar issues affecting them.

The 2012 Symposium was opened by two invited keynote speakers, Dr Gwynne Dyer and Dr Steven Chown, both of whom described global challenges to supporting our science, and internal Antarctic Treaty System challenges to managing support for such activities. Both keynote speakers then asked the question, “What is the role of national Antarctic programmes in finding sustainable solutions to these emerging challenges?”

This is a very good question indeed. National Antarctic programmes have the greatest first-hand knowledge of the Antarctic. Such expertise is clearly of the utmost importance, and means that national Antarctic programmes should, and will, play a key role in addressing Antarctic challenges.

The Symposium was an opportunity for many of the COMNAP national Antarctic programmes to showcase their innovative responses, some of which are already in place, some that are in testing phase and a few that are a view of future responses to emerging challenges.

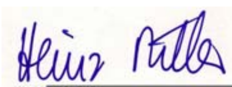
The presentations were themed around three focussed topics, which were:

1. Sustainability Challenges and Solutions;
2. Sustainable Logistics Support; and
3. Technology Enabling Sustainability.

In addition to inviting the keynote speakers, the Symposium Review Committee selected 16 proposals for oral presentations and eight for posters. Submission was open, and a number of individuals and organisations had responded. The result was an informative and productive day that saw over 180 people in attendance.

It was a pleasure to participate and to see many of the innovative ways that national Antarctic programmes are continuing to respond to Antarctic challenges, and how experience leads to a higher degree of sustainability.

The open COMNAP Symposium and its published proceedings will continue to be an excellent opportunity to share our Antarctic knowledge and experience with each other and with anyone else who has an interest in Antarctica.



Dr Heinrich Miller
COMNAP Chair

Oral Presentations

MINIMISING SCIENCE PROGRAMMES' ENVIRONMENTAL FOOTPRINT

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Introduction

The Chilean Antarctic Scientific Programme has grown considerably in the last decade. However, by using several strategies, it has managed to keep to a minimum the environmental footprint, in spite of this growth.

During the last few years, several working papers and information papers have been introduced to the Antarctic Treaty Consultative Meetings on the issue of human environmental footprint in the Antarctic. The subject has become a continuous agenda item on the Committee of Environmental Protection *Five Year Strategic Plan*.

The *Practical Guidelines for Developing and Designing Environmental Monitoring Programmes in Antarctica*, developed by COMNAP (2005), provided a concise description of footprint as, "An area subject to human activity, e.g. spatial coverage of buildings and associated impact including roads, pipes, etc; number and location of field expeditions."

It has been noted that the concept could be classified as either, (1) a footprint that has a lifetime longer than one year, visible, such as a building, or not necessarily visible, but measurable, such as soil contamination, or (2) a footprint that has a lifetime of typically less than one year. Other concepts, such as the "Evolution of Footprint" and "Human Residence Time" in Antarctica, defined in person-days, have also been mentioned, implying footprint is growing.

Thinking in terms of person-days, in Antarctica most of the tourism, and most of the work scientists do in field parties, particularly when taking samples, campaigning in tents or navigating from one study site to the next one, falls into the category of short lived footprint. It can be argued, though, that the human residence time has been lately growing with the increasing scientific interest in Antarctica.

This paper aims to show that this is not necessarily the case, in particular in the area of the Antarctic Peninsula, due to the increasing use of aeroplanes, tourism–science links, budgetary restrictions and the strategies and collaborative approaches that several National Antarctic Programmes have been implementing in the last few years.

The Antarctic Peninsula

As we know, many National Antarctic Programmes had been operating stations in the Antarctic Peninsula area since before 1990. Figure 1 shows some of their facilities, including, at the end of the table, those of three Non-Consultative Parties that have recently started doing research in the area.

Several National Antarctic Programmes have noted that this significant number of stations, vessels and aeroplanes is an opportunity to reduce costs, and environmental footprint, and we should develop strategies to take advantage of the different resources available.

	FACILITIES IN THE ANTARCTIC PENINSULA AREA			
National Antarctic Programme	Stations	Airfields	Vessels (every 1-2 years)	Aeroplanes (every year)
Argentina	X	X	X	X
Brazil	X		X	X
Bulgaria	X			
Chile	X	X	X	X
China	X		X	
Ecuador	X			
Germany	X		X	
Peru	X			
Poland	X			
Republic of Korea	X		X	
Spain	X		X	
Ukraine	X			
United Kingdom	X	X	X	X
United States	X		X	
Uruguay	X		X	X
Czech Republic	X			
Portugal				X
Venezuela				

Figure 1: Facilities in the Antarctic Peninsula area

This cooperation has been, in fact, growing year by year, and this paper shows that different National Antarctic Programmes have benefited from it. The cooperation has been particularly useful for the Chilean Antarctic Scientific Programme, which has grown considerably during the last decade, as shown in Figure 2.

The opportunity given to Chilean scientists to lodge in other National Antarctic Programme's stations (i.e. those of Bulgaria, Spain and Poland) has been reciprocated by ship or helicopter time or by having scientists from those countries staying at or doing their research from Chilean stations, mainly Professor Julio Escudero Station on King George Island.

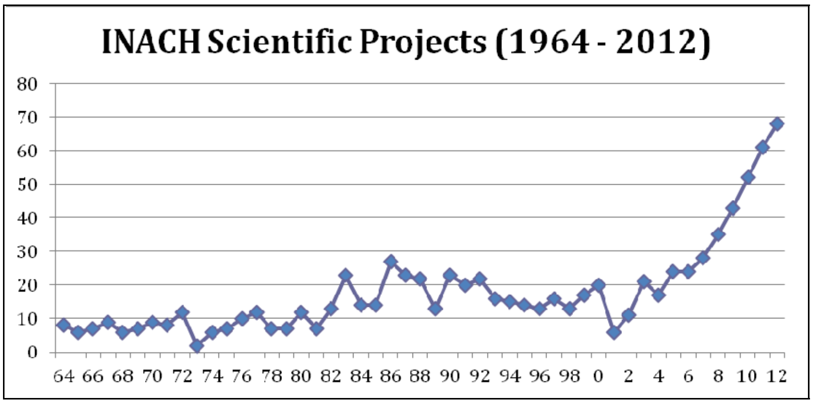

Figure 2: The Chilean Scientific Antarctic Programme 1964–2012: number of projects

One strategy implemented has been to have a special selection process running for research proposals that do not necessarily have to travel to Antarctica to get their data: what we call "lab projects". Another strategy has been to look at ways of collaboration between projects in the field. As a result, only 29 out of the 2011 Antarctic season's 61 research projects, less than 50 per cent, had to go to Antarctica.

An even more important strategy has been to keep the scientists in Antarctica only the number of days they need to perform their research, and to share, as much as possible, charter flights with other National Antarctic Programmes. This, at the same time, has allowed Instituto Antártico Chileno (INACH) to keep Escudero Station small.

This would have never been made possible without the fact that there are so many flights available every season. As shown on Figure 3, during the 2011–12 season Chilean scientists were able to fly on 27 South American air force C-130 flights and 18 private BAE-147 flights on the Punta Arenas–King George Island route.

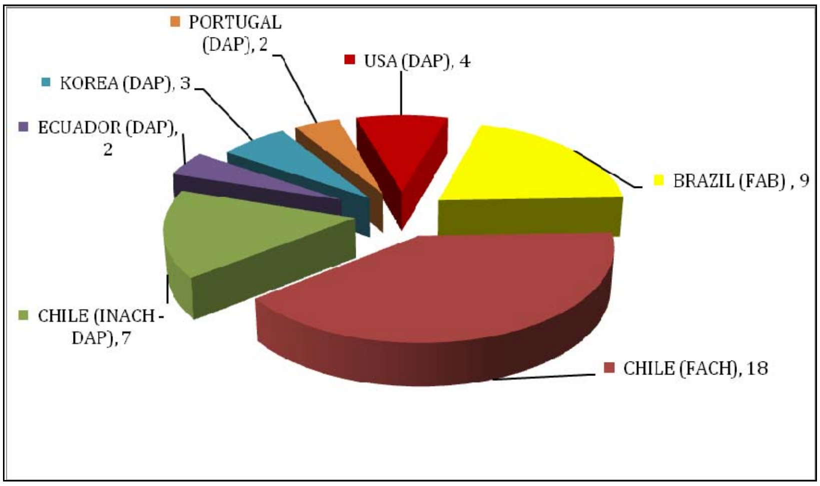

Figure 3: Punta Arenas–King George Island flights carrying INACH scientists, 2011–12 season

Altogether, around 3,000 passengers fly on that route every year, with plenty of international cooperation going on every season. INACH has information only on the Chilean private flights it charters or shares, but even that limited information tells us that for every Chilean passenger there were approximately two non-Chilean scientists flying, to a total number of 486 passengers.

Of the 18 private incoming (to Antarctica) or outgoing (from Antarctica) flights recorded for the 2011–12 season, there were seven flights chartered by INACH, four by the US National Science Foundation (two return flights), three by the Korean Polar Research Institute and two each by Ecuador and Portugal. On every one of them there were scientists and personnel from several National Antarctic Programmes.

For more than 20 years, from 1980 to 2001, INACH chartered a vessel for all its work in the summer season. The *Alcázar* could carry only around 20 scientists plus logistics and crew.

As the graphic in Figure 4 shows, for the 2011–12 season alone, if INACH had had to move all the different nations' 486 scientists by ship it would have required 25 crossings of the Drake Passage to transport them and their cargo. Cooperation between National Antarctic Programmes would have been much more difficult, due to the vessel space limitations.

Still, the vessels *Lautaro* and *Viel* have been used for short periods of time, plus helicopters and Twin Otters, to take scientists into the field.

Another strategy that has been used is locating the research projects in areas not far from stations, huts or landing sites, saving on ship time and logistic personnel.

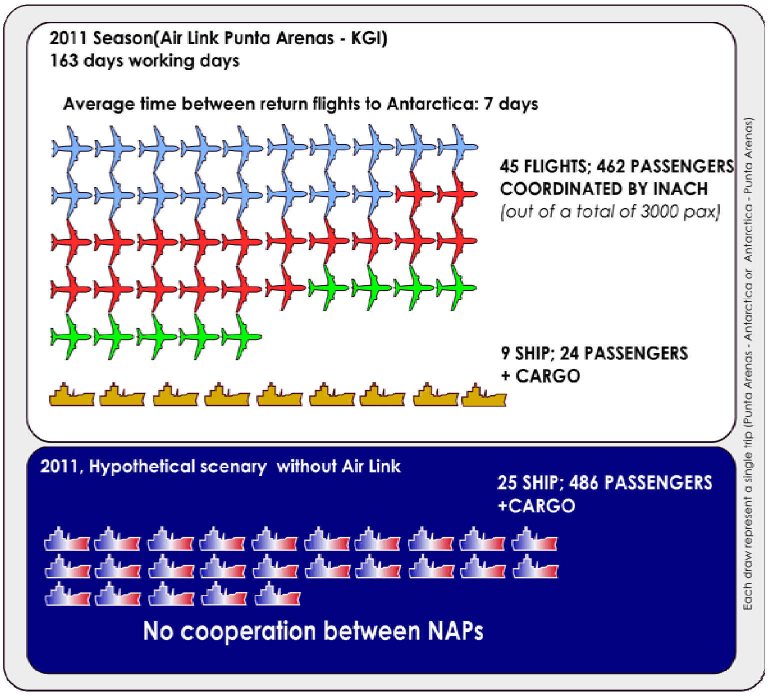

Figure 4: Number of flights from Punta Arenas to King George Island (KGI) that actually took place in the 2011–12 season, and the hypothetical scenario if only ships had been used to transport the same numbers

Comparing last season with the 2001–02 season, when the *Alcázar* was chartered (Figure 5), the sum of all strategies means that, although the number of projects in Antarctica has gone up by 45 per cent, the number of scientists has gone down by 11 per cent and the human residence time is now only 40 per cent of what it used to be.

Season	Scientist Days	INACH Scientists	No. of Projects
2001–02	3,278	75	20
2011–12	1,296	67	29
Conclusions:	Scientist Days down 60%	Scientists in Antarctica down 11%	Antarctic Projects up 45%

Figure 5: Comparison of activity of INACH in 2001–02 and 2011–12

Summarising INACH's Strategies

Cooperation amongst National Antarctic Programmes remains the key to reducing environmental footprint in Antarctica. Trading use of station facilities with ship- or aeroplane-time is a useful tool. Lab projects versus projects that require actual presence in Antarctica should be employed when possible. Cooperation between projects is also ideal. Scientists should utilise research huts not far from airfields and scientists should be in the field for the minimum possible time.

In conclusion, this paper shows that the intensive use of aeroplanes brings down the human residence time, and that, at least for the short-lived science environmental footprint, the footprint has not necessarily been growing with the increase in the science that is done: ”old times are not always better ones.”

To the future, sharing our travelling agendas and our maritime and airline schedules can bring only benefits, not only to all of us but also to the environment.

See “Presentation 1 Retamales” on DVD for full oral presentation.

SUSTAINING ANTARCTIC RESEARCH IN AN INCREASINGLY CHALLENGING ENVIRONMENT: AUSTRALIA'S MODERNISATION PROCESS

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Introduction

As the international delegates who attended the Antarctic Treaty Consultative Meeting in Hobart in June 2012 appreciate, Australia is a long way from the rest of the world. Even within Australia itself, the major population centres are a long way apart from each other.

In 1966, one of Australia's leading historians, Geoffrey Blainey, published a book entitled *The Tyranny of Distance*, which argued that Australia's history, and the world view of the Australian people, were strongly influenced by our experiences of distance and isolation. It strikes me that a familiarity, and even comfort, with geographical isolation must have been an influence on the decision of Phillip Law and the others who set up the Australian Antarctic Program to establish our four southern stations – Mawson, Davis, Casey and Macquarie Island – across such a large geographical area. A return voyage from Hobart calling at all four stations must cover around 6,500 nautical miles (12,000 kilometres). Allowing for icebreaking and other delays, this journey likely takes well over one month to complete on our flagship, *Aurora Australis.*

This geographical spread of stations creates an enormous operational challenge for the Australian Antarctic Program. This is accentuated by Australia's long-standing tendency to conduct our activities on a largely self-sufficient basis: far more so than most other Antarctic nations. This has been partly a matter of necessity – given the relatively small number of nations operating in eastern Antarctica until recently – but is also, I believe, a product of our cultural acceptance of working and living in isolation.

It is my argument that this isolated, self-sufficient approach is becoming less tenable for Australia and other Antarctic nations in the context of tight fiscal environments and growing expectations of the levels of utility, safety and comfort that our programmes will provide. In Australia's case, this challenge is accentuated by age-related and other problems with our infrastructure and transportation assets.

The following paper is a thought piece that describes the methodologies we are using to develop responses to these challenges, along with some of our possible future thinking about how to overcome the challenges. The possible solutions I will discuss are only ideas at this stage and do not represent official Australian government policy.

Ageing infrastructure and transportation assets, and associated issues

Australia's flagship Antarctic icebreaker, the *Aurora Australis,* has undertaken more than two decades of high-intensity operation in Antarctica. A recent life-expectancy survey for the vessel clarified that a process for replacing it will need to commence shortly.

Likewise, our three continental stations largely comprise buildings that date back to the 1980s or earlier, and several of the buildings at our station at the sub-Antarctic Macquarie Island date back to the 1950s and 1960s. Our station designs are becoming outmoded in terms of operational efficiency, energy use and expeditioner comfort, and extensive rebuilding and/or refreshment is likely to be required over the next two decades.

Australia's Antarctic aviation system has been developed significantly in recent years, but remains somewhat fragile. The Wilkins ice runway represents a substantial engineering achievement, but is subject to closure in some seasons over mid-summer because of sub-surface melt. We have received peer-reviewed scientific advice that the runway will experience such melting in around 60 per cent of seasons. We have also found that the location and ice structure of the runway made snow paving all but impossible to achieve, and that the known voids and crevasses under the runway service would always necessitate significant preparation time after any period of extended runway closure.

All of these problems present significant obstacles to the achievement of our goal of using Wilkins runway as a hub for our inter- and intra-continental aviation in Antarctica to enable us to reliably connect our three continental stations by air to Hobart.

Of course, a reliable network of transport and infrastructure is critical to supporting our Antarctic scientific research. Australia's increasingly fragile and ageing suite of transport and infrastructure assets is giving rise to ever-increasing challenges in operational planning. When assets fail, sub-optimal operational and scientific outcomes result, and, at times, unwelcome additional costs arise.

Against this background, in 2011 the Australian Antarctic Division (AAD) embarked on a systematic review of all our future requirements for operating our Antarctic programme and conducting scientific research in Antarctica and the Southern Ocean. This review encompassed logistics, station design, information and communication technologies, procurement of goods and services, scientific and operational planning, and existing and potential future collaboration with other Antarctic nations and private suppliers.

We engaged in this comprehensive review because we recognised that the sustainability of our programme can be fully understood only from a system perspective. We need to map our projected requirements over the next few decades against our existing suite of resources, assets and capabilities and to then identify the problems and deficiencies that we need to address. An integral part of this work was a focus on environmental sustainability: considering the potential impact of environmental variables on the operational systems and scenarios we modelled and, conversely, the potential impact of those future operational models on the environment.

Model-based System Engineering (MBSE)

Our modelling approach is based on the methodology of model-based system engineering (MBSE).   Our starting point in the modelling process has been to develop projections of climate and environmental conditions in terms of their impact on transportation logistics and station resupply.   The AAD and the Australian Bureau of Meteorology jointly compiled and reviewed all historical and forecast environmental data affecting East Antarctica and the surrounding areas of the Southern Ocean. These data were then incorporated into a computer-based modelling system as a random variable input. This modelling process has enabled us to greatly enrich our systemic understanding of how to develop future programmes of Antarctic and Southern Oceans activity that will be both operationally and environmentally sustainable.

The data we analysed in our modelling process included

- all sea-state and wind data, including frequency of sea-state and wind for every month by every degree of latitude and across multiple longitudes;
- 21 years of environmental information recorded by *Aurora Australis* in the course of its voyages*;*

- monthly sea-ice thickness and extent (historical and forecast for next 30 years); and

- all monthly meteorological data for Casey, Davis, and Mawson stations and for Macquarie Island since records began, to glean information about flying conditions, skiway rectification times following blizzards, environmental factors affecting ship and station-resupply operations, and a range of other factors.

For instance, we undertook in-depth modelling of variability in Southern Ocean wave conditions and how this affects shipping operations. We processed wave data (significant wave height, primary wave period and 10-metre wind-speed data) between 69^{o} S and 30^{o} S and 50^{o} E to 150^{o} E with model data every three hours. From this, we calculated a minimum, mean and maximum, by latitude, for wind speed, wave height and wave period. The project meant working through 135 million data points across four variables to provide the outputs for waves in the Southern Ocean. This information will be crucial for us in selecting/designing our future shipping capability.

Utilising the random environmental variables list above, the MBSE approach allowed us to model a series of “seasons” to identify how many sea days or flying hours would be required to move a certain amount of bulk cargo (containers, liquid fuels, break bulk etc.) and personnel to, from and around East Antarctica and the adjacent parts of the Southern Ocean. Outputs would change for each modelled season because of the randomly changing environmental variables.

The model was run for 100-year cycles to ascertain left and right of arcs for the best possible season, and for the worst possible season. The median point between those arcs was used to benchmark potential operational capabilities and funding levels.

The median figure produced by the model of 161 sea days per annum for station resupply and logistic support was slightly higher than our existing planning assumption of 150 sea days for this activity. Given that the model is predicting somewhat more-difficult environmental conditions for shipping in the Southern Ocean, we see this particular result from the modelling process helping to validate the model as a whole.

The graphic in the presentation depicts just one aspect of the overall logistic system model, which included all known environmental variables to provide an accurate simulation of an Antarctic season, inclusive of projections of seasonal variability that had been previously developed in a far less formal way, largely on the basis of expectations derived from past experience. The model-based systems engineering work, when it is completed, will allow the AAD to project what it would take to maintain a sustainable system at all levels (people, capabilities, assets, funding) across capability life cycles.

We will shortly be combining ship and air simulations and will run the model as a combined 100-year operational cycle, to capture the effect of integrated behaviours, and to understand and then adjust capability specifications and funding baselines if required. Another step in the process will be to develop models in which the system as a whole will produce the minimum achievable levels of emissions and waste.

We hope to develop and maintain the model as an integrated planning system for future seasons to ensure efficient use of the system is planned and occurs.

Solutions being considered

Improved Icebreaker Technology
In the two decades since *Aurora Australis* was built, icebreaker technology and technology generally have come a long way. For example, double acting hull forms have been

developed. These allow for the ocean-going hull form to be used in one direction, while the icebreaking hull-form can be used in the other direction. This provides significant efficiency for long Southern Ocean voyages in terms of improved fuel efficiency and better use of space. Also, azimuth drives now provide significantly improved manoeuvrability and position holding for exact science and critical resupply operations.

If the Australian Government decides to finance the build of a new flagship for the Australian Antarctic Program, the design will need to take account of the modelling of ice and weather conditions mentioned above. This modelling indicates that a resupply ship operating in East Antarctica may need to be able to break ice with a thickness 25 per cent or more greater than does the *Aurora Australis* (which can break up 1.23 metres), plus 0.4 metres of snow loading on top of the ice. It also indicates that an ideal future ship would be able to fully resupply two of our stations on a voyage (whereas the *Aurora Australis* typically resupplies only one per voyage). To achieve this goal, a future ship is likely to require greater storage capacity for cargo and liquid fuel, and more hangar space for helicopters.

Intercontinental Airlink Options
Our current Antarctic airlink through Wilkins Aerodrome, 60 kilometres inland from Casey Station, is based on the concept of a “hub and spoke” operations, in which the A319 Airbus flying from Hobart connects at Wilkins to intracontinental turboprop aircraft (currently Baslers and Twin Otters) to take expeditioners onwards from Wilkins to our continental stations and field camps. (NB: Because of environmental and climatic factors, we are not contemplating any fixed-wing aviation operations to our station on Macquarie Island.)

The two weak links in this model are

- the mid-season melt problems at Wilkins noted above; and

- the prevailing weather patterns in East Antarctica, in which adverse weather conditions for flying typically come from the west to the east, which means that through-journeys by air from Hobart to Davis and Mawson stations are likely to be delayed one or more times by adverse weather.

Our modelling has identified that the ideal operational model for our aviation system would involve using Hobart as the "hub" and would fly passengers and light cargo directly to each of our three continental stations by ski-equipped long-range intercontinental aircraft. This would enable us to "shop" between the three continental stations for weather windows, as adverse weather patterns move slowly from west to east across our operating area. It would also enable us to reduce our reliance on smaller intracontinental fixed-wing aircraft for moving people and small cargo to and from each continental station. Such a model would, of course, require greatly increased capabilities for fuel storage and handling at our stations, and investment in storage capabilities such as double-bunded tanks, which will meet strict environmental guidelines. This requirement in turn will place additional pressure on the storage capacity for cargo and liquid fuel of any future flagship vessel.

This Hobart-based "hub and spoke" model would expand our current aviation capability in terms of the numbers of personnel and small cargo that could be transported each season. It would also improve Australia's search and rescue capability in the more remote parts of the Southern Ocean, where a number of passengers have need to be rescued from fishing vessels and yachts in recent years.

At present, there are no aircraft operating anywhere in the world that have the capability of operating our "Hobart hub and spoke" model. Further developmental work is therefore required for this model to be translated into a reality.

Station Rebuild or Refresh Decisions

As I noted above, the AAD will soon begin developing a programme of station rebuilding and refreshment stretching over a period of up to two decades. The size and location of our buildings in inland and other field locations will also be considered, along with the traverse capabilities we require to service them (the AAD having significantly reduced its traverse capability in recent years).

Some Hobart-based infrastructure supporting our Antarctic operations is also being upgraded: in particular, the construction of a state-of-the-art cargo operations facility at Macquarie 2 wharf, which will achieve a high level of biosecurity and energy efficiency. This project, which is a collaborative effort between the AAD and TasPorts (the local port authority) and the Australian Antarctic Division, is scheduled for completion in early 2013 and will benefit all Antarctic vessels making port calls in Hobart. AAD experts in property and cargo logistics have been working closely with our science and environmental experts in order to maximise the biosecurity of the wharf building. Upgrades include the addition of rapidly opening/closing doors, rodent proofing, bird proofing and procedures for keeping out seeds.

Conclusion

AAD's vision through the modelling process I have described above is of a future integrated system of shipping, aviation, cargo handling, terrestrial vehicles, built infrastructure, information and communication technologies, planning and environmental protection, all working together to deliver the best possible outcomes in terms of Antarctic operations and scientific research.

The biggest obstacle to the realisation of this vision is, as you would expect, its potential cost. Some of you might say that, in the current global economic environment, Australia is better placed than most nations to meet such a cost. But the Australian Government, like all national governments, is faced with the need to retain tight fiscal control and to restrict the budgetary choices it makes. This is a situation with which I am sure most of you are only too familiar: the struggle of Antarctic programmes to compete for government funding against other sectors such as health, education, public works, social welfare and defence.

These problems raise a crucial question that we all might wish to consider. In a world of rising costs and growing expectations of safety and comfort, a fully autonomous national system of operation in Antarctica might no longer be a realistic prospect for most of us; particularly if we aspire to achieve the sort of integrated, efficient, environmentally sustainable system I have outlined above. So, I am predicting that the extent to which we currently collaborate with each other in terms of operations and logistics will need to increase and become far more systematic and rigorously planned.

As I stated at the outset, Australia's approach in Antarctica has typically been to try to do as much as we can on our own, perhaps trading some spare capacity on a quid pro quo basis with other programmes. Adopting a more systemic approach to collaboration will require something of a cultural shift for us, and perhaps also for some of you, but it is one that we are willing to make. By being relatively open in this paper about some of our long-term strategic thinking, I have made a small step forward. I propose in future to give other COMNAP nations access to the planning methodology I have described above, with the aim of enhancing the opportunities for collaboration among us all to sustain our scientific research efforts in the most difficult and fragile environment on earth.

See "Presentation 2 Wooding" on DVD for full oral presentation.

“LESSONS FROM THE ARCTIC – DRIVERS FOR DEVELOPMENT”

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Abstract

Within a few years, politicians will have to consider how to manage a wide variety of issues related to a rapidly changing Arctic. These issues include new shipping routes, migrating marine species resulting in new fisheries, opening of new areas for oil and gas exploitation, mining industry developments, expanding tourism, military presence, mitigating potential conflicts with indigenous peoples’ traditional lifestyles, and so on.

The Arctic Council, an intergovernmental body that promotes cooperation, coordination and interaction among the Arctic states, is addressing many of these important issues. It is absolutely critical that future political decisions are based on comprehensive management plans that are, in turn, based on scientific research and knowledge achieved through international collaboration.

Even though the drivers are weaker in Antarctica, lessons can be learned from the Arctic. A development related to one going on in the Arctic cannot be ruled out from happening in Antarctica sometime in the future. Thus, studying the Arctic development can enable us to be better positioned when similar issues become relevant for the Antarctica.

See “Presentation 3 Winther” on DVD for full oral presentation.

SUSTAINABLE SCIENCE AT HALLEY VI

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Introduction

The first station at Halley was established by the Royal Society in 1956 and was used to conduct research into meteorology, glaciology, seismology, radio astronomy and geospace science for the International Geophysical Year. Since then, there have been five new bases built near the original site, as each station became buried by snow drifts and as the ice shelf moved the station along towards the sea–ice interface. In 2004, the British Antarctic Survey (BAS) decided to design and build a replacement station at a safe location on the Brunt Ice Shelf to replace Halley V, which had begun operations in February 1992. Thus, a new station was designed and subsequently built and it is now open for use. The new station incorporates modern and energy-efficient design and is an innovative hub from which to support Antarctic science. This paper describes the station's design criteria and discusses results from the project.

Halley VI Design

The design of Halley VI utilises the benefits of the jackable and ski-based buildings in use at Halley V. The station is made up of eight individual modules, which are connected by short, flexible corridors (Figure 1). The design can accommodate up to 16 people in the winter, and 52 in the summer months. The modules are kept above the snow surface using hydraulic legs mounted on skis. As well as keeping the buildings above the rising snow level the new design allows the station to be periodically relocated across distances of many kilometres. If the station must be moved, the individual modules are designed to be separated, towed across the ice shelf by bulldozer, and then reconnected at the new site. This makes it possible for the station to remain a safe distance from the edge of the Brunt Ice Shelf.

Figure 1: Halley VI Station

In addition to the modular design, the skis and the hydraulics, the base features a steel frame that is clad in glassfibre reinforced plastic panels. For energy efficiency, the station utilises a Combined Heat and Power system, with up to 4 x 125 kilovolt-amperes of electrical power being available. A VSAT system is used for communications, with current bandwidth limited to 256 kilobytes per second.

“Whole Atmosphere” Research Station

BAS and the National Environmental Research Council have constructed and equipped the station to be a world class, polar, atmospheric research station, capable of doing process studies from a broad range, starting from a few metres into the snow pack and extending out to the magnetosphere.

Halley also has an exemplary long term monitoring dataset, including the stratospheric ozone dataset that led to the discovery of the Antarctic ozone hole. These long term observations will continue and BAS would welcome approaches to develop science at Halley.

For now, the initial science focus will be

- vertical coupling through the whole atmosphere;
- atmospheric chemistry; and
- the role of solar variability in climate.

However, the station has the capacity to develop new science study areas, including ocean–ice shelf interactions using instrument deployments through the ice shelf (such as hot water drill holes) into the ocean cavity below the ice, and emperor penguin behaviour in a colony of some 20,000 birds located on the coastline adjacent to Halley.

Halley VI as a “Regional Gateway”

By air from Halley, autonomous geophysical field stations can be deployed on the Antarctic Plateau. The schematic in Figure 2 shows the SuperDARN radar network fields of view (coloured pie segments); the red dots indicate the location of geomagnetic field instruments deployed from Halley. Together, these form a powerful space-weather diagnostics system.

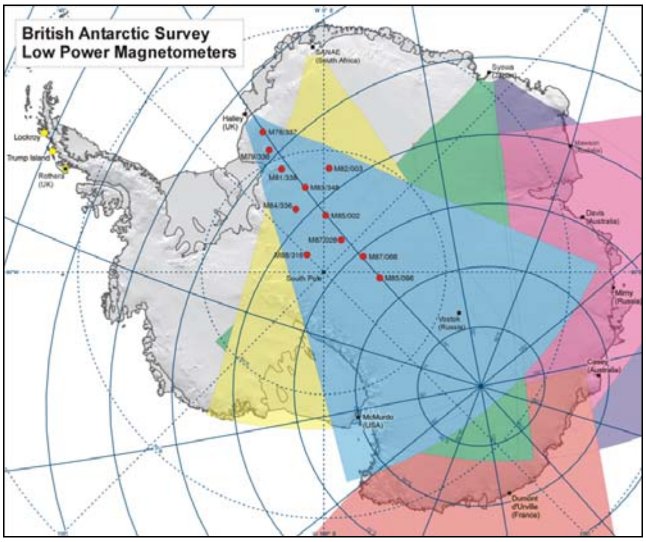

Figure 2: SuperDARN radar network fields of view

Other instruments deployed in regional networks around Halley have included ground ozone monitors, and devices for boundary layer profiling and geo-electric field measurements. Halley’s location has made it ideal for positioning large antenna arrays and for conducting the first ever unmanned aerial vehicle campaign, which targeted air–sea-ice interactions over the coastal zone.

Conclusions

The new Halley VI station has laboratory and office space and science and engineering staff that can support collaborative science projects. These allow for new partnerships and for the development of collaborative science programmes like never before. BAS encourage any COMNAP national Antarctic programme to contact them to discuss ideas for the next generation of Antarctic research.

See “Presentation 4 Culshaw” on DVD for full oral presentation.

The New Zealand Antarctic Programme – A Case Study Approach to Sustaining Science

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Introduction

Antarctica New Zealand is the New Zealand national entity charged with carrying out New Zealand's Antarctic research programme. This paper presents Antarctica New Zealand's response to recent challenges, including fiscal restraint, increasing complexity and demands of Antarctic science, and long lead-in times for logistics planning.

Background

In 2008, when the Global Financial Crisis began, the Board of Antarctica New Zealand instructed management to deliver on four key objectives:

1. Recognise that the New Zealand government is entering a prolonged period of fiscal restraints.
2. Reduce the New Zealand Antarctic science scope from a wide focus to areas of key relevance to New Zealand and its work with the Scientific Committee for Antarctic Research and with the Antarctic Treaty Consultative Meeting.
3. Increase sectoral leadership of Antarctic activity across New Zealand government agencies.
4. Increase productivity of the organisation by 33 per cent (doing more with less).

Management Response

The management response to these instructions was to

1. eliminate waste;
   - "zero harm" safety goal
   - helicopter replacement with Eurocopter EC-130 B4 (180 litres per hour fuel use, versus 370 litres per hour for the Bell 212)
   - building management system
   - ozone water treatment (20 per cent water reduction)
   - energy conservation (CEMARS) (carbon emissions reduced by 47 per cent from 2008–09)

2. embed principles of sustainability;
   - US–NZ Crater Hill Wind Farm Pilot (400,000 litres of fuel targeted savings; 660,000 litres actual savings)
   - LEAN continuous improvement across organisation
   - reduced staff numbers (Christchurch and Scott Base)

3. focus organisation on "zero harm";
   - Antarctica New Zealand Awareness Programme, Christchurch
     - team leader / team member
     - decision-making model (D4TR)
     - task assignment
     - judgement over rules
   - Antarctic skills programme, Scott Base
     - sequentially teaching leadership models in live Antarctic environment
   - health, safety and environment system

4. lead a New Zealand Government Antarctic science strategy;
   - whole-of-government approach
   - reduce scope of New Zealand Antarctic Research Programme to focus on research that is critical to New Zealand
   - increased priority on applied research over pure research
   - three key research programmes:
     - climate, cryosphere, atmosphere and lithosphere
     - inland and coastal ecosystems
     - marine systems

5. improve monitoring of science performance and cost; and

6. establish the New Zealand Antarctic Research Institute as an independent charitable trust.

Figure 1: Example of learning material from the Antarctica New Zealand Awareness Programme

Conclusion

While numerous management responses have been established and positive outcomes are already being realised, there is still more work to do. For example, an inventory management system and a waste management system have been proposed. Science performance and logistics support measurements will continue and allocation of resources will be linked to science performance, with strong performers being given continuing support.

See “Presentation 5 Sanson” on DVD for full oral presentation.

RUSSIAN ANTARCTIC EXPEDITIONS – SUSTAINABLE TRANSPORT AND THE NEW RESEARCH VESSEL

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Introduction

Ships remain the primary means of supporting logistics activities of the national Antarctic programmes and are the main means of transportation to and from the Antarctic continent. For many years, a sole ship, the *Akademik Fedorov*, was in use in support of the Russian Antarctic Expedition (RAE). However, in 2007, RAE launched a project to design and construct a new vessel. As a result, the *Akademik Tryoshnikov* is now under development and will be in use in the near future in support of Antarctic operations. This paper includes a discussion of some of the many innovative and energy efficient design features of the new vessel.

The *Akademik Fedorov*

In 1987, the special research expedition vessel the *Akademik Fedorov* was built in Finland for providing support for activity of the Russian (Soviet) Antarctic Expedition. On 9 September 1987, the vessel was introduced into operation. The vessel incorporates a combination of different functional peculiarities of transport ships into one design in order to respond to the various needs of researchers and others that use the vessel.

The research expedition vessel transports expedition personnel and various cargoes, including heavy transport vehicles, food products, and fuel for maintaining operations at the Antarctic stations. The vessel also has deck equipment and scientific laboratories and facilities for conducting marine studies while the ship is in transit.

Beginning in 1994, the *Akademik Fedorov* became the only RAE ship used for support of its activity in the Antarctic. Recently, it was recognised that there was a need to design and develop a new vessel as the *Akademik Fedorov* approached its predicted useful life expectancy.

The New Vessel

In 2007, the Roshydromet held a tender competition for design and construction of the new research expedition vessel for support of the Russian Antarctic Programme, and, in late 2008, the contract for ship construction was signed with the Admiralty Shipyards in St Petersburg. Construction began in 2009, with a planned completion date of late 2012.

The new vessel (see Figure 1) will be called the *Akademik Tryoshnikov*, in honour of the former Director of the Arctic and Antarctic Research Institute, Academician Aleksey Tryoshnikov, who was a pioneer of Vostok Station in 1958.

The new vessel is classed as a special purpose vessel with an unrestricted navigation area, including unescorted navigation under the ice conditions of the Antarctic seas, and navigation in the tropical seas.

The vessel will have two decks, with the developed foredeck and the bow board sling, with the midship superstructure developed to the stern; stern helicopter pad and hangar; midship location of the engine spaces; a twin-shaft, diesel-electric power plant with a total capacity of about 17 megawatts; fixed pitch propellers; bow and stern thrusters with cargo fuel tanks; space for transport of explosives or dangerous cargo; space for transport of dry cargo; and refrigeration holds.

Figure 1: A computer-generated model showing the proposed design of the new vessel *Akademik Tryoshnikov*

Technical particulars are as follows (See Figure 2):

- Overall length – about 133.5 metres
- Length between perpendiculars – 124 metres
- Overall breadth – 23 metres
- Freeboard – 13.5 metres
- Draft (at full displacement) – 8.5 metres
- Full displacement – 16,900 tons
- Passenger-carrying capacity – 80 plus 60 crew (140 people in total).

The vessel will be equipped with 11 laboratories, which will cater for specific research, including meteorology, hydrography, oceanography, hydrology, hydrochemistry, ecology and ice pressure monitoring. Additionally, the vessel can be supplied with laboratory modules for studies of ice, biology, geophysics and atmosphere.

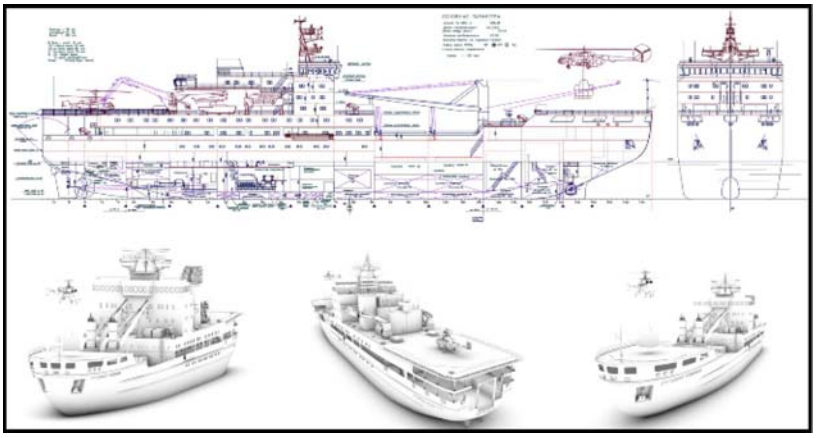

Figure 2: Design diagrams showing technical details of the *Akademik Tryoshnikov*

Future Plans

On 30 October 2010, the Russian Federation Government approved the *Strategy for the Development of the Russian Federation's Activity in the Antarctic for the Period until 2020 and Longer-Term Perspective*. In accordance with this document, the plan is to resume the year-round operation of Russkaya Station, temporarily closed in 1990.

For this purpose, a new RAE transport scheme was developed (Figure 3). The scheme includes the use of the *Akademik Fedorov*, which will continue operation in the Indian Ocean sector of the Antarctic in the area between the Novolazarevskaya and Mirny Stations (including Oasis Base, located in the Bunger Hills). It will carry out technical resupply and personnel rotation at these stations and organise seasonal studies at the seasonal field bases Molodezhnaya, Druzhnaya-4 and Soyuz. It is planned that the ship will be visiting the aforementioned stations and field bases twice each season.

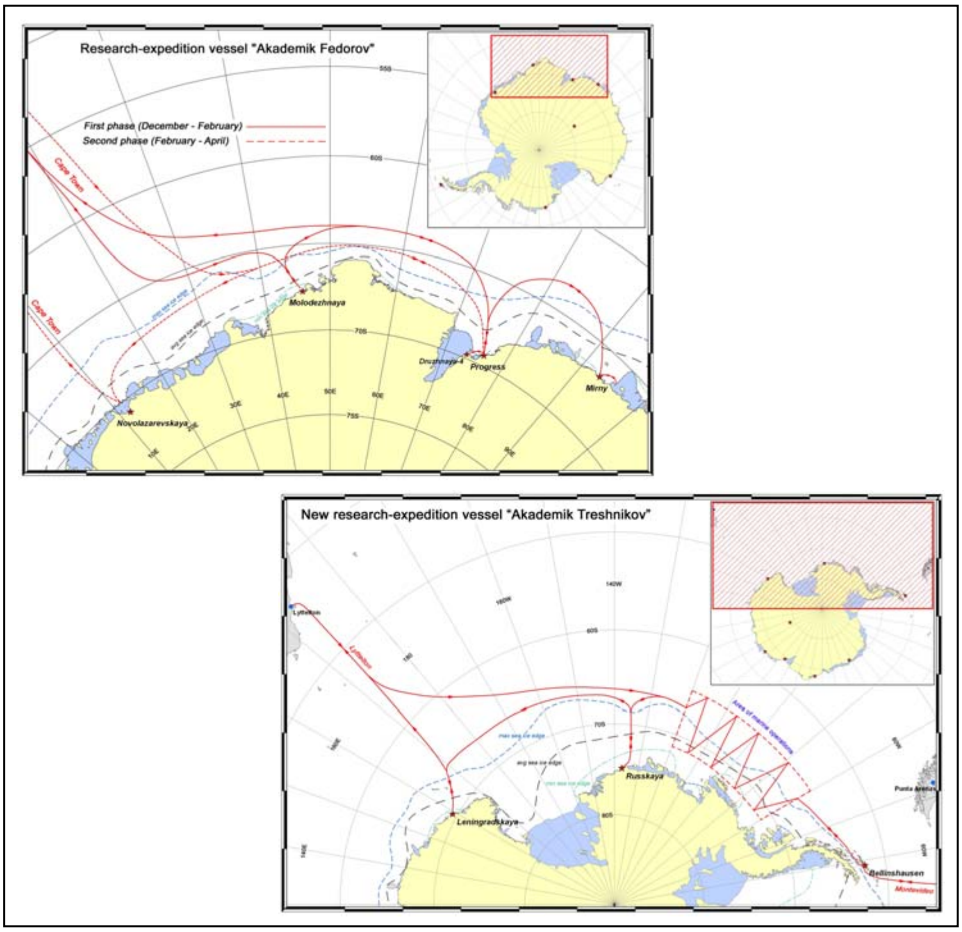

Figure 3: Proposed operation of *Akademik Fedorov* (top); Proposed operation of *Akademik Tryoshnikov* (bottom)

Beginning from the 2013–2014 season, the *Akademik Tryoshnikov* will annually operate in the Pacific sector of the Antarctic in the area between Bellingshausen Station and the seasonal base Leningradskaya, with a single call in mid-February to Russkaya Station. The seasonal studies at Russkaya Station and the seasonal base Leningradskaya will be arranged by means of aviation. Closing of seasonal programmes will also be annually carried out by the vessel.

See “Presentation 6 Lukin” on DVD for full oral presentation.

AUTO GUIDANCE – UNMANNED TRACTORS FOR LOGISTICS

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Introduction

An unmanned snow vehicle for transportation of heavy cargo is presented in this paper. Two types of vehicles are used in a Japanese Antarctic programme transportation mission. One is an ordinary vehicle, called a “multi-task snow vehicle”, operated by a human driver. The vehicle has a front snow-blade, three or four seats for the crew in the cabin, and a crane. It tows on sledges an observation module, a living module and a power module. The other is an unmanned vehicle dedicated for all other cargo. It follows in the path of the human-operated vehicle. The distance between these vehicles is approximately 100 to 200 metres, depending on the total length of the sledges towed by the first vehicle. Since the distance is too long for tracking using a vision system, the route is recorded by the leading vehicle using GPS and is transmitted to the unmanned vehicle as waypoints through a wireless communication system.

Background

The Japanese Antarctic Research Expedition has launched a new project of astronomical observation at Dome Fuji Station, located inland on the Antarctic plateau, 1,000 kilometres away from Showa Station. In this project, heavy cargo such as the telescope, power plant and fuel have to be transported on the snow surface over long distances. From the experiences of a previous project it was known that it would be necessary to reduce the operator’s burden caused by heavy vibration due to rough terrain and by the long duration of the drive. Therefore, a project was begun to test, and then add, an additional, unmanned, snow vehicle to the traverse, in support of the logistical mission and eventually of the sustainability of the entire project.

The project team was composed of the National Institute of Polar Research / Japanese Antarctic Research Expedition, with technical support from the National Defense Academy's departments of mechanical engineering and of computer science. The Mechanical Engineering Department was in charge of designing the off-road vehicle, and the Computer Science Department was in charge of guidance-control software. The manufacturing of the system was done by the Hitachi Advanced Systems Corporation.

The mission was to design, test and develop a long-range transportation system that would cover a distance of 1,000 kilometres over a period of three weeks and that would be capable of towing a load of up to 10 tons. The idea of developing the automated system was to reduce operator burden, to provide sustainable logistics support and to create innovative technology.

Autonomous vehicle

An autonomous vehicle is one that is capable of travelling to a destination by itself. To do so, the vehicle requires accurate positioning and orientation and also the ability to detect and avoid obstacles in its path.

Antarctic navigation presents particular difficulties, including the following:

- Localisation
  - Less accuracy and precision expected with GPS (Figure 1)
  - No landmarks available, such as urban areas
- Slippage
  - Instability of vehicles
  - Inaccurate odometry
  - Difficulty with prediction
- Snowy and icy environment
  - Hard to test
  - Crevasse detection

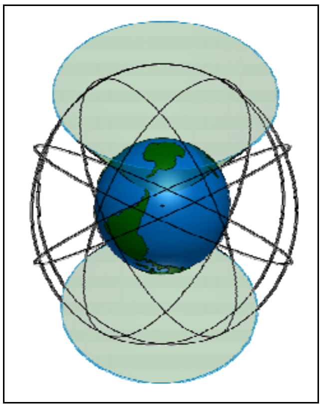

Figure 1: Orbits of the GPS satellites, showing the unvisited cone that includes Antarctica. GPS is indeed available in Antarctica, but limited elevation angle degrades the accuracy

These particular difficulties required us to choose a unique solution according to the availability of equipment at the time. The solution was that two types of vehicles would be used: a multi-task vehicle in the lead, with a human operator; and, following, an unmanned tractor (Figure 2). The multi-task vehicle tows cargos on sledges, including a living module. The human driver is responsible for watching the path, for driving the vehicle in the right direction and for avoiding obstacles. The majority of autonomous tasks are thus supported by the driver. The follower is automated by a computer system and tows sledges that cannot be carried by the multi-task vehicle. The distance between the two vehicles ranges from 100 to 200 metres, which is out of the range of a vision-based tracking system. Therefore, both vehicles are equipped with moving-base RTK GPS. It utilises carrier phase measurement and corrects the error on either of two receivers by another, to achieve 0.2 metres of relative positional accuracy. The trajectory of the front vehicle is transmitted to the follower as a series of coordinates via wireless communication, together with the correction signal for the GPS. Thus, the follower is expected to trace the same trajectory of the lead with the accuracy of the RTK GPS.

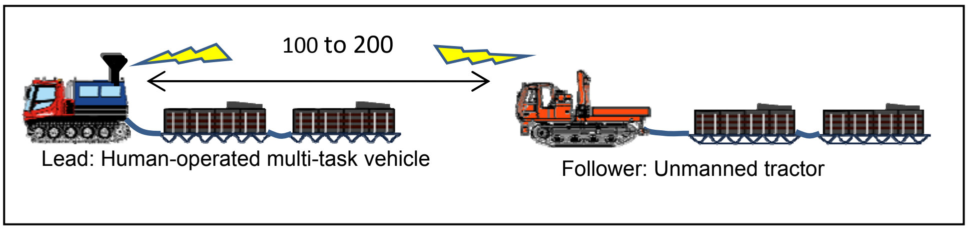

Figure 2: Two vehicle configuration for logistic support

Hardware specifications

The unmanned tractor was manufactured based on a commercially available off-road vehicle equipped with rubber tracks. Its specification is summarised in the presentation. Special equipment was added for the cold climate and for towing tasks (Figure 3).

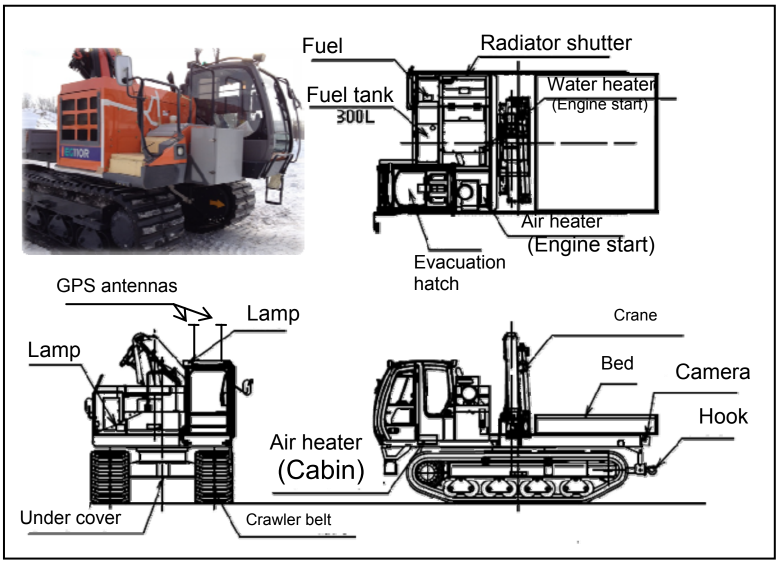

Figure 3: Unmanned tractor and diagrams identifying special equipment

Control system and guidance control

Both vehicles receive GPS signals from satellites and communicate with each other via a Wi-Fi communication channel. Wireless communication transfers a correction signal for RTK-GPS, waypoint coordinates and a video signal for monitoring purposes (Figure 4). Choosing the correct path and avoiding obstacles are the responsibilities of the human operator, and the unmanned tractor simply follows the points where the lead vehicle passes, based on so-called proportional navigation; the yaw rate is controlled to be proportional to the azimuth error between the vehicle and the waypoint. While the distance between two vehicles is monitored and maintained based on positional information from GPS, the tractor also uses the front-view camera to watch for a sign board placed on the last sledge of the lead vehicle and to activate an emergency brake when necessary. Multilevel security for sensor and system faults is also implemented.

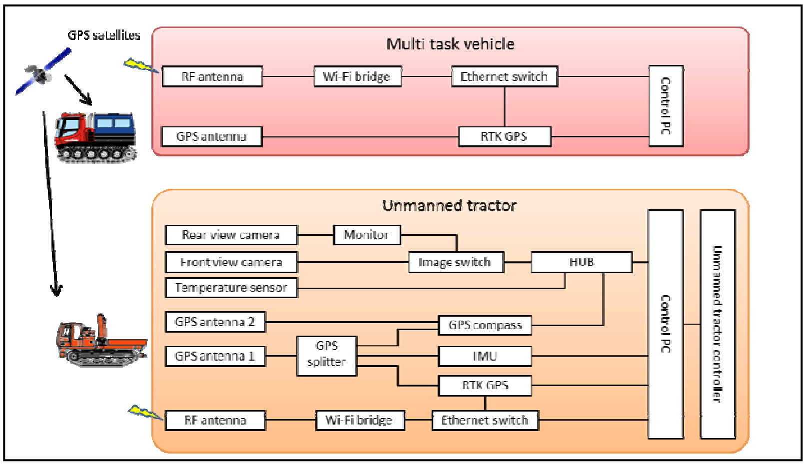

Figure 4: Diagram of the entire system

Performance test and conclusion

The performance test was conducted for the unmanned vehicle on a snowfield in Hokkaido, Japan. Since the vehicle is equipped with rubber caterpillar tracks, there is always slippage between the tracks and the terrain surface. This would be of concern, especially on a curved trajectory. This unexpected slippage may cause unstable behaviour of the vehicle. Therefore, the slip ratio was measured in a variety of circumstances in advance. By considering the ratio in the control algorithm, we finally confirmed stable navigation and firm tracking within the error of at most five metres. On-site tests in Antarctica and further development for full autonomy remain as future issues.

See “Presentation 7 Date” on DVD for full oral presentation.

UNITED STATES ANTARCTIC PROGRAM UPDATE

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Background

The United States Antarctic Program (USAP), managed by the National Science Foundation, Office of Polar Programs, is undergoing a period of sustained change. There are two major activities that have occurred in the past year that will likely set programmatic direction for the next several years. The purpose of this paper is to provide context for the COMNAP members on these changes and how they may affect priorities and decisions of the USAP. Additionally, there are external financial considerations affecting US polar research at present, as well as initiatives from other federal agencies, such as the National Aeronautics and Space Administration, the National Oceanographic and Atmospheric Administration and the Department of Defense.

Prime Contract Transition

On 23 December 2011, the National Science Foundation (NSF) awarded a contract of up to 13 years in duration to Lockheed Martin Corporation for base and research support operations in Antarctica. The transition-in was completed on 31 March 2012, and the prior contractor, Raytheon Polar Services, has now ceased operations. The new contract with Lockheed (which refers to itself as “ASC”, for “Antarctic Support Contract”) is a hybrid structure, which NSF developed specifically to provide flexibility on the part of the government to incentivise the contractor, depending on the operational need. NSF has the ability to adapt profit and contract types to best match the type of work being done (e.g. fixed-price work, fixed-fee work or incentive-fee arrangements). Lockheed is a large company with considerable “reachback”, and there are many opportunities for NSF to achieve major programme savings over the years to come, particularly in areas of operation with hidden costs, such as purchasing and inventory management.

NSF also expects to improve areas critical to effective research support in Antarctica, such as cost estimating, cost control, scheduling, and project planning. To achieve this, Lockheed will be implementing modern project-management software, such as Primavera and other commercially available tools used commonly in industry. Additionally, NSF has placed priority on cost savings and overall improvements in efficiency, which Lockheed will be working on in the coming years.

Blue Ribbon Panel Report

On 23 July 2012, a Blue Ribbon Panel of experts chartered by the White House and the NSF Director will deliver its report, More and Better Science in Antarctica Through Increased Logistical Effectiveness. This panel spent several months visiting all sites of USAP operations and reviewing the overall logistics and research support operations.

Although the content of the report is not available yet, the major themes the panel focused on during its public discussions involved investments in areas such as

- supply-chain modernisation, to include upgraded warehousing and software systems for inventory management;
- multi-modal transportation systems;
- improved energy efficiency, to include additional renewable energy usage and new technologies such as waste-to-energy conversion;
- better standardisation of equipment and centralised management; and
- additional international collaboration and better leveraging of cooperative partnerships.

The Blue Ribbon Panel Report and subsequent follow-up actions from the NSF will likely set the strategic direction for the USAP for the next 15–20 years.

See “Presentation 8 Stone” on DVD for full oral presentation.

INTRODUCTION OF THE FLEXIBLE TANKS USED IN CHINESE ANTARCTIC EXPEDITIONS

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Introduction

Oil supply is one of the most important missions for an inland Antarctic expedition. When oil was transported by oil drum, there were some problems that became more obviously present as oil consumption increased, such as low transport efficiency, high transfer labour intensity, difficulty in recycling of the empty drums, and so on. However, these problems could be effectively solved by using flexible tanks. In this paper, the investigation of the 5000-litre flexible tanks used in Chinese Antarctic Expeditions is introduced, including capacity confirmation, structure design, material choice and contour machining. After the flexible tanks were used in the Chinese Antarctic Expedition to Kunlun Station, the results showed that they satisfied the applied requirements of an inland Antarctic expedition.

Context

Eight countries have constructed Antarctic inland scientific expedition stations, including the US, Russia, France, and China. All of these stations are more than 1000 km away from the Antarctic coastline, so the supply of materials, including oil, is one of the most important missions in scientific expeditions. Objectively speaking, although many new kinds of energy sources have been developed, oil is still the main energy used to support Antarctic expeditions.

During the 28th Chinese Antarctic Expedition, the team completed notable research missions in the Dome A area. The expedition lasted 163 days, from 27 October 2011 to 8 April 2012. At the Chinese Kunlun Station in Dome A, the team mainly installed the guide tube of drilling fluid to the deep ice core, and debugged the telescope AST-3. The aviation kerosene taken by the Kunlun Station team was about 120 000 L and weighed about 100 t, thereby being over one third of the total materials.

At the initial stage after the construction of the station, the oil demand was small and the oil was mostly supplied in oil drums, because the drums had the advantages of mature technology, conventional shape, and convenient transportation. When the US Army constructed the South Pole Station in 1957, the oil supply was accomplished by airdropping the 200-litre drums, and this method to supply oil lasted for several decades.

It took four years for the US to complete the Antarctic inland traverse route to the South Pole, and from then the oil was supplied in new flexible tanks hauled on special sleds. Compared with the airlift, the hauling method has advantages as follows. One is its huge capacity: the freight carried by one such trip is equal to that of 11 sorties of the aerotransport LC-130. The other is the low cost: because the flexible tanks are light, and slide plates replace conventional sleds, the oil transport cost is significantly reduced.

In 1997, the 13th Chinese Antarctic Expedition first pushed forward to the Antarctic inland. Until the 27th Chinese Antarctic Expedition in 2010, the oil supply to each inland scientific expedition had been all transported in drums. The 25th Chinese Antarctic Expedition in 2008 consumed the biggest quantity of oil, in order to construct the first Chinese inland expedition station, Kunlun Station. The total oil volume was 200 000 L, in more than 1100 drums.

With the development of scientific expeditions, oil consumption continuously increased and some problems appeared. Consequently, the 28th Chinese Antarctic Expedition in 2011 started to supply oil in 5000-litre flexible tanks for the inland expedition.

Flexible tank design for Chinese Antarctic Expeditions

The oil-supply stages for Chinese Antarctic inland expeditions include ocean transport, Antarctic unloading, base transfer, expedition supply and container recycling. Yuansheng Li, the vice-director of Polar Research Institute of China, and Yongxiang Chen, the section chief, are the experts, each with rich expedition experiences. They creatively proposed the use of helicopters to simplify the oil-supply process, swinging the flexible tanks from the helicopters then transporting them by sled.

The ocean transport is completed by the icebreaker *Xuelong*. The oil carried by *Xuelong* is transported from China to Chinese Zhongshan Station through the Pacific and Indian Oceans. When the ship arrives in the Antarctic, the oil is transferred to the flexible tanks. The tanks are swung by a K32 helicopter to the inland expedition base, 10 km from Zhongshan Station. After the tanks are transferred onto the sleds by a hoist, the sleds are hauled to Kunlun Station, and the station receives its oil supply. Finally, the empty flexible tanks are recycled: they are stacked flat on the sled, and taken back to Zhongshan Station for the following year.

Capacity confirmation

During the five stages of oil supply, the helicopter lifting capacity in the base transfer stage is the bottleneck to transport efficiency. The helicopter used in Chinese Antarctic Expeditions, the K32, was imported from Russia, and has a maximum lifting capacity of 5 t. Under normal working state, the highest efficiency is in lifting 4 t of supplies. At this point, the flexible tank load is as close to 4 t as possible and the density of 3# jet fuel is 775–830 kg/m3, so the flexible tank capacity should be designed for 5000 L.

During the stage of expedition supply, the conveyance is by sled and the maximum load of the sled is 15 t. Working normally, the highest efficiency is in carrying 12 t of supplies. So, carrying three fully filled 5000-litre flexible tanks makes full use of the capacity, and the flexible tank capacity is confirmed as 5000 L.

Structure design

The size of the sled's carrying-face is 2438 × 6058 mm. When the sled takes three flexible tanks, each flexible tank takes up an area of only 2000 × 2400 mm. Considering transport stability, the oil height in the flexible tank should be under 1500 mm. A comparison of the usual structures for flexible tanks, such as pillow-like and column shape, shows that the square base shape of the flexible tank design is better suited for the sled's requirements.

Accordingly, the preliminary design of the flexible tank shape is as shown in Figure 1. The lower base size of the flexible tank is 1800 × 2150 mm, the upper size is 1260 × 1610 mm, and the height is 1400 mm. At this time, the theoretical capacity is 4500 L. However, the flexible container will have a natural expansion and deformation, and the capacity generally increases about 10%, so the detailed sizes need to be amended by the capacity test.

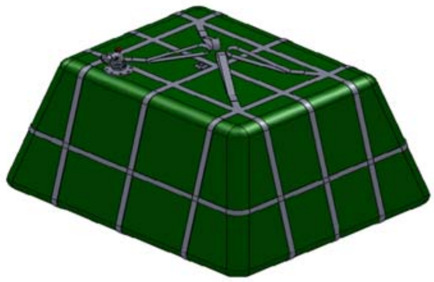

Figure 1: The flexible tanks with a square base structure making best use of the capacity of helicopters and sleds

The hole used for filling and releasing oil is designed on the top of the flexible tank, corresponding to the regulations of the type A-1 nominal diameter 50 mm fast connection in the standard GBT16693-1996. The vent is designed in the middle of the upper bottom, avoiding the intersections of lifting belts and fixed belts. The lifting device for the helicopter is two U-shape lifting belts, bypassing the abdomen of the flexible tank. The strength of lifting belts is 30 000 N, and the lifting weight can reach 10 t by these means.

The four fixed belts are designed as the subsection structure, two for the lifting belt and two for the horizontal U-shape belt, and they bypass the abdomen of the tank. For fixing the tank on the sled, eight belts with binding facilities go through the tie-in of the U-shaped belt, and connect the flexible tank with the sled.

Material choice

The flexible tank material needs to meet certain requirements:

- no contamination of the 3# jet fuel contained
- adaptable to a minimum temperature of -40°C
- high tensile and peel strength under application

The flexible tanks, prepared with thermoplastic polyurethane (TPU) coating fabrics, create no pollution, and possess low-temperature resistance and ageing resistance, in addition to other required characteristics. They have gradually replaced the traditional rubber fabric containers, which were coated with polyvinyl chloride (PVC).[1] We have already mastered the key technology for the production of TPU coating fabric, for the materials manufacturing and for the related container design.[2] The Construction Engineering Research Institute of the General Logistics Department has strong scientific research ability, and the tanks, designed and manufactured by us, have higher strength and lighter weight than similar equipment.

The reinforced materials for TPU coating fabrics need to be designed in accordance with the mechanical analysis of the tanks. The scientific method is based on the fluid structure nonlinear interaction, according to the turbulence level and the extreme transporting circumstances, and then the tensile strength of the tank materials is designed to higher than 35 000 N/5cm.

The fabrics having this quality comprise polyester fabrics, polyamide fabrics and aramid fabrics. The conglutination technology of TPU with polyester fibres and polyamide fibres is basically mature, while the technology with aramid fibre is under development.[3,4] The deformations of polyamide fabrics are too big, so the TPU-polyester coated fabrics are used as the materials for flexible tanks.

From the existing high-strength coated fabrics available, the RTC-fabric M1500-type D TPU coating fabric is used. Its performance parameters are as follows:

- Tensile strength (N/5cm): T ≥ 5000, W ≥ 4200
- Peel strength (N/5cm): ≥ 300
- Coating amount (g/m^2): 300 ± 10
- Weight of per square metre (g/m^2): 1050 ± 20

- Low temperature performance: -40°C, flexible, no cracking
- Oil resistance: 70°C ± 1°C, 14 days, peel strength (N/5cm) ≥ 135
- Oil safety: conformity to GJB4219-2001, “Specification for fabric collapsible tanks for fuel storage”
- Hygienic safety: conformity to “Standard for Hygienic Safety Evaluation of Equipment and Protective Materials in Drinking Water (2001)”

Contour machining

The flexible tanks are fabricated by high-frequency welding and all the joints are sealed by special glue. The shape of the full flexible tank, that is when it is filled with oil, is shown in Figure 2. The rated capacity was less than 5000 L, so the height and upper bottom size were appropriately amplified. The sizes were finally confirmed as 1800 × 2150 mm for the lower bottom, 1280 × 1630 mm for the upper bottom, and 1400 mm for the height.

Figure 2: The shape of the full flexible tank

The capacity now conforms to the design requirements. After the bottoms are further strengthened, the tank quality is 51 kg. The packed size is 1000 × 800 × 800 mm, and the packaging value is 133 kg. Twelve such flexible tanks have been produced for the 28th Chinese Antarctic expedition.

Application of flexible tanks in Chinese Antarctic Expeditions

According to the report, Logistical Support Implementary Precept of the 28th Chinese Antarctic Expedition (2011/2012), the flexible tanks were first used in the tasks of suspended transport by helicopters, sled transport and temporary oil storage.

The oil filling of the flexible tanks was undertaken as the *Xuelong* arrived at Zhongshan Station and was unloaded. The filling management needed five workers and each tank could be filled to capacity in 30–40 minutes. The full tanks then could be directly transported by suspension under helicopters. There were more than 100 t of oil filled in less than two days. In previous years the oil was transported by oil drums and the drums would be rolled into a net pocket. The helicopter could bear two net pockets, with eight to nine drums in each one, and the whole work would be finished by 30 workers over four days. However, the use of flexible tanks can reduce the labour intensity from 120 person days to 10 person days, decreasing labour requirements by 90%.

In the first experiment of suspended transport by helicopter on 3 December 2011 (Figure 3), 12 flexible tanks full of aviation kerosene were transported from the *Xuelong* portside to the inland departure base. According to the principal of the aircrew on the helicopter, the fly state of the helicopter and the suspensory state of the tanks were all very stable. Subsequently, on 5 December and 7 December, the expedition used these flexible tanks 14 times to transport oil. When oil drums are used, the helicopter can bear 3600 L each time. The use of flexible tanks could increase the transport efficiency by 38%.

Figure 3: Lifting the 5000 L flexible tank by the helicopter

Transported by sled, each flexible tank had a capacity equivalent to 25 oil drums. Every sled could load three tanks of 15 000 L of oil (Figure 4), equivalent to 75 drums. But the sled can load only 64 drums, about 12 800 L of oil, so the use of flexible tanks can increase the sled transport efficiency by 17%.

Figure 4: During the inland transport, three flexible tanks were fixed on each sled, equivalent to 75 drums

On 16 December, these flexible tanks full of oil were carried along with the 28th Antarctic Expedition. From Zhongshan Station, expedition members experienced a long journey of 1260 kms and accomplished the task of oil supply to vehicles and dynamotors along the way. One of the fully filled tanks was carried from Kunlun Station to return it to Zhongshan Station, and was transported 2500 kms in 56 days. During the journey, most of the road was quite bumpy and the vehicles and sleds shook strongly, but the tanks were still in good condition and without leakage. Three tanks full of oil were left alongside the road on the outward journey, and they were still able to be used during the return, a month later.

Shortly after the expedition's departure for Kunlun Station, a snowstorm hit the team, and a low temperature of -35°C was recorded. During the expedition at Kunlun Station, the lowest temperature reached was -39°C. This inclement weather lasted for more than 30 days, but the tanks were still flexible and in good condition, and so passed the test of the extreme environment.

When it came to recycling the flexible tanks, they were stacked together and they occupied only half of the sled (Figure 5). A sled weighed 3 t and the whole thing weighed 3600 kg when loaded with the tanks. However, four sleds were needed to recycle conventional drums with the same oil capacity, with a total weight of 17 120 kg. Comparing the two methods, the use of tanks could reduce the transport intensity by 79%. According to experts in the Polar Research Institute, the oil consumption for materials transport in Antarctica inland was 1 L for 1 kg. Therefore the use of flexible tanks could greatly reduce space and weight of materials during the transportation, and could also save on expenditure, which compensated for the cost of recycling the containers.

Figure 5: A stack of all empty flexible tanks

Conclusions

The 5000-litre flexible tanks have been successfully used for the first time in oil supply on the 28th Chinese Antarctic Expedition. Twelve flexible tanks were filled with oil, transported by suspension under helicopters, fixed on a sled, transported over rough snow terrain, and employed under very low temperatures in Dome A. Results showed that the new flexible tanks could satisfy the requirements of the inland Antarctic Expedition.

Compared with using oil drums, employing flexible tanks reduced labour intensity by 90%, the efficiency of suspensory transport by helicopter increased by 38%, and the efficiency of sled transport increased by 17%. What's more, the transport intensity of the empty tanks for recycling decreased by 79%. So, the application of flexible tanks could solve the problems of low transport efficiency, high transfer-labour intensity and the difficulty of recycling of empty drums.

The use of flexible tanks in Antarctica could greatly reduce energy use and impact on the environment.

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See "Presentation 9 Li" on DVD for full oral presentation.

HARD ROCK RUNWAY PROPOSAL – STARTING A FEASIBILITY STUDY

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Introduction

This paper looks at the first stages of a proposal to build a hard rock runway near Mario Zucchelli Station, Antarctica. Such a runway would improve efficiency of operations, would provide financial savings to the Italian Antarctic programme, would reduce carbon footprint and would increase emergency response capability in the region.

The choice of a gravel runway

Since the beginning of Italian activities in Antarctica in 1989, ENEA, the Italian National Agency for New Technologies, Energy and Sustainable Economic Development, has operated a fast-ice runway. In recent years, a reduced availability of this runway has been experienced. This has been caused by, among other factors, temperature increase and the reduction by five kilometres in 2006–07 of the Campbell Glacier Tongue. As a consequence, blue-ice operations started in 2006. However, because of increased water streaming in the summer and reduced wind ablation in winter, the blue ice runway availability also began to be unpredictable.

These physical realities, along with the need to make financial savings and reduce the carbon footprint of operations, are forcing the Italian Antarctic programme to reconsider its own arrangement for the intercontinental connection of Mario Zucchelli Station.

The ice class ship *Italica* is chartered from Italy to supply fuel, cargo and personnel and to carry out the oceanographic campaigns. The ship is the largest centre of cost of the Italian expedition (probably of any Antarctic expedition) and it is also the largest fuel burner among the expedition's activities. Having a gravel runway would mean having the possibility to transport personnel out of Antarctica at the end of the season without the need to charter *Italica* and without impacting on other national programmes. This would result in a lower operational cost. In effect, we would need to charter the *Italica* only once every two years, for fuel, cargo, supplies and for the oceanographic campaign.

Towards the realisation of a gravel runway

As an overall and permanent solution to the above-mentioned problems, the Italian Antarctic programme is moving towards the realisation of a gravel runway. A gravel runway would make it possible for the reliable placement of our expeditions at the beginning of the season and would eliminate the present uncertainties.

The availability of the runway at the end of each season would allow the reliable movement of our personnel by air, saving much time for their trip and eliminating the need for the ship to carry the personnel.

With the availability of a suitable runway during most of the year, life at the stations will be safer and the performance of activities made more efficient, through the certainty of a reliable air link to New Zealand.

In addition, a permanent, stable runway is an obvious benefit to other national programmes in the area for a more efficient way of transporting personnel, for managing medical evacuations and as an alternative to other runways for aircraft.

Where to build

As the proposal is moved forward, a decision needs to be made as to where such a runway could be built. The suggestion is shown in the following diagram (Figure 1), but a full technical feasibility study needs to be carried out.

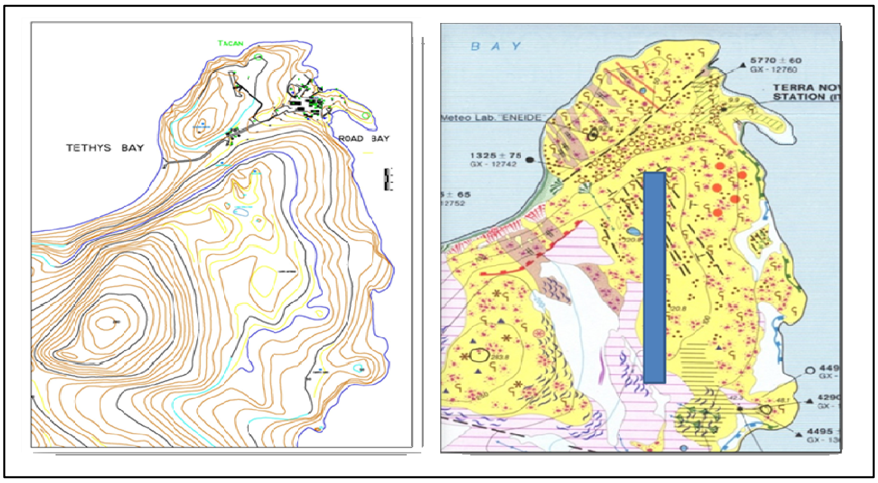

Figure 1: Possible location of a proposed gravel runway near Mario Zucchelli Station

Climatic variability is affecting the use of ice runways. To increase the reliability of the system ensuring the realisation of scientific research, a long term solution is needed. A gravel runway would

- increase reliability at the opening of the summer campaigns;
- allow air transportation of personnel at the end of campaigns and multi-year programming of activities;
- reduce the costs of vessel chartering, fuel consumption and carbon footprint of an expedition;
- favour cooperation between national programmes and sharing of logistic resources, thus diminishing the logistics costs;
- be a support facility all year round in case of emergency.

See “Presentation 10 Mecozzi” for full oral presentation on DVD.

AMPS AND SUSTAINABLE ANTARCTIC LOGISTICS SUPPORT

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Introduction

Working toward sustainability of operations in Antarctica involves considering various facets of the logistical efforts. For example, the resources and costs of a nation's programme will determine its financial sustainability. The impact a programme has on the Antarctic landscape will define its environmental sustainability. And, overall financial and environmental sustainability will reflect a programme's use of its physical assets in the harsh setting. At the intersection of these sides of sustainability are effective planning and decision-making for the one factor that strongly shapes activities in Antarctica: the weather. Predicting and assessing the weather are thus central to the sustainability of Antarctic logistical and scientific activities.

Accurate weather forecasting represents one avenue for promoting the sustainability of operations in Antarctica. A key American effort in support of forecasting for the United States Antarctic Program (USAP) is the Antarctic Mesoscale Prediction System, AMPS (Powers et al. 2003; Powers et al. 2012). This paper describes ways in which this capability contributes to sustaining USAP, US National Science Foundation, and international efforts in Antarctica. While the discussion focuses on AMPS, it is recognised that any nation's Antarctic weather efforts can have a large role in the sustainability of its operations.

AMPS is a real-time numerical weather prediction system covering Antarctica that has served a wide range of groups and activities for over a decade. It employs the Weather Research and Forecasting (WRF) model (Skamarock et al. 2008) to generate a variety of tailored products for weather guidance. Figure 1 shows the AMPS forecast grids. WRF currently runs twice daily, with 0000 UTC and 1200 UTC initialisations. The horizontal spacings for the six main WRF grids stand at 45 km, 15 km, 5 km, and 1.67 km (Figure 1). The coarser 45- and 15-km grids run out to five days, while the 1.67-km (Ross Island) and 5-km grids run for 36 hours.

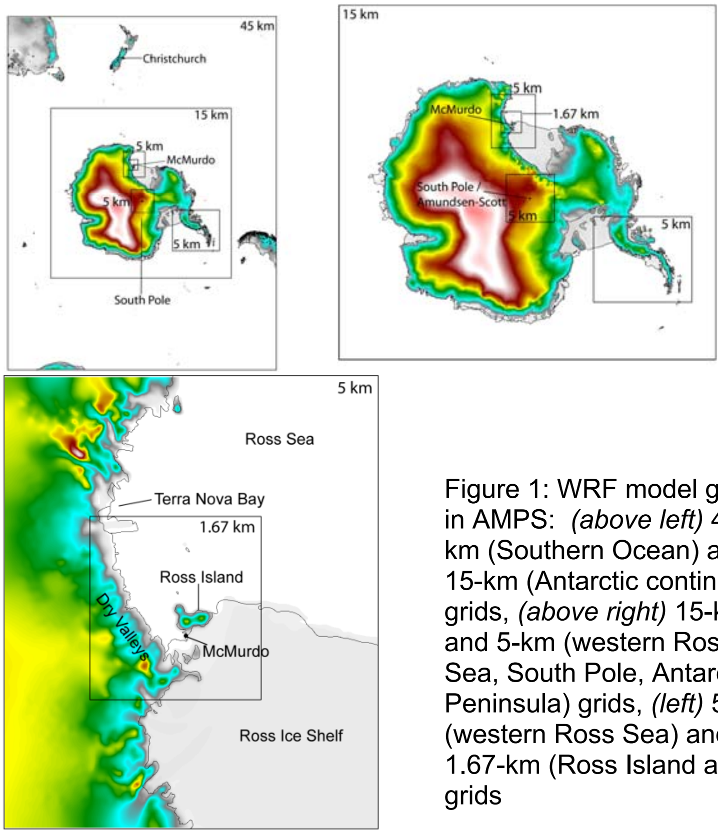

Figure 1: WRF model grids in AMPS: *(above left)* 45-km (Southern Ocean) and 15-km (Antarctic continent) grids, *(above right)* 15-km and 5-km (western Ross Sea, South Pole, Antarctic Peninsula) grids, *(left)* 5-km (western Ross Sea) and 1.67-km (Ross Island area) grids

The AMPS effort is a collaboration of the National Center for Atmospheric Research and the Ohio State University. The programme is funded by the US National Science Foundation, Office of Polar Programs, and its priority mission is to support the forecasters of the USAP. Over the years, however, it has evolved to assist a host of scientific and logistical needs for an international user base. As illustrated here, its applications contribute to logistical, programmatic, and environmental sustainability in Antarctica.

AMPS Contributions to Sustainability

AMPS has four main user groups/areas: *(a)* USAP weather forecasters, *(b)* field campaigns, *(c)* international weather forecasters, and *(d)* researchers and students. The programme's priority is the USAP weather forecasters, who are responsible for forecasting for stations (i.e., the American bases of McMurdo Station, South Pole Station and Palmer Station) and field camp forecasting, air operations forecasting, and, to an extent, marine forecasting. AMPS provides the USAP meteorologists with twice-daily model forecast products.

Second, AMPS supports field campaigns through providing model forecast products for the areas of the studies. Third, as resources allow, AMPS also offers products for the meteorologists of other Antarctic programmes, such as those of Italy, the UK, Germany, and Australia. For example, AMPS is used by the German forecasters for the DROMLAN (Dronning Maud Land Air Network) consortium of nations. Fourth, AMPS is used by researchers and students, primarily through its archive, which, in addition to supporting programme decision-making (described below), assists atmospheric research and graduate student training.

It is mostly with the first three groups that AMPS can contribute to sustainability, as their applications are most directly tied to logistics. AMPS's real-time weather information can be directed to optimise deployment of assets, to identify and avoid risk, and to plan more effectively. The results can be improved resource use and decreased likelihood of accidents (and possible environmental damage). Analysis of historical weather data, such as that in the AMPS archive (described below), can also advance sustainability. The methodology can be applied to avoid or reduce the waste of resources (money, *matériel*); to reduce risks to life, facilities, and the environment; and to optimise facilities and activities on the Ice.

AMPS forecast products range from traditional charts (e.g., surface and upper-air) to animated fields. Popular products are tables of weather parameters and meteograms at stations/camps across the continent (Figure 2).

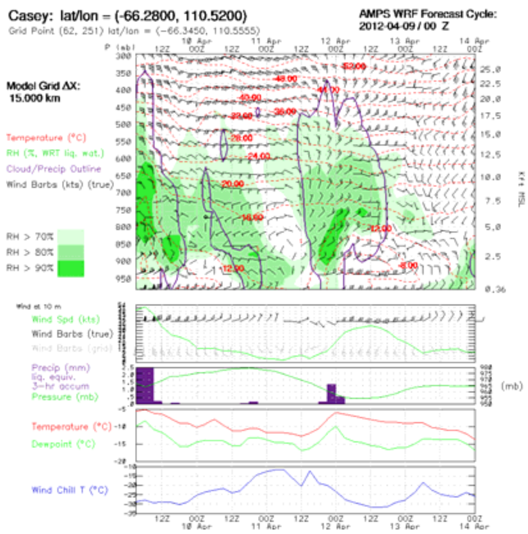

Figure 2: Example of AMPS forecast product: meteogram for Casey Station (Australia). Forecast period: 0000 UTC 9 Apr. – 0000 UTC 14 April 2012. Top half displays time-height cross-section of winds (barbs), relative humidity, temperature and outline of cloud/precipitation. Bottom half displays time series: wind speed and direction, three-hourly precipitation and pressure, temperature and dewpoint, and wind chill (top to bottom)

These provide point forecast information that can be critical for site short-term forecasts and activity planning. The primary means for disseminating the AMPS forecast information is through the AMPS site: http://www.mmm.ucar.edu/rt/amps.

Using AMPS as their principal numerical guidance, personnel of the Space and Naval Warfare Systems Center (SPAWAR) issue the weather forecasts for the USAP. SPAWAR's forecasting for the USAP is dominated by the needs of air operations, both inter- and intra-continental (i.e., Christchurch–McMurdo, McMurdo–South Pole, McMurdo–field camps). The US Air Force and the New York Air National Guard command the heavy-lift air transport for the USAP. The SPAWAR forecasting also supports the air operations of the smaller aircraft (viz., Twin Otter) of Kenn Borek Air, Ltd and the helicopters of Petroleum Helicopters, Inc. that the USAP contracts. Lastly, SPAWAR does marine-area forecasting. This is for the NSF research vessels *Nathaniel B Palmer* and *Laurence M Gould* when they operate south of 60° S, as well as for the forecasting for the annual icebreaker and supply ship convoy to McMurdo. The more accurate and reliable that the weather forecasts from SPAWAR are, the more cost-effective and safe the USAP programme can be. By working to improve those SPAWAR forecasts that bear so critically on transportation needs on the Ice, AMPS advances the sustainability goals.

As an example of applying model weather information to further financial sustainability, AMPS has reduced costly flight aborts on the intercontinental Christchurch–McMurdo route. These run about $150,000 (USD) per occurrence for each C-17, and up to $100,000 per occurrence for each LC-/C-130. For the period primarily before AMPS (August 1997–February 2001) an average of 7.5 planes per season (intercontinental) were turned back. For the period of August 2001 through 2008, this average dropped to 3.6 planes per season. Using an average of $125,000 per turnaround, such a cost reduction would translate to about $487,000 per season. This partial estimate, however, considers only the category of aircraft operating costs. Other costs saved reflect lost/delayed missions and their consequential logistical costs and science losses, additional personnel time, and opportunity costs. Above all, though, are the reduced risks to lives and the enhanced safety of flight and ground operations.

AMPS provides guidance for the cruises through the Ross Sea of NSF's research vessels, the *Palmer* and *Gould*. For this application, a ship-following plot view was developed to keep the forecast charts centred on the moving vessel. Figure 3 gives an example. The *Palmer* appears in the western Ross Sea, and the low to the southwest of the vessel is an example of the mesoscale cyclones that frequently form near Terra Nova Bay (Bromwich 1991).

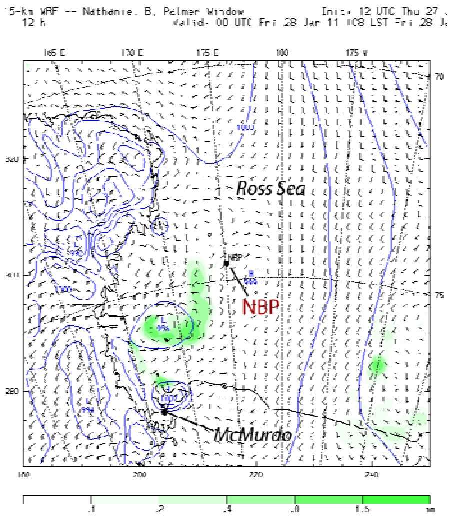

Figure 3: AMPS plotting window following the RV *Nathaniel B. Palmer* (NBP) during its 2011 Ross Sea cruise. 12-hour AMPS forecast shown, valid 0000 UTC 28 February 2011. Winds (barbs; full-barb= 10 kt), sea level pressure (contours; interval= 2 hPa), and three-hourly accumulated precipitation (shaded; mm; scale below shown. NBP marks location of the RV *Nathaniel B. Palmer*

AMPS can also contribute to the sustainability of Antarctic scientific activities through its assistance to field campaigns. AMPS's role is typically to supply new forecast grids, windows, or products over the study areas. As an example, in September 2009, the University of Colorado led a field study to investigate the Terra Nova Bay polynya, using unmanned aerial vehicles (UAVs) flying out of McMurdo (Cassano et al. 2010). For this, AMPS delivered special products (Figure 4) for the planning of UAV missions.

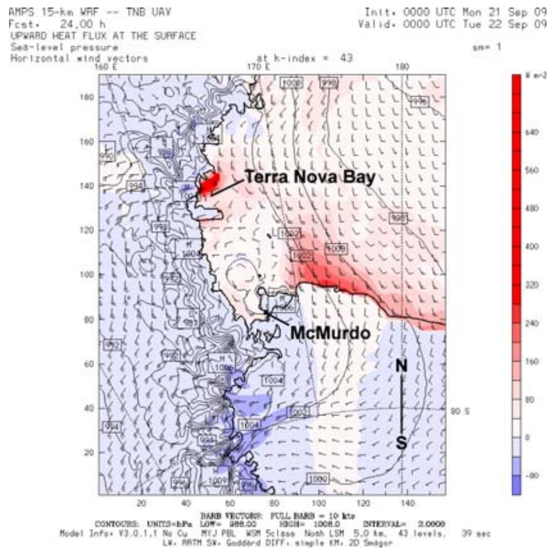

Figure 4: Forecast plot produced for Terra Nova Bay polynya field campaign. Fields shown are near-surface winds and surface sensible heat fluxes. Wind barbs: full barb=10 kt. Surface sensible heat fluxes (W/m^2) shaded. The enhanced areas of upward sensible heat flux (red) are those of the Terra Nova Bay and Ross Sea polynyas

AMPS forecasts of large upward sensible heat flux, appearing prominently in Figure 4 (red areas), were used to identify periods when open water and high winds occurred over Terra Nova Bay, yielding strong air–sea coupling, one of the basic study aims of the campaign. AMPS can improve campaign planning and operations, and as the limited time and funds of scientific teams on the Ice are more effectively spent, AMPS furthers the sustainability of these activities.

Per the Antarctic Treaty, Antarctic nations share the objective of scientific exploration, and they team for greater efficiency in logistical operations. The forecast information sought most has been station-specific data such as soundings, surface tables, and meteograms. Regional windows are also popular, and AMPS generates these for Queen Maud Land (German forecasting), the Davis/Mawson and Casey station region (Australian forecasting), and the South Atlantic (South African forecasting). Nations that AMPS has served include Italy, Australia, UK, Germany, South Africa, China, Chile, Norway, Russia and Japan. The DROMLAN consortium also uses AMPS, and these nations are Germany, Russia, Belgium, Finland, India, Japan, the Netherlands, Norway, South Africa, Sweden and the UK. The typical application of AMPS is for forecasting at bases, for both ground and air operations. Examples are use by the German forecasters at Neumayer Station (who forecast for DROMLAN operations) or the Australian users at Casey Station (Figure 2).

Another AMPS tool useful for Antarctic planning, and thus sustainability, is the AMPS archive. This is a repository of the model forecast output since 2001. NCAR's data storage facility houses the archive, which currently has well over 100 terabytes of data. AMPS archive information is at http://www.mmm.ucar.edu/rt/amps/information/archive_info.html.

The archive has served a range of research and applications. It has been used for model verification, climatologies and meteorological studies. Specific archive-based research has targeted mass–energy balance in Antarctica, the climate of

West Antarctica and the Dry Valleys (Nicolas & Bromwich 2011; Speirs et al. 2010) and the Ross Ice Shelf air stream (Steinhoff, Chaudhuri & Bromwich 2009). Furthermore, climatologies based on the model output for facility- camp- and field-campaign planning exploit the archive to improve decision-making and thus enhance sustainability.

Site climatologies have been based on archived output as a proxy for *in situ* observations at field locations. These can give an idea of expected weather at a site, critical for planning. One example is the consideration of potential alternate McMurdo airfield locations. Pegasus Runway is one of the main McMurdo airfields and sits about 16 km south of McMurdo Station (Figure 1) on permanent ice. Another airstrip, Ice Runway, is closer to McMurdo, but must shut down in mid-season when the underlying sea ice deteriorates. To explore the possibility of a single airfield serving the whole season, the archive was used to produce estimates of the weather at alternative sites to Pegasus, ones closer to McMurdo (Figure 5).

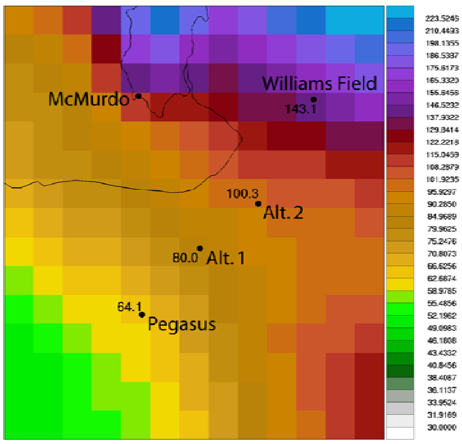

Figure 5: Accumulated precipitation (mm) based on AMPS forecasts in Pegasus area for field seasons (Oct.–Mar.) in the 2008–2011 period. Locations of Pegasus Field, Alternative 1 (Alt. 1), Alternative 2 (Alt. 2), and Williams Field shown

Figure 5 shows seasonal (October–March) precipitation in the area for the years 2008–2011 based on the forecasts from the 1.67 km Ross Island domain (Figure 1). It was found, for example, that the precipitation increases significantly in going from Pegasus to Alternative 1 and Alternative 2.

Similarly, prior to proposed field activity in the Pine Island Bay Glacier (PIG) region for the 2011–2012 field season, data from the AMPS archive were reviewed to estimate the conditions that could be expected. This kind of information has proved valuable for planning, contributing to better deployment and use of limited resources.

Summary

Through its provision of numerical weather prediction (NWP) guidance, AMPS has been serving Antarctic scientific and logistical needs for over a decade. While AMPS has had the priority mission of supporting NSF forecasting, over the years it has been extended to cover a broad spectrum of services, most of which bear on the sustainability of Antarctic operations. AMPS's applications include not only daily, real-time weather forecasting, but also field campaign assistance and facility planning. It is found that the system's enhancement to weather forecasting and analysis for Antarctica can improve logistics and facilitate the more effective and efficient use of resources.

Whether applied in real-time or analysed from an archive, the use of model weather data can aid Antarctic logistical planning and decision-making. It is noted that AMPS is not the only source of NWP guidance over Antarctica, and countries may have their own weather support tools that can provide comparable benefits. Thus, in more general terms, any judicious use of model-derived weather guidance for Antarctica can improve a programme's use of limited financial and material resources and can reduce its impacts to the environment. This furthers the sustainability of its logistics in

Antarctica. As a prime example of such an application, AMPS has contributed to this goal.

Acknowledgments

The author thanks the US National Science Foundation, Office of Polar Programs for its support of AMPS.

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See “Presentation 11 Powers” on DVD for full oral presentation.

SEAICEVIEW TOOL: AN AID TO EFFICIENCY AND SUSTAINABILITY

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Abstract

Advances in remote sensing technology and increased observations of sea ice conditions around the poles have allowed increasingly effective capture, distribution and utilisation of imagery for Antarctic operators, to aid sustainability of operations. Access to timely observations of sea ice extent and structure offers significant advantages in terms of efficiency, safety and operational decision making for ships operating in Antarctic sea ice.

The Polar View Antarctic programme, funded by the European Space Agency and managed by the British Antarctic Survey, has been operating for the past five years. The primary aim of this activity is to make near-real-time information about sea ice easily accessible to ships operating in the Southern Ocean. Working with partners from Denmark, Germany and Norway, Polar View provides a range of information, including coarse resolution hemispheric data about sea ice concentration, high resolution radar satellite images, formal ice charts, and information about sea ice motion. Considerable effort has also been invested in ensuring easy access to these information products over limited data communication links on board most ships.

The ability to effectively use this imagery has been greatly assisted by the development of a SeaIceView tool by the Australian Antarctic Division and the Antarctic Climate and Ecosystems Cooperative Research Centre for use by ships' crews, planners and scientists. By having recent ice conditions information coupled with ship track and other information the Australian Antarctic Division has been able to save many days of ship time, and, as a result, has made real savings on fuel burnt. With shipping being the major fuel consumer for many national Antarctic programmes the system has real application in achieving greater sustainability, both environmentally and financially. Coupled with Polar View imagery the SeaIceView tool allows enhanced voyage route planning, increases safety and assists operational decision makers, while greatly aiding scientists planning research that is dependent on the presence or absence of sea ice.

See “Presentation 12 Clifton” on DVD for full oral presentation.

FUELS SPILLS – AN AUTOMATED EARLY-WARNING SYSTEM

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Introduction

In 2007, a new fuel tank with 200 m^3 capacity was set up at the Ukrainian Antarctic Station Vernadsky. This tank has dual cylindrical walls and is welded from bent components *in situ*. In addition to the generally accepted constructive solutions in Antarctica to prevent fuel spills, this tank includes the development of an automated early-warning system for spills. Such an early-warning system will provide a “smart” quality to the tank, which will include, amongst other innovations, sensor arrays to analyse the dynamics of nucleation and evolution of defects in welds, and of the modes of deformation and vibration in the tank construction.
This paper describes the system and the work done on such a system to date, and encourages consideration from COMNAP colleagues to consider such a system in support of Antarctic environmental protection.

The Fuel Tank at Vernadsky Station

The nature of Antarctica requires special protection in the areas in and around research stations, where there is increased pressure on the environment from built infrastructure and from the materials and equipment required to support personnel. In particular, some of the most dangerous sources of possible pollution around stations are welded fuel reservoir tanks and the accompanying fuel pumping equipment and their associated procedures related to fuel handling. The risk of spills is increased by the conditions the tanks are often exposed to in Antarctica, coupled with the design of the tanks, which are often made of metal and contain a series of welds.

In 2007, a new fuel reservoir with a 200 m^3 capacity was installed at Vernadsky Station. The new reservoir has double cylinder walls and a double base and was welded *in situ* from factory-manufactured components (Figure 1). It is estimated that this fuel tank will be in use for the next 40 years.

Figure 1: Vernadsky Station showing fuel reservoir installed in 2007

Antarctic conditions are such that the tank will be exposed to

- load from wind pressure up to 45 m/sec;
- humidity up to 100%;
- temperature differences in the range of +10^{o}C to -50^{o}C;
- load snow pressure of up to 2 m;
- the appearance of condensate between the walls of the tank; and
- earthquakes, which occur in the Vernadsky Station region.

The dynamics of defects developing in the welds that were created during *in situ* welding (such as lack of penetration, pores, cavities, cracks, undercuts), the creation and development of new use defects in the welds (such as corrosion pits, blowholes, cracks) under influence of the variable natural disturbances, as highlighted above, and the static concentrations of mechanical stresses in the metal and in the joints formed during electric welding, will contribute to the loss of integrity of the tank over time. Such defects have less mechanical strength than welded metal. When the critical volume of defects in the joints is reached, mechanical destruction can occur, resulting in fuel spills. Figure 2 shows when the critical volume of defects is reached.

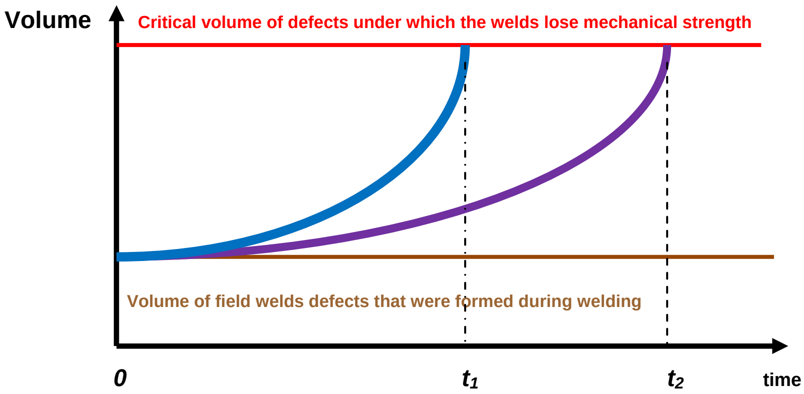

Figure 2: Dynamic of nucleation and development of defects in welds during the operation of the reservoir; where t_1 is the time of welds' mechanical strength loss after reservoir construction that had caused vibration with resonance frequencies (and with greater amplitudes), and t_2 is the time of welds' mechanical strength loss after reservoir construction that had caused vibration with non-resonance frequencies (with lower amplitudes)

Because of these conditions and the need to protect the Antarctic environment from fuel spills, the fuel reservoir has special features, and this paper presents a proposal for the development of an automated early-warning system that would be used to prevent spills. When completed, this will be a first such system for use in Antarctica.

Innovative Developments: Automated Early-Warning System

The tank and pipelines' functional conditions are characterised by

- tensely deformed state of internal and external shells of the fuel tank;

- presence of tension (stress) concentrators at the internal and external tank shells that are caused by technology of the tank electro-welding from separate elements;
- modal (natural modes and shapes) and dynamic (vibration) characteristics, which are caused by constructional and technological conditions of the tank assembly, and which also depend on external dynamic excitations, such as wind, snow- and ice-loadings, seismic waves, daily and seasonal temperature variations, and seasonal variations of the fuel level in the tank; and
- micro- and macro-defect topography in the tank construction, which can lead to fuel leakage.

Taking into account such characteristics, the project will look at

- mathematical models for new tank modes of deformation and construction dynamics, both at the primary time and at the later time, for comparing the characteristics of these models and diagnosis of possible damage;
- a system of vibration and acoustical emission sensors, which will be placed in the tank to supply the information for mathematical simulation of the construction current vibration state and for monitoring of tank functional conditions;
- the vibration monitoring technique of tank functional condition;
- the procedure of air sampling between the tank walls for detection of fuel leakage and condensate presence;

- algorithmic and software supports for vibration signals and air-sample processing to identify the current tank functional condition; and

- software requirements for the automatic system's operation.

Expected Project Results

Scientific Results

The range of scientific results from this project includes, but may not be limited to, the following:

1. Amplitude-frequency characteristics of acoustic emission transducers made from different materials, and transducers' directional diagrams will be investigated; the correlation will be studied between different manners of tank breakdown and monitored parameters under Antarctic conditions.
2. New methods will be developed of vibration signal analysis, to determine and study diagnostic features of the fuel tank functional condition.
3. A dynamic model of the tank will be created on the basis of information about the real oscillation state of both the tank foundation and its construction.
4. Current descriptions of stability and tensions of tank construction will be determined, the changes in these descriptions will be identified and the tank dynamic state will be forecast in the real operating conditions of the climatic and dynamic loadings in the Antarctic.

Technical Results

In addition, it is envisioned that the project will produce many technical results, including but not limited to the following:

1. Acoustic emission methods will be improved for tank structure inspection and new acoustic emission signal transducers will be developed. The acoustic emission inspection method will take account of Antarctic conditions.

2. New inspection and control subsystems will be developed for integrated control of the fuel tank functional condition at Vernadsky Station.
3. A multi-channel automatic integrated system will be developed for control of the fuel tank and pipelines' functional condition at Vernadsky Station.

Work Completed to Date

To date, the project team has made the following steps to develop the automated system:

1. The experimental data analysis has been carried out of fracture of welded joints in oil reservoirs and in oil pipelines under Russian Far North conditions, which are similar to natural Antarctic conditions. On the basis of this analysis and new reservoir design documentation analysis, and on the grounds of natural inspection *in situ* of the new reservoir, the potentially most vulnerable welds were identified; these require priority monitoring.
2. A three-dimensional model of reservoir construction was developed, in particular, for any possible design upgrade simulations in response to the possibility of the reservoir's mechanical strength loss.
3. An analysis was made of the stability of the reservoir outer tank under Antarctic periodic kinematic perturbations (particularly wind, earthquakes).
4. Methods and software were developed for the simulation of the frequencies spectrum of resonance mechanical vibrations of the reservoir construction and its outer and indoor tanks, which are especially dangerous with respect to the welds' mechanical strength.
5. A non-linear mathematical model was developed of the defects' growth dynamics in welded joints under field Antarctic conditions (particularly, the reservoir mechanical vibrations) to forecast the joints' mechanical strength loss.

At the present time, the work continues on the project according to the Request for Proposal and the State Target Scientific and Technological Research Programme of Ukraine in Antarctica for 2011–2020. It should be noted that work is being carried out by the project team and our colleagues from the UK, Germany and Canada to obtain extra-budgetary financing of the project from the International Science and Technology Center in Ukraine and to accelerate the development of the automated system.

Conclusions

To give new impetus and quality to the developing project and to make use of operating experience with welded reservoirs at the other Antarctic research stations, the project team requests our COMNAP colleagues to consider the following: *(a)* the inclusion of the automated system development into the COMNAP Project *Oil Spill Contingency Planning and Equipment Survey*; *(b)* national Antarctic programme collaboration in the development of the automated system jointly with the Action Group on Antarctic Fuel Spills of SCAR; and *(c)* developing an international standard for additional protection of the Antarctic environment against fuel spills from welded tanks by means of the proposed automated system.

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See “Presentation 13 Kuzko” on DVD for full oral presentation.

Logistical Support to Antarctica: Responding to Challenges with the New Vessel *SA Agulhas II*

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Abstract

South Africa's new polar research and supply vessel, the *SA Agulhas II* (Figure 1) was built by STX Europe in Rauma, Finland. The handover to SANAP was on 4 April 2012 and she arrived in Cape Town, South Africa on 3 May 2012. This is the first polar ship to be built according to the IMO's 2009 SOLAS (Safety of Life at Sea) Regulations – Safe Return to Port (implemented from 01 July 2010).

Figure 1: An aerial view of the *SA Agulhas II*

Being classified as a passenger ship posed serious challenges for the shipyard and the Classification Society (Det Norske Veritas – DNV). Innovative engineering solutions were required and achieved, in particular, with regard to the transporting of bulk fuel with low flash points.

SA Agulhas II will take over the logistic role of the current ship in the Southern Ocean and Antarctica, and will have spare capacity for cargo. Having ice-breaking capability of 5 knots through 1 metre of ice, the SANAP Antarctic season will be extended – going in earlier and coming out later. A number of special features like a drop keel and a moon pool will enhance the ship's research support role.

See "Presentation 14 Valentine" on DVD for full oral presentation.

HUMAN MICRO-ORGANISMS IN ANTARCTIC ENVIRONMENTS

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Introduction

During the last meeting of the Committee on Environmental Protection (CEP) of the Antarctic Treaty, CEP XV, (Hobart, Australia), Chile introduced Working Paper 55 (WP55): *New records of the Presence of Human Associated Micro-organisms in the Antarctic Marine Environment*. This paper informed the CEP of new scientific information obtained from sewage-treatment plant discharges in the Antarctic. Chile referred to Instituto Antartico Chileno research projects that reported the presence of a new case of extended spectrum β-lactamase in the Antarctic Peninsula region and the existence of *E. coli* resistant to antibiotics.

A number of the CEP members advised the meeting they were also undertaking research related to the impact of human-associated micro-organisms from waste-water discharge. In WP55, Chile recommended that the CEP make a request to COMNAP to update its Waste Management Workshop 2006 outcomes. It also recommended that the national Antarctic programmes (NAPs) evaluate their existing precautions and their established sewage treatments to avoid the incidental introduction of micro-organisms to the Antarctic, and that they effectively monitor microbial activity in marine areas near their Antarctic stations.

The CEP agreed that members should strengthen their precautionary monitoring of microbial activity in areas near sewage-treatment plant discharges and noted that COMNAP would consider the possibility of reviewing relevant information and guidelines concerning waste-water management at its July 2012 Annual General Meeting.

State of the art

In 2009, Gröndahl et al. published the results of a survey of the waste-water practices of the 28 NAPs. Their results showed that 48% of all the stations had sewage treatment for waste water in Antarctica. About two thirds (63%) of the permanent stations that answered the survey had some kind of treatment in place, but only one third (31%) of the summer stations had one. The most common type of treatment system used by the stations was biological treatment (20%), followed by maceration (10%) and secondary treatment (10%).

The researchers concluded that the use of efficient technology at all permanent (and most summer) Antarctic stations would greatly reduce human impact on the Antarctic environment, such as introduced human-derived microbial agents.

In 2006, COMNAP, through its Antarctic Environmental Officers Network (AEON), carried out a Workshop on Waste Management in Antarctica, with the focus on sharing practical information on waste management practices. The aim of the workshop and of subsequent actions resulting from it was to eventually favour new standards, conditions and scenarios for waste management on the continent. During the workshop Australia, Brazil, France, South Africa, the UK and the US described how they were managing their wastes in Antarctica at the time.

The workshop concluded the following:

- There is a need to increase the flow of information at a technical level among those within national programmes who are responsible for waste management in Antarctica. Participants agreed that the COMNAP website was the most adequate tool to achieve such a goal, and that the AEON (now the Environmental Expert Group) workspace should be adjusted to allow an easier flow of information.

- The incorporation of the Environmental Management System concept into waste-management practices could be a very convenient way to facilitate such activities.

- With respect to incident reporting, there is a need to provide feedback on the information forwarded by operators, as a way to increase confidence in the usefulness of their work and in the reporting system itself.

- On the issue of waste management, the NAPs Environmental Officers would benefit from closer links with TRAINET and other COMNAP networks.

The Chilean experience

All permanent and main summer Chilean stations in Antarctica have implemented waste-water treatment systems according to the needs and characteristics of each. These stations are located on Cape Legoupil, Antarctic Peninsula, and on King George and Greenwich Islands in the South Shetland Archipelago.

The Bernardo O'Higgins Station, located at Cape Legoupil has an annual staff of 22 people, a number that during summertime may increase up to 60, including scientists. This station has a sophisticated treatment plant designed to treat 13.6 m^3/day waste water, based on an electrolysis system, OMNIPURE 12MC. The system consists of two main ponds, the first one for maceration and to controllably mix the waste water with sea water to achieve an adequate salinity for the proper operation of an electrolysis cell on it. The mixture is conducted through loaded electrodes, where the sodium chloride is electrolysed to form sodium hypochlorite, the compound responsible for removing nearly 100% of bacteria and for oxidising 95% of the organic matter. The electrolysed waste water flows to a second tank, where its velocity is reduced and degassing occurs (for hydrogen and other gases that are produced in the hydrolysis process). The residence time also allows decanting of partially oxidised particles, which are recirculated to the first pond.

The Arturo Prat Station, located at Greenwich Island, has a permanent staff of 12 people. The waste-water treatment includes a biological system, which allows treatment of 12 m^3/day. This consists of an initial anaerobic chamber, which acts as the decanter sludge trap, while some degradation of organic matter occurs. The main treatment takes place in a conical activated sludge plant, where the aerobic biological treatment of matter and the settling of the sludge occur. This single unit, in its upper part, performs clarification of the water through radial outlet weirs throughout its structure. The treated water enters a chamber for ultraviolet disinfection, performed under pressure within a single tube.

The Eduardo Frei Station, located on King George Island, has implemented a system of waste-water treatment without sludge generation, known as a Biofilter or Toha system. The system was designed to treat a volume of 60 m^3/day and can handle the water of the whole station, where the population ranges from 80 in winter to 150 in summer. The pre-treatment system comprises degreasing, and processes to remove untreatable solid material. After pre-treatment the waste water irrigates a system of biofilters. The biofilter uses earthworms and micro-organisms, and includes a ventilation system and a double bottom. Earthworms digest the retained organic matter on the surface, turning it into humus. Biological processes inside the filter can transform the organic matter to carbon dioxide and water, without producing sludge as waste. The treated water is conducted through a UV disinfection chamber, which removes approximately 100% of the bacteria.

The Maritime Station, located on King George Island, has a staff of eight people in winter, with a total capacity of 30 in summer. It shares a treatment plant with the Professor Julio Escudero Station, which may receive up to 36 scientists in summer. There are differences in the volumes of waste water to be treated, due to the variations of the population at the stations. The treatment plant's waste-water system was designed modularly, based on three trains in parallel, which can act independently or together. The treatment system is based on extended aeration of activated sludge. In a first process, waters enter an equalisation basin, whose function is to reduce the peaks in flow and to grind the material; then the water is conducted to a primary tank to allow the settling of sand and solids while some degradation of organic matter processes occurs anaerobically. The main component is an activated sludge biological reactor, which purifies water through the action of aerobic micro-organisms assimilating organic matter. New sludge is generated; however, because of long residence times, endogenous respiration processes reduce the quantity of sludge. The treated water is conducted to a secondary clarifier chamber that separates the mixture of treated water from micro-organisms, and then the water is subjected to an ultraviolet disinfection treatment.

In Chile, the discharge on the surface of sewage and of liquid waste of industrial origin is established by the Supreme Decree No. 90/2000. The system regulates the emission of specific pollutants by concentration of the effluent discharged, regardless of the capacity of the receiving body to assimilate a defined type of waste. Because of that, it is not possible to compare the Chilean legislation with that of countries such as the US, Japan and Australia. However, the regulation establishes a national emission limit of faecal coliform of 1000 per 100 ml, which is equivalent to the regulations of Spain, Mexico, and most Latin American countries, although less stringent than that of Canada, a country with a limit of 400 per 100 ml. Methodologies for waste-water analysis are contained in the Chilean Standard 2313.

Although the main Chilean stations in Antarctica have implemented waste-water treatment systems according to the needs and characteristics of each station, all of them require a skilled operator for periodic maintenance and to verify the optimal performance in each of the processes. The availability of these operators becomes a weakness of the system, as the staff of the stations are sometimes renewed every year, which may not allow them to reach the experience to detect possible failures and resolve them quickly. This could lead to inefficient operations, which would result in a higher load than expected in some parameters.

Since 2011, the Chilean Scientific Antarctic Programme, PROCIEN, has been supporting an initiative to monitor the operation of the Chilean sewage-treatment plants in Fildes Bay (Maritime and Escudero Stations) and on the Antarctic Peninsula (O'Higgins Station), and plans to support the other Chilean stations in the region.

Alternative technologies

In spite of the treatment that most of the stations apply to their sewage, human micro-organisms have been found in marine water samples in the Antarctic Peninsula region. Therefore, the implementation of better technologies or the improvement of the present treatments is needed.

As a couple of countries indicated during the 2006 COMNAP workshop, an alternative technology to manage waste in their stations, including grey- and black-water, is incineration. For camps, there are portable incinerators available, which allow transforming the human waste into ash, burning around 100% of bacteria and other material present in them, thereby minimising the risk of eventual introduction of pathogens to the environment. The better known and most commonly used incinerators are Usenburn (http://www.storburn.ca/).

Monitoring the operation of the sewage-treatment plants *in situ* is another alternative to consider. It would allow a quick response to any problems the stations face.

Conclusions

COMNAP could task its Environmental Expert Group with

- updating its 2006 Waste Management Workshop with new or improved technologies;
- looking at ways of monitoring microbial activity near sewage-treatment discharges;
- suggesting ways of training staff at the stations to appropriately operate treatment systems in cases of emergencies;
- advising NAPs on whether it is appropriate to continue operating sewage-treatment plants that discharge to the marine environment, or whether it would be better to separate the black water from waste water and to treat it separately in incinerators.

See “Presentation 14 Vallejos” on DVD for full oral presentation.

APPENDICES

Appendix A: COMNAP Symposium 2012 Programme

Sustainable Solutions to Antarctic Challenges
Columbia Falls Ballroom of the University Place Hotel & Conference Center, Portland, Oregon, USA
15 July 2012

SYMPOSIUM PROGRAM		
Time	**Presentation/Event**	**Presented by/ Program(s) from**
0900-0910	Introduction by Lou Sanson, Symposium Convener	
Session 1. Keynote Speakers – Chair, Lou Sanson		
0910-0940	Climate Change, the Geopolitics of Scarcity, and Antarctica *Gwynne Dyer*	UK
0940-1010	Addressing Conservation Governance Challenges in the Antarctic: The role of National Programmes *Steven Chown*	Australia
1010-1040 Coffee Break/Poster Session		
Session 2. National Programmes – Sustainability Challenges and Solutions – Chair, Kazuyuki Shiraishi		
1040-1100	Minimizing Science Programs Environmental Footprint *José Retamales*	Instituto Antártico Chileno (INACH), Chile
1100-1120	Sustaining Antarctic Research in an Increasingly Challenging Environment: Australia's Modernisation Process *Rob Wooding*	Australian Antarctic Division (AAD), Australia
1120-1140	Lessons from the Arctic – Drivers for Development *Jan-Gunnar Winther*	Norwegian Polar Institute, Norway
1140-1200	Sustainable Science at Halley VI *Robert Culshaw*	British Antarctic Survey (BAS), UK
1200-1220	The New Zealand Antarctic Programme – A Case Study approach to Sustaining Science *Lou Sanson*	Antarctica New Zealand, New Zealand
1230-1330 Lunch Break		

Session 3. Sustainable Logistics Support – Chair, Iain Miller		
1330-1350	Russian Antarctic Expeditions – Transport Options *Valery Lukin, Victor Pomelov*	Russian Antarctic Expedition/Arctic & Antarctic Research Institute (RAE/AARI), Russia
1350-1410	Auto Guidance – Unmanned Tractor for Logistics *Hisashi Date, Keiji Watanabe, Kenji Ishizawa, Masanori Chiba*	Japan Antarctic Research Expedition/National Institute for Polar Research (JARE/NIPR), Japan
1410-1430	USAP – An Update *Brian Stone*	US Antarctic Program, National Science Foundation Office of Polar Programs
1430-1450	The Introduction of Flexible Tanks used in the Chinese Antarctic Expedition *Li Zhongdong*	Chinese Arctic and Antarctic Administration/ Polar Research Institute of China (CAA/PRIC), China
1450-1510	Terra Nova Hard Rock Runway Proposal *Roberta Mecozzi*	Programma Nazionale di Richerche in Antartide (PNRA/ENEA), Italy
1510-1530 Coffee Break/Poster Session		
Session 4. Technology Enabling Sustainability – Chair, David Blake		
1530-1550	Antarctic Mesoscale Prediction System – Sustainability of Antarctic Logistic Support *Jordan G. Powers*	National Center for Atmospheric Research/US Antarctic Program (NCAR/USAP), USA
1550-1610	Remote Sensing Ice Navigation *Robb Clifton, Andrew Fleming*	Australian Antarctic Division (AAD), Australia
1610-1630	Fuel Spills – An Automated Early Warning System *O Kuzko, V Lytvynov, N Bouraou, Y Zukovsky, O Kyrychuk*	National Antarctic Scientific Center of Ukraine (NASC), Ukraine
1630-1650	Bulk Fuel Transport – Innovative Engineering *Henry Valentine*	South African National Antarctic Program (SANAP), South Africa
1650-1710	Making of Bharati – India's New Permanent Station *Rasik Ravindra, Javed Beg*	National Centre for Antarctic & Ocean Research (NCAOR), India
1710-1730	Human Micro-organisms in Antarctic Environments *Verónica Vallejos*	Instituto Antártico Chileno (INACH), Chile

List of Selected Posters
A Hydrogen Electric Power Generation System for Antarctic use - Preliminary Results of Domestic Experiments *K. Ishizawa, Y. Katsuta, H. Fujino, I. Ono & Y. Motoyoshi*
Energy Conservation at India's New Station Bharati *Rasik Ravindra, Anoop Tiwari & Javed Beg*
Innovation in Operation: The Direk Gerritsz Laboratory (Antarctic Peninsula) *Dick van der Kroef & John Shears*
Logistics Support to Scientific Activities of Maitri *Rasik Ravindra*
Making of Bharati – India’s New Permanent Station in East Antarctica *Rasik Ravindra*
National Centre for Antarctic and Ocean Research Ministry of Earth Sciences Antarctic Activities *Rasik Ravindra*
Renewable Energy - Sources & Their Use in the Common Energy System of the Bulgarian Antarctic Base *Christo Pimpirev, Dragomir Mateev & Yordan Yordanov*
System for Remote Environmental Monitoring and Creating Information Products through Small Satellite and Related Ground Infrastructure *Christo Pimpirev, Dragomir Mateev, Mario Gatchev, Ognayan Ognyanov, Plamen, I. Dankov, Vesselln Vassllev, Yavor Shopov & Yordan Yordanov*

Appendix B: List of files contained on Accompanying Symposium DVD

Oral Presentations

Presentation 1 Retamales
Presentation 2 Wooding
Presentation 3 Winther
Presentation 4 Culshaw
Presentation 5 Sanson
Presentation 6 Lukin
Presentation 7 Date
Presentation 8 Stone
Presentation 9 Li
Presentation 10 Mecozzi
Presentation 11 Powers
Presentation 12 Clifton
Presentation 13 Kuzko
Presentation 14 Valentine
Presentation 15 Vallejos
Presentation 16 NCAOR

Posters

Poster 1 Van der Kroef
Poster 2 Pimpirev
Poster 3 Ishizawa
Poster 4 Pimpirev2
Poster 5 Ravindra
Poster 6 Ravindra2
Poster 7 Ravindra3
Poster 8 Ravindra4