

ANTARCTIC AIR TRANSPORT



1999/2000 INVESTIGATIONS

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CONTENTS

	<u>Page</u>
1. INTRODUCTION	1
2. BACKGROUND	
2.1 Antarctic Air Transport Scoping Study recommendations	1
2.2 The Government response	2
3. THE TASKS	
3.1 Bunger Hills investigations and automatic weather station deployment	3
3.2 Davis investigations and automatic weather station deployment	4
3.3 Mawson automatic weather station deployment	4
4. METHODOLOGY	
4.1 Logistics options for supporting the investigations	5
4.2 Personnel required for the investigations	
4.2.1 Project management	6
4.2.2 Bunger Hills	6
4.2.3 Davis	6
4.2.4 Mawson	6
4.2.5 Casey	6
4.3 Actual transport arrangements	
4.3.1 General	7
4.3.2 Bunger Hills	8
4.3.3 Davis	9
4.3.4 Mawson	10
4.3.5 Casey	10
4.3.6 Other stations	10
5. RESULTS OF THE INVESTIGATIONS	
5.1 Introduction	12
5.2 Potential airfields	
5.2.1 Bunger Hills	
5.2.1.1 Apfel Glacier blue-ice runway	13
5.2.1.2 Transkriptsii Gulf lake-ice runway	16
5.2.2 Davis	
5.2.2.1 Sea-ice skiways	17
5.2.2.2 Blue-ice runways	18
5.2.3 Casey skiway	20
5.2.4 Mawson	
5.2.4.1 Sea-ice runway	21
5.2.4.2 Blue-ice runway	21
5.2.5 Larsemann Hills skiway	22
5.2.6 Other airfields	
5.2.6.1 Beaver Lake	22
5.2.6.2 Mirny	23

5.3	Infrastructure requirements	
5.3.1	Introduction	25
5.3.2	Accommodation	25
5.3.3	Communications	26
5.3.4	Meteorological requirements	27
5.3.5	Navigational and landing aids	27
5.3.6	Fire-fighting	28
5.3.7	Aircraft service and support equipment	28
5.3.8	Cargo handling equipment	28
5.3.9	Medical	29
5.3.10	Fuel storage and handling	30
5.3.11	Control and coordination	30
5.4	Potential aircraft	
5.4.1	Intercontinental aircraft	31
5.4.2	Intracontinental aircraft	31
5.4.2.1	Runway requirements	32
5.4.2.2	Aircraft equipment requirements	32
5.4.2.3	Delivery arrangements for intracontinental aircraft	33
5.4.2.4	Selection of future intracontinental aircraft	33
5.4.3	Issues requiring resolution with CASA	34
6. IMPLICATIONS FOR AIR SYSTEM OPTIONS		
6.1	Introduction	35
6.2	Analysis of options	
6.2.1	Option 1: Ski-equipped Hercules to Casey skiway	35
6.2.2	Option 2: Wheeled Hercules to Bunger Hills blue-ice runway	36
6.2.3	Option 3: Wheeled Hercules to Bunger Hills and Davis blue-ice	37
6.2.4	Option 4: Wheeled Hercules to Davis blue-ice runway	38
6.3	A suggested alternative air transport system	38
7. RECOMMENDATIONS		
7.1	The recommended system	40
7.2	Recommended future actions	41
7.3	Timetable for future actions	42

Appendices

- Appendix A - Distances and approximate flight times
- Appendix B - Chronology of events
- Appendix C - Runway locations
- Appendix D - Bunger Hills environmental considerations and potential impacts

1. INTRODUCTION

The Antarctic Air Transport Scoping Study recommended that several options for establishing a direct intercontinental air link between Australia and Antarctica be the subject of further field investigations. The purpose of this paper is to briefly report on the key outcomes of these field investigations that were undertaken in Antarctica during the 1999/2000 summer, and to suggest what should now occur.

While some detail is included on how this season's investigations were undertaken, the primary aim of this paper is to identify those findings of the 1999 Scoping Study that were either confirmed or invalidated by the investigations and, where necessary, to suggest alternatives.

In addition to discussing what was learned regarding potential airfields, aircraft and infrastructure, the paper includes an analysis of the implications of these lessons for the overall feasibility of the previously recommended air system options. On the basis of this analysis, the paper also includes a suggested approach to the establishment and operation of a long-term Antarctic air transport system for Australia, and makes a number of recommendations for further work.

2. BACKGROUND

2.1 Antarctic Air Transport Scoping Study recommendations

Following examination of more than fifty theoretically-possible Antarctic air transport system options, the Antarctic Air Transport Scoping Study (July 1999) shortlisted twelve options which had the potential to deliver all the benefits identified by the Antarctic Science Advisory Committee and the Government as desirable for an effective and efficient Australian Antarctic air transport system. Each of these shortlisted options was assessed as being able to provide significantly reduced travelling times for scientific and other personnel, greater flexibility of access, and improved capacity to support remote area and airborne research.

Having shortlisted these twelve options, the Study carefully assessed their operational, environmental and financial implications. At the end of this process, it was concluded that none of the twelve options could be singled out as being the best on all counts but four of the options were selected as offering the most attractive overall balance of capability and cost (which includes financial, environmental and operational factors).

The four preferred Antarctic air transport options were all based on use of existing areas of ice and snow for airfields and would not require the construction of runways. By doing so, they would avoid the need for significant capital investment in infrastructure and thus minimise the costs and environmental impacts, while maximising long-term flexibility and the potential for phased introduction.

The Scoping Study's four preferred Antarctic air transport options (in no particular order) were:

- A ski-equipped Hercules aircraft flying direct to a skiway at Casey, with smaller ski/wheel-equipped aircraft providing the intracontinental links from Casey to skiways and sea-ice runways at Davis and Mawson.

- A wheeled Hercules aircraft (or equivalent) flying direct to a blue-ice runway at the Bunger Hills, with smaller ski/wheel-equipped aircraft providing the intracontinental links from Bunger Hills to skiways, sea-ice and blue-ice runways at Casey, Davis and Mawson.
- A wheeled Hercules aircraft (or equivalent) flying direct to a blue-ice runway at the Bunger Hills and then continuing to a Davis blue ice runway, with smaller ski/wheel-equipped aircraft providing the intracontinental links from Bunger Hills to a skiway at Casey, and from Davis to sea-ice/blue-ice runways at Mawson.
- A wheeled Hercules aircraft (or equivalent) flying direct to a blue-ice runway at Davis, with smaller ski/wheel-equipped aircraft providing the intracontinental links from Davis to skiways, sea-ice and blue-ice runways at Casey and Mawson.

While indicating a preference for these options, the Study noted that they would be reliant on use of airfields or aircraft that had not been extensively considered by previous studies and suggested that further investigations were needed to resolve several outstanding issues. In particular, the Study recommended that the following investigations be undertaken in Antarctica during the 1999/2000 summer:

- Glaciological observation of the Bunger Hills blue-ice runway site to confirm that melting is not a problem during the warmest months;
- Field surveys and glaciological observations to ascertain the suitability of potential blue-ice runway sites near Davis station; and
- Installation of automatic weather stations at potential blue-ice runway sites at the Bunger Hills, Davis and Mawson.

2.2 The Government response

Following consideration of the Air Transport Study report, the Minister for the Environment, Senator Robert Hill, announced in September 1999 that he had accepted its recommendations and had asked the Australian Antarctic Division (AAD) to carry out the recommended field investigations during the 1999/2000 summer.

When releasing the report, the Minister stated that a final decision to proceed with implementation of an Australian Antarctic air transport system would follow the completion of these field investigations and further analysis of the cost of the service based on a competitive commercial tender process. The Minister also confirmed that a full environmental impact evaluation in accordance with Commonwealth legislation and Antarctic Treaty obligations would be undertaken before any final decision was taken.

3. THE TASKS

3.1 Bunger Hills investigations and automatic weather station deployment

Two potential runway sites for operations by heavy wheeled aircraft have previously been identified in the Bunger Hills. The first of these sites, which was reconnoitred and surveyed by Polar Logistics Ltd during the 1998/99 season, is an area of blue ice on the Apfel Glacier immediately to the south of the Bunger Hills. The second site is an area of multi-year lake ice on Transkriptsii Gulf adjacent to Australia's summer base 'Edgeworth David'.

While the investigations by Polar Logistics during the 1998/99 season indicated that both the Apfel Glacier and Transkriptsii Gulf sites met all required specifications relating to dimensions, gradient and surface roughness, the 1999 Scoping Study concluded that there was a need to further monitor the sites to determine whether there were likely to be any problems with surface or sub-surface melting during the warmest period of the summer. In particular, the monitoring program at these sites needed to include observations of surface characteristics (surface roughness, undulations, snow cover, surface melt, crevassing and drainage), and ice coring to examine sub-surface characteristics such as ice strength, porosity, structure and saturation. To enable this monitoring program to occur, Polar Logistics provided the Australian Antarctic program with details of the location of the blue-ice runway site that it had surveyed on the Apfel Glacier.



Figure 1: Twin Otter at Apfel Glacier blue-ice runway site

In addition to these glaciological observations, there was a requirement to commence the collection of meteorological data at the blue-ice runway site. While limited data had been collected by previous Russian, Polish and Australian expeditions to the ice-free areas of the Bunger Hills, no information was available for the adjacent inland ice plateau. To fill this gap in knowledge and to commence developing an understanding of the weather conditions that could affect any future flying operations to the blue-ice runway site, an automatic weather station needed to be installed.

It was desirable that any party visiting the Bunger Hills to monitor the runway and to install the automatic weather station also take advantage of the opportunity to collect additional baseline environmental information to assist in the future preparation of a full environmental impact evaluation for an air transport system.

3.2 Davis investigations and automatic weather station deployment

Preliminary investigations during the 1998/99 summer indicated that suitable areas of blue ice for heavy wheeled-aircraft operations were likely to exist at two sites about thirty kilometres from Davis - the first of these was inland on the ice plateau east of the Vestfold Hills, the other was inland of the Rauer Islands to the south of Davis. While these initial investigations had produced promising indications, the Scoping Study report noted that further detailed surveys and glaciological investigations were required to confirm the suitability of the identified blue ice sites.

The first requirement at Davis during the 1999/2000 summer was to inspect all areas of blue-ice in the region, including those sites previously suggested, in the hope of identifying at least one site that met all of the basic criteria for a blue-ice runway. These criteria include being free of crevasses and approach and departure obstructions, having an acceptable overall gradient, being virtually snow-free and being aligned with the prevailing wind. Following identification of such a site, there was a need to conduct a detailed survey of the site to confirm that it satisfied all requirements relating to longitudinal and transverse gradients and surface roughness.

As with the Bunger Hills site, any site in the Davis region that met all survey and other requirements also needed to be regularly monitored during the warmest period of the summer to detect any problems with surface or sub-surface melting.

Similarly, given the lack of existing meteorological data for the ice plateau in the Davis region, an automatic weather station needed to be installed as soon as possible at any potential blue-ice runway site near Davis. The information collected is necessary to underpin decisions on whether such a site could be operated safely and for what proportion of the time.

3.3 Mawson automatic weather station deployment

As the Mawson sea-ice cannot be relied upon after mid-December, fixed-wing aircraft operating to that station later in the summer need to land on the inland ice plateau. Even though several blue-ice runway sites in this area have been used in the past by Australian and Russian aircraft, no surface meteorological information is currently collected at these locations. Given that these areas are known to experience very strong winds and severe turbulence, an automatic weather station needed to be installed at a suitable site as soon as possible.

4. METHODOLOGY

4.1 Logistics options for supporting the investigations

Three major options for logistically supporting the 1999/2000 air transport investigations were considered:

- using existing shipping and helicopter resources only;
- using existing shipping and augmented helicopter resources; or
- using a specially-contracted fixed-wing aircraft in conjunction with existing shipping.

All of these options included aircraft because of the need to work at remote sites that are not accessible by ship or over land from our established stations. For example, the Bunger Hills are located approximately 450 km from the nearest station (Casey), and about 80 km from the nearest point accessible by a ship. Similarly, even though the blue ice sites at Davis are within about 30 km of the station, they cannot be reached by vehicle during the summer.

The first option was rejected because it could not support the Davis investigations due to unsuitable shipping schedules and the fact that the single helicopter at Davis was not permitted to fly beyond the edge of the Vestfold Hills to the areas of interest for the blue-ice runway investigations. Any reassignment of the existing shipping and helicopter resources to better suit these air transport investigations would have caused massive disruption to previously-planned, high priority scientific programs. Similarly, while it may have been possible to deploy and retrieve personnel involved in the Bunger Hills investigations from planned voyages, this would have required diversion and delay of the ship with significant risk of disruption to major scientific programs and increased ship-hire costs.

The second option involved the charter of an additional helicopter and its delivery to Davis by arrangement with another national Antarctic program. This option was attractive in that it solved the problem of access to the potential blue-ice runway areas near Davis. However, it did nothing to reduce the significant costs and impacts likely to be involved in delivering and retrieving the Bunger Hills personnel by ship and helicopter. As a result, this option was rejected.

The third and selected option was to charter a fixed-wing aircraft (a ski/wheel-equipped Twin Otter) to provide access between Australia's existing stations and the sites of interest to the air transport investigations. As was the case with the other options, scheduled ship transport would be utilised as an adjunct to the air charter to move some of the investigation personnel and their equipment between Australia and Antarctica.

While chartering a fixed-wing aircraft was more expensive than chartering a second helicopter solely for the Davis investigations, the Twin Otter had the major advantage that it also provided an independent means of deploying and retrieving the Bunger Hills personnel. By doing so, this option avoided the significant risk of ship delays and excessive additional costs associated with attempting to conduct the Bunger Hills operation by helicopter from a ship that was already tightly scheduled. Importantly, this option also provided the opportunity to gain contemporary first-hand experience of the operation of fixed-wing aircraft in support of Australia's Antarctic program, including flights to and between each of Australia's Antarctic stations.

4.2 Personnel required for the investigations

4.2.1 *Project management*

Overall planning and coordination of the 1999/2000 field investigations was the responsibility of the Antarctic Air Transport Taskforce Manager, James Shevlin, operating

under the broad direction of the Director of the Australian Antarctic Division. As part of this function, the Taskforce Manager directly participated in many of the field activities and was responsible for their overall management and logistics support.

4.2.2 *Bunger Hills*

To achieve all of the required tasks, and for reasons of safety and efficiency, a four person team was selected to undertake the investigations in the Bunger Hills. This team comprised a field leader (Gary Kuehn), a biologist/chemist (John Gibson), an AAD environmental officer (Belinda Harding) and a field assistant (Damian Flynn). In addition to leading the field party, Mr Kuehn was responsible for the glaciological monitoring and coring program at the runway sites and for deployment of the automatic weather station. Dr Gibson and Ms Harding were responsible for the collection of information that would be required for any future environmental evaluation of air operations to the sites. Mr Flynn provided field assistance to all other members of the party.

4.2.3 *Davis*

A glaciologist (Mike Craven) and a qualified surveyor (Simon Manser) were selected to conduct the initial inspection of all potential blue-ice runway sites near Davis, followed by a detailed survey of any promising site. These two personnel were chosen because they had the necessary skills, were already going to Antarctica as part of other glaciological projects, and were available to support the planned runway investigations. Following discussions with overseas experts, specialist glaciological advice on blue-ice runway selection was provided to these personnel before departure by one of the AAD's senior glaciologists, Dr Jo Jacka.

Undertaking the investigations in the Davis area also required the assistance of a large number of Davis station personnel during the summer. In addition to deploying the automatic weather station, station personnel assisted in the physical examination of potential blue-ice runway sites and provided direct support to the aircraft involved in the investigations. This support included: preparing and maintaining a sea-ice airstrip at Davis; loading, unloading and refuelling the aircraft; providing communications and meteorological support; and feeding and accommodating the aircrew and runway survey party.

4.2.4 *Mawson*

The 1999/2000 air transport investigations required the assistance of a number of Mawson station personnel not only to deploy the automatic weather station but also to select and prepare a suitable blue-ice runway for use by the aircraft involved in the investigations. Mawson personnel also provided assistance with refuelling, communications and meteorological support for the aircraft.

4.2.5 *Casey*

As at Davis and Mawson, a wide range of Casey station personnel were involved in providing vital assistance to the air transport investigations this summer through their direct support of the associated aircraft operations.

4.3 *Actual transport arrangements*

4.3.1 *General*

Delivery of all the necessary personnel and equipment to conduct a range of investigations at three widely dispersed sites (Bunger Hills, Davis and Mawson) required the innovative use of a novel combination of aircraft and shipping. While the chartered Twin Otter was used for all transport and access to study sites within Antarctica, intercontinental movement of investigation personnel and equipment was achieved using a combination of scheduled voyages and commercial Hercules aircraft.

The charter agreement for the Twin Otter was arranged with a commercial operator, Polar Logistics, with a starting and finishing point at that company's Patriot Hills camp at the base of the Antarctic Peninsula. The charter agreement also included the provision of seats on connecting intercontinental Hercules flights between Chile and the Patriot Hills. For reasons of efficiency, these seats were used by four of the investigation personnel, who then flew in the Twin Otter from the Patriot Hills to their destinations at Davis and the Bunger Hills. The route taken was westwards around the coast of East Antarctica with refuelling stops at Halley, Syowa and Mawson stations, and at a blue ice runway site approximately mid-way between Halley and Syowa (see Figure 1). All other personnel and the investigation equipment were delivered to Antarctica by scheduled ship voyages and then deployed to their study sites by Twin Otter.

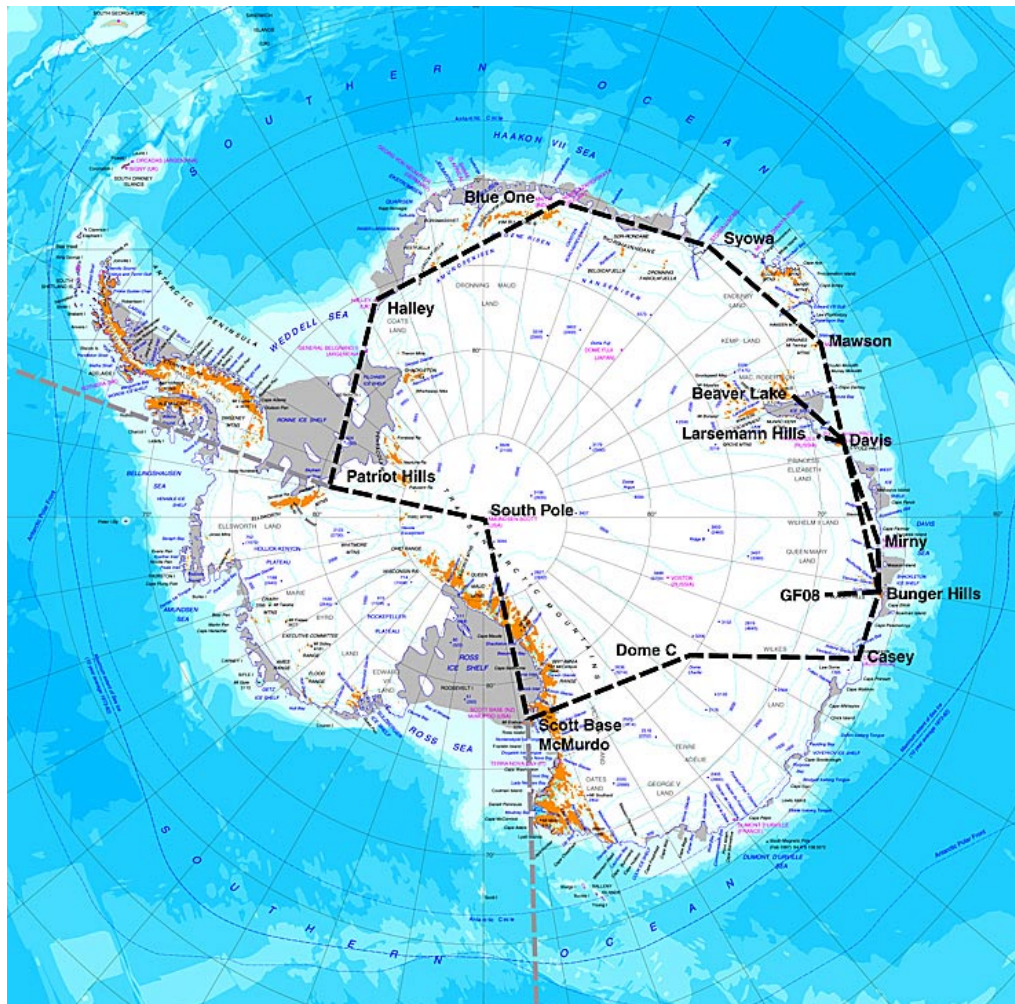


Figure 2: Routes flown by Twin Otter and Hercules aircraft during 1999/2000 investigations

Following completion of the field investigations, all personnel (other than the Taskforce Manager and the AAD's Facilities Engineer) returned to Australia by ship. The Taskforce Manager and the Facilities Engineer travelled with the Twin Otter to McMurdo and Patriot Hills respectively and then flew out of Antarctica by Hercules aircraft.

While details of the distances and approximate flight times between all locations are provided at Appendix A and a full chronology of all flights and other events is included at Appendix B, the transport arrangements for each study area are briefly described below.

4.3.2 Bunger Hills

Three of the members of the Bunger Hills field party, plus approximately 2 000kg of equipment, travelled from Hobart to Casey on Voyage 2.1 in November 1999. The initial plan had been for the Twin Otter to pick up and deliver these personnel to the Bunger Hills in early to mid-December. However, due to a range of weather-related and other factors that delayed the commencement of the Twin Otter contract, the delivery of these personnel and equipment to the Bunger Hills did not occur until about three weeks later on 1 January 2000. The fourth member of the field party plus the Taskforce Manager arrived in the Bunger Hills five days earlier (on 26 December 1999), having been delivered there by the Twin Otter while en route from the Patriot Hills to Casey to pick up the rest of the party.

A total of three return Twin Otter flights on 1-2 January 2000 was needed to deliver the field party and all their equipment from Casey to the Bunger Hills - these flights were also used to backload a large volume of waste, empty fuel drums and obsolete equipment from Edgeworth David to Casey. A fourth return flight was undertaken on 4 January to deliver additional fuel to the Bunger Hills. Three return flights were also made between Edgeworth David and the Apfel Glacier during this period for the purpose of inspecting the surface and delivering personnel and equipment to the proposed runway site (see Figure 3).



Figure 3: Twin Otter at the Apfel Glacier blue-ice runway site - looking east.

Following completion of all planned activities in the Bunger Hills, all members of the field party and their equipment were returned to Casey in three Twin Otter flights on 18-20 January 2000. This retrieval exercise included two return flights

between Edgeworth David and the Apfel Glacier runway site. The four members of the field party travelled home to Australia on Voyage 5 in early February 2000.

As a separate science support exercise, the Twin Otter was also used on 17 January 2000 to deliver a replacement automatic weather station (plus a five-person installation party) to GF08, a remote site on the ice plateau approximately 140 nautical miles inland from the Bunger Hills (see Figure 4). The installation was completed successfully in four hours and the aircraft returned to the Bunger Hills.



Figure 4: Installation of automatic weather station at site GF08, 140nm inland from Bunger Hills

4.3.3 Davis

Because the timing of available ship travel opportunities was unsuitable for the planned investigations, the glaciologist and surveyor involved in the Davis investigations (plus the Taskforce Manager and one member of the Bunger Hills party) travelled to Davis with the chartered Twin Otter - arriving on 22 December 1999.



Figure 5: Sea-ice at Davis provided a convenient skiway for local Twin Otter operations

The inspection of potential blue-ice runway sites in the Davis area commenced almost immediately upon arrival of the Twin Otter at Davis and continued over the next three days. During this period, the Twin Otter was used extensively to conduct a comprehensive aerial survey of all possible blue-ice runway areas, followed by landings and on-ground examination of the surface at the four most promising sites. The Twin Otter was also used to visit the Larsemann Hills and inspect the Russian's proposed compressed snow runway site on the adjacent snow plateau. Following completion of these runway inspections, the glaciologist and surveyor remained in Antarctica to undertake their other glaciological programs, and travelled home to Australia by ship at the end of the summer.

In addition to operating from Davis for several days in late December 1999 while inspecting potential blue-ice runway sites in the area, the Twin Otter returned on 5 January 2000 and was based at Davis for the next ten days undertaking flights in support of other scientific programs and undergoing routine maintenance. During this time, the Twin Otter made five 500 nautical mile return flights to Beaver Lake and delivered more than five tonnes of scientific equipment and fuel to that location.

Following departure of the Twin Otter, an automatic weather station was installed by a team of personnel from Davis station at a selected blue-ice site on the ice plateau inland from the Rauer Island group (approximately 30km from Davis). The installation team and the automatic weather station (which had been delivered to Davis by Voyage 4) were deployed to the blue-ice site by helicopter. The helicopter was also used to re-visit and check on the condition of potential runway sites that had previously been used by the Twin Otter.

4.3.4 *Mawson*

The Twin Otter landed at Mawson on 20 December 1999 while en route to Davis from the Antarctic Peninsula. After one day's delay due to poor weather, the aircraft continued to Davis on 22 December. This was the Twin Otter's only visit to Mawson during the summer.

Selection and preparation of the blue-ice runway site used by the Twin Otter near Mawson was undertaken by station personnel using over-snow vehicles. These vehicles were also used to support the installation at the runway site of an automatic weather station that had been delivered to Mawson on Voyage 4.

4.3.5 *Casey*

The Twin Otter first landed at Casey on 29 December 1999 and over the next six days undertook four return flights to the Bunger Hills. Following its return from Davis on 18 January 2000, it spent another three days shuttling between Casey and the Bunger Hills before finally departing on 21 January for its return flight to the Patriot Hills.

Over-snow vehicles were used for preparation and maintenance of the skiway used by the Twin Otter at Casey. These vehicles were also used to move all personnel, cargo and fuel between the station and the skiway.

4.3.6 *Other stations*

Getting the Twin Otter between the Antarctic Peninsula and blue-ice runway survey sites at Davis and the Bunger Hills required a number of refuelling stops along the route. The Twin Otter visited Halley (UK), Syowa (Japan) and Mawson stations during its twelve-day delivery flight around the coast of East Antarctica from the Patriot Hills to Davis.



Figure 6: Twin Otter refuelling on the sea-ice at Syowa station during delivery flight to Davis

The seven-day return flight from Casey, using the alternative and slightly more direct South Pole route, required stops at Dome C (Italy/France), McMurdo (US) and Amundsen-Scott (US) stations. A refuelling stop was also made at Mirny station (Russia) during the first flight from Davis to the Bunger Hills. The amount of fuel required to refuel the aircraft at each of these locations is set out below.

Halley	1 800 litres (9 drums)
Syowa	1 400 litres (7 drums)
Dome C	1 400 litres (7 drums)
McMurdo	2 000 litres (10 drums)
South Pole	1 600 litres (8 drums)
Mirny	600 litres (3 drums)

In addition to providing fuel and very professional meteorological and communications support for the Twin Otter's flights, the personnel at all of these stations extended a very warm welcome and generous hospitality to the runway survey personnel and aircrew travelling with the Twin Otter. This assistance was greatly appreciated.

5. RESULTS OF THE INVESTIGATIONS

5.1 INTRODUCTION

The field investigations conducted during the 1999/2000 Antarctic summer successfully achieved all their planned objectives: the potential blue-ice runway sites at Davis were surveyed; glaciological and environmental information was collected at the Bunger Hills; and automatic weather stations were installed at Davis, Mawson and the Bunger Hills. The means by which the investigations were undertaken also created a number of additional opportunities.

Use of the Twin Otter aircraft provided the capacity to directly support a number of other scientific projects, and enabled contemporary experience to be gained of the benefits and difficulties associated with using fixed wing aircraft in support of Australia's Antarctic program. In addition, the aircraft provided the means by which potential landing areas could be genuinely trialed for possible future use.



Figure 7: Twin Otter at a remote blue ice site in Queen Maud Land during its delivery flight

While some detail is provided in this and previous chapters on how the investigations were undertaken during the 1999/2000 summer, the primary focus of this chapter is to identify what has been learned regarding potential airfields, infrastructure and aircraft as a result of those investigations. In particular, this chapter will highlight those findings of the July 1999 Antarctic Air Transport Scoping Study that were either confirmed or invalidated by the investigations.

5.2 POTENTIAL AIRFIELDS

5.2.1 Bunger Hills

5.2.1.1 *Apfel Glacier blue-ice runway*

For the purpose of undertaking the recommended glaciological observations of the blue-ice runway site, the 1999/2000 Bunger Hills party marked and studied a rectangular strip 2 300 metres x 100 metres on the Apfel Glacier (see Appendix C for exact location). Surface characteristics were recorded on several occasions and a total of 36 ice cores were collected, including at the time of warmest temperatures and greatest surface melting. While full details of the observations are set out in the Bunger Hills Field Leader's report, the most relevant findings are included below.

The surface observations during 1999/2000 supported the findings of the 1999 Scoping Study (Section 4.2.6) that the site appears to meet all required specifications relating to dimensions, gradient and surface roughness. While the runway rises from west to east, the gradient is small and both the approach and departure paths are free of obstructions as the runway site (at 150 metres above sea level) is above the height of the Bunger Hills. The surface, which is free of undulations and has sun cups of about 25 mm depth, was also undoubtedly the smoothest of the five blue-ice runways used by the Twin Otter at a number of locations around the Antarctic continent during the summer.

While some melt water (2-3 mm deep) was visible on the surface in small patches on the warmest and sunniest days, the runway site was found to be well-drained by small 'crevasses' which ran perpendicular to the runway orientation. The majority of these crevasses were approximately 50-150 mm in width, although some were 150-250 mm in width. The typical surface length of the crevasses was 20-30 metres and no individual crevasse crossed the entire width of the strip. Importantly, none of these crevasses posed a problem for the Twin Otter when operating to and from the site during the summer.



Figure 8: *Apfel Glacier blue-ice runway site - including small transverse crevasses*

The ice cores taken from the site suggest that, at least during the 1999/2000 summer, sub-surface melting was not a problem adversely affecting the strength of the runway. While the surface ice was relatively saturated and water seepage occurred into many of the core holes, this did not appear to compromise the strength of the ice cores. Thin sections of a number of cores, including the most suspect, were analysed in Australia and the ice crystal

structure indicated that sub-surface melting had not occurred and that the ice was sufficiently 'hard' to support operations by heavy wheeled aircraft. Initial surface observations conducted during the 1998/99 summer also indicated that the blue ice was suitable in that season for heavy aircraft operations.

A cautionary note is required before extrapolating these results to other seasons. The large size of the ice crystals found during analysis in Australia indicated that the temperature of the ice at the Apfel Glacier runway site has been at or near zero degrees Celsius at some time. Meteorological data from Casey and Davis stations also suggests that the 1999/2000 summer was significantly cooler and cloudier than average. The combination of these two factors means that it is not possible to be absolutely certain that the ice conditions will be suitable for heavy aircraft operations at all times during average or warmer seasons in the future. On the other hand, no evidence has yet been found to show that there definitely would be problems with the ice.

In addition to there being limited data available on ice conditions, little is currently known about the weather conditions at the runway site. While the information collected during the 1999/2000 season indicates that the prevailing wind at the site is favourably aligned with the proposed runway, much more data is required to develop a good understanding of the weather conditions that could affect any future flying operations to the site. The automatic weather station that was erected immediately to the south of the runway on 5 January 2000 (see Appendix C for exact location) will assist in filling this knowledge gap over time, following ongoing data monitoring and analysis by the Bureau of Meteorology.

Another question that remains regarding the use of the Apfel Glacier blue-ice runway for intercontinental aircraft operations is whether such use would be environmentally acceptable. While this question can only be definitively answered following a full environmental evaluation in accordance with Australian and Antarctic Treaty requirements, the environmental information collected during the 1999/2000 season does provide some guidance regarding the potential type and level of impacts (see Appendix D). A number of special environmental features were identified, including several lakes and populations of lichen, moss, invertebrates, birds and Weddell seals. Several possible threats to these features were also identified, including those arising from atmospheric emissions by aircraft and potential fuel spills. Overall though, the information collected suggests that, with appropriate safeguards and practices, it should be possible to conduct operations to and at the Apfel Glacier blue-ice runway site in an environmentally acceptable manner.

One major factor affecting the extent of potential environmental impact is the type and placement of any associated infrastructure. The investigations conducted during the 1999/2000 season included consideration of several potential locations for the infrastructure associated with a blue-ice runway on the Apfel Glacier. These investigations suggest that it would be more convenient and result in less environmental impact if any infrastructure were to be located on the snow surface of the Apfel Glacier to the south of the runway, rather than on the rock surface of the adjacent southern margin of the Bunger Hills (see Figure 9).



Figure 9: Ice slope between Apfel Glacier blue-ice runway site and southern margin of the Bunger Hills

As discussed later in this paper, the opportunity this season to see how other national and commercial operations conduct their air operations at remote sites validated the suggestion in the Scoping Study that all required infrastructure could and should be air transportable. The issue of how best to move and handle fuel at remote airfields (such as the Bunger Hills) does however require further consideration. While the operations this season were able to demonstrate that it was feasible to move drummed fuel over considerable distances using ski-equipped aircraft, the operations also highlighted that the movement of large numbers of fuel drums would be labour-intensive, time-consuming and expensive. All options for moving fuel the 60 nautical miles from a ship-accessible location at the edge of the Shackleton Ice Shelf to a blue-ice runway at the Bunger Hills need to be thoroughly examined.

Given the obvious need for caution with any intercontinental flights to new locations, and the fact that many years of experience will be required to better understand the reliability of ice and weather conditions at the blue-ice runway site, any such flights should only occur following on-site confirmation of the suitability of conditions. This has been the standard practice with other runway sites used for heavy wheeled aircraft operations in Antarctica. All operations to these sites are preceded by an intracontinental aircraft that deploys personnel to set up the required infrastructure and to provide reports on weather and ice conditions. Prior to the first intercontinental flight, the proposed runway is also personally inspected for suitability by a senior pilot from the company operating the intercontinental aircraft. Similar procedures should apply to any future intercontinental aircraft operations from Australia to the Apfel Glacier or to any other runway site in Antarctica.

While some questions remain about the reliability of the blue-ice runway for intercontinental aircraft operations, the use of the Twin Otter to support the investigations in 1999/2000 did conclusively demonstrate the practicality of operating ski/wheel-equipped intracontinental aircraft from the Bunger Hills to both Casey and Davis. Even if the Apfel Glacier site was not useable at times for any reason, the investigations indicated that there were other areas of blue-ice to the east of the Bunger Hills that were likely to be suitable for ski/wheel-equipped

intracontinental aircraft. These sites include an area of blue-ice that has previously been used as a runway by Russian aircraft (see Attachment C for exact position and a brief description).

5.2.1.2 *Transkriptsii Gulf lake-ice runways*

For the purpose of undertaking the recommended glaciological observations of the Transkriptsii Gulf as a possible location for an intercontinental runway, the 1999/2000 Bunger Hills party marked out a 2 200 metre strip on the main body of the Gulf about 2km to the west of Edgeworth David base. A separate but less expansive area of ice directly adjacent to Edgeworth David was used for all Twin Otter operations this season (see Appendix C for exact locations of both sites).

The seven ice cores taken along the length of the possible intercontinental strip confirmed that the Transkriptsii Gulf is covered by a level freshwater icecap of about 3.8 metres thickness, which would be more than sufficient to support operations by heavy wheeled aircraft. However, while the observations of the site indicated that there were no undulations in the surface and that the sun cups were only about 40 mm deep, these observations also found periodic snow drifts up to 0.8 metres in height and ice mounds up to 0.4 metres high. During periods of melt, water also collected 30-50 mm deep between these snow and ice mounds.

The surface features and the melt-water found on the main part of Transkriptsii Gulf would present some problems for large aircraft operations to this site. While some form of snow-blower machine could be used to remove the snow and ice mounds and to maintain the strip, it is likely that the presence of surface water would prevent aircraft operations during periods of warmer temperatures and melt. These factors don't rule out the possible use of this site, but they do make it less attractive than other sites (such as the Apfel Glacier) that do not have these problems.

Unlike the potential intercontinental runway site, the less expansive area of ice directly adjacent to Edgeworth David base provided a good surface on which the Twin Otter was able to land throughout the season using either wheels or skis (see Figure 10). This area remained free of the larger-scale snow and ice mounds that affected the main part of Transkriptsii Gulf.



Figure 10: Twin Otter on Transkriptsii Gulf lake ice directly adjacent to Edgeworth David base

In addition to questions about the suitability of its surface for heavy wheeled aircraft operations, the investigations during the 1999/2000 season raised a major concern about

the environmental acceptability of using the Transkriptsii Gulf for regular aircraft operations. The investigations confirmed that the Gulf is one of very few epishelf lakes in the world (a lake that is located between land and a floating ice shelf and typically contains a freshwater layer overlying seawater) and suggested that it should therefore be given strong protection from the potential risk of contamination associated with aircraft operations (see Appendix D). This concern should be addressed in detail in any environmental evaluation of the proposed air system.

5.2.2 Davis

5.2.2.1 *Sea-ice skiways*

Use of the Twin Otter to support the investigations in 1999/2000 confirmed that the sea-ice immediately in front of Davis station provides an excellent and very convenient early to mid-season base for ski-equipped aircraft operations in the region. In fact, during the 1999/2000 season this area of sea-ice remained more than 1.5 metres thick and was used by the Twin Otter until the middle of January. Even though this is considerably later than the normal mid-December finish date suggested in the 1999 Scoping Study (Section 4.2.3.4), it is possible that the ice was more persistent due to the lower than average spring and summer temperatures experienced at Davis this season.

While the sea-ice immediately in front of Davis is very convenient and desirable to use whenever possible, the experience in the 1999/2000 season confirmed that, even in a very favourable summer, it does not provide an all-season solution for fixed wing operations to the station.



Figure 11: Davis sea-ice rapidly breaking up - the skiway used was at the bottom right of this photograph

After starting to break up near Gardner Island on the evening of 13 January, all of the sea-ice in front of Davis completely broke out during just a few hours on 15 January (see Figure 11). In the event, pre-planning meant that this did not present any real problems as the aircraft was moved in advance to a more stable area of sea-ice that had been identified and marked adjacent to Plough Island about 5km

north-east of Davis. If necessary, the aircraft could also have been flown to a blue-ice site that had been selected on the ice plateau inland of the Rauer Islands about 30km from the station. The exact locations of both of these sites are given in Appendix C.

The experience this summer highlighted the requirement both to regularly monitor the condition of the sea-ice (for thickness, strength and cracking) and to ensure that alternative landing sites have been identified and are available for use at very short notice. The operations during the 1999/2000 season also confirmed the need to have at least one helicopter at Davis from early December onwards to provide the necessary link between the station and any fixed-wing landing area other than the sea-ice directly in front of Davis.

While a very good skiway was prepared at Davis using existing station vehicles, the experience during the summer demonstrated that at least one person and a suitable vehicle (e.g. a Hagglund with a tracked trailer) were required for several hours each day to support the Twin Otter whenever it was operating from the station. This factor should be taken into account when determining support requirements for any future fixed-wing operations to the station.

5.2.2.2 Blue-ice runways

Despite a comprehensive aerial survey of all possible areas of blue-ice in the vicinity of Davis, and an on-ground examination of the four most promising sites (exact locations given at Appendix C), the 1999/2000 survey team was reluctantly forced to conclude that none of the areas were suitable at that time for operations by larger intercontinental aircraft. Unfortunately, the extensive areas of bare blue-ice that had appeared promising during preliminary investigations last year (Section 4.2.3.5 of the 1999 Scoping Study) were found this summer to be completely covered by ice bumps and ridges and/or at least 20cm of snow.



Figure 12: This snow-covered site inland of the Rauer Islands had been bare blue-ice in 1998/99

Even though it is possible that the conditions found in late December 1999 were the result of abnormally heavy snow accumulation in the preceding months, their occurrence even in one year suggests that these sites should not be relied upon as a landing area for intercontinental aircraft operations from Australia. However, given that subsequent inspections in late February 2000 found that much of the snow had cleared from these sites, it is possible that suitable areas of blue-ice may be available near Davis in more favourable seasons and could at least be used opportunistically for some heavy wheeled aircraft operations.

To get a better understanding of the changes that occur in the snow and surface conditions at these blue-ice areas, and to enable assessments to be made of the potential for future opportunistic or regular use of these sites by intercontinental aircraft, these areas should continue to be monitored.

In addition to questions about the suitability and reliability of the blue-ice for heavy wheeled aircraft operations, a further concern regarding use of these sites near Davis as the sole intercontinental terminus relates to their distance from Australia. Whereas the distances from Hobart to Casey (1846 nautical miles) or from Hobart to Bunger Hills (2063nm) are closely comparable to the Christchurch-McMurdo distance (2065nm) regularly flown by the US and New Zealand programs, the 2597nm distance from Hobart to Davis is considerably greater. This additional 530nm is significant because it would extend a Hercules aircraft's Point of No Return (PNR) by a further two hours from its destination - Christchurch-McMurdo flights already have a PNR about four hours from McMurdo.

Given the lack of suitable alternate airfields and the unpredictable weather conditions, it is preferable that all intercontinental flights have a PNR as close as possible to their destinations and any factor that serves to extend the PNR is clearly not desirable. This factor should be taken into account in any further consideration of the potential of Davis blue-ice areas as the sole intercontinental terminus for flights from Australia.

While none of the blue-ice areas near Davis were found at the time to be suitable for intercontinental aircraft operations, one blue-ice site on the ice plateau inland of the Rauer Islands was definitely suitable for the Twin Otter (see Figure 13). As this was the only such site found during the summer, and because it may need to be used in the future for intracontinental aircraft operations following the break up of the sea-ice at Davis, an automatic weather station was installed at this site on 4 February 2000 (see Appendix C for the exact location).



Figure 13: The blue-ice runway site used by the Twin Otter on the plateau inland of the Rauer Islands

If the Rauer Islands blue-ice site is to be used in future years for intracontinental aircraft operations later in the season, some form of temporary accommodation and equipment storage facility should be provided near the runway for use by the aircrew and transiting passengers. While it is possible that traverse vans or similar towed structures could be used for this purpose, it would be easier and more consistent with the practice adopted at other blue-ice runways for the required capacity to be provided by some form of air-transportable structures. These structures could be quickly dis-assembled and flown back to Davis at the end of each season.

5.2.3 Casey skiway

The Twin Otter operations at Casey this summer confirmed that it was possible to prepare an acceptable skiway for this type of aircraft near Casey station - the site chosen on this occasion was at Penguin Pass only about 5 minutes by vehicle from the station (see Appendix C for exact location). However, the difficulty experienced in preparing the skiway using the existing bulldozers and Hagglunds at Casey also clearly demonstrated the need for some more efficient means of preparing the strip if regular operations are planned to this station.

The lack of the right skiway preparation equipment at Casey not only greatly increased the number of hours that station personnel and equipment needed to devote to the task but also meant that it was not possible to produce a completely level surface. To increase the efficiency of the operation and to ensure that the condition of the skiway does not adversely affect the amount of payload that can be carried safely by an aircraft, some form of towed snow groomer should be acquired for use at Casey. A potentially suitable model was used at Patriot Hills this season and apparently greatly improved the condition of the skiway used by the Twin Otter and DC3 at that location.



Figure 14: The Twin Otter unloading and refuelling at the Casey skiway

In addition to the days required for preparation of the skiway, station personnel also had to devote a significant amount of time during aircraft operations to deliver fuel and equipment to the aircraft, to collect returned equipment and waste, and to provide communications and meteorological support. This suggests that, in addition to ensuring adequate communications and meteorological resources at the station, at least one dedicated support person plus a suitable vehicle and fuel sled must be available at Casey whenever intracontinental aircraft are operating to or from the station.

5.2.4 Mawson

5.2.4.1 *Sea-ice runway*

While a possible sea-ice runway near Mawson had been identified earlier by station personnel, by the time the Twin Otter arrived at Mawson on 20 December 1999 the sea-ice at the site had deteriorated to the extent that it was no longer useable. This situation is consistent with the findings of the 1999 Scoping Study (Section 4.2.4.3) which suggested that the sea-ice was not likely to be useable after about mid-December each summer due to decreasing ice thickness.

5.2.4.2 *Blue-ice runway*

Due to the unavailability of a suitable sea-ice runway at Mawson, the Twin Otter landed instead on a very good area of untreated blue-ice that had been selected and marked by station personnel at a site about 10 nautical miles (55 minutes travel by Haggglund) from Mawson (see Appendix C for exact location). While this operation confirmed that an aircraft of this type could be safely operated to unprepared areas of blue-ice inland of Mawson station, it should be noted that it was also carefully planned with reference to satellite weather pictures and forecasts so as to avoid any chance that the aircraft would be caught on the ground by a severe weather system.

Given that five aircraft have previously been destroyed by very strong winds and severe turbulence while tied down on the blue-ice near Mawson, it is highly desirable that any future operations to this area are planned in the same way as the flight this season. Specifically, flights to Mawson should be planned as brief transit or round-trip visits and only at times when conditions are suitable to allow the aircraft to continue or return to a safer destination.



Figure 15: The Twin Otter on the blue-ice runway inland of Mawson

5.2.5 Larsemann Hills skiway

Advantage was taken of the availability of the ski-equipped Twin Otter this season to make a brief visit from Davis to inspect the progress that the Russian Antarctic Expedition (RAE) was making with establishment of a compressed snow runway on the ice plateau behind the Larsemann Hills (see Figure 16). While this visit confirmed that a marked but otherwise unprepared 2 500 metre skiway exists at the site, there was no evidence that any snow compaction had yet occurred. This observation was later confirmed in discussions with the RAE's Assistant Director who advised that snow compaction work at the site will now not commence until the 2000/01 season.



Figure 16: Twin Otter at the proposed Russian compressed snow runway site at the Larsemann Hills

5.2.6 Other airfields

5.2.6.1 Beaver Lake

As mentioned earlier, advantage was also taken of the availability of the Twin Otter to fly more than five tonnes of scientific equipment and fuel from Davis to the frozen surface of Beaver Lake - approximately 250 nautical miles from Davis.



Figure 17: Twin Otter on Beaver Lake, January 2000

The operations to Beaver Lake confirmed what was known from previous experience of fixed-wing flights to the site - that the southern end of Beaver Lake provides an excellent surface for fixed-wing aircraft operations with many kilometres of level ice allowing aircraft to land in any direction (see Figure 17).

Unfortunately, while the frozen surface of Beaver Lake would probably be suitable for landings by intercontinental aircraft, it is too distant from the Bunger Hills (750 nautical miles) to be useful as a standard alternative for intercontinental flights to this location. It is also too far from Australia (about 2 700 nautical miles) to be used as the primary intercontinental hub.

5.2.6.2 *Mirny*

The Twin Otter refuelled at Russia's Mirny station on 25 December 1999 during its initial flight between Davis and the Bunger Hills. While very generous assistance was provided by the Russian personnel at Mirny, this exercise did highlight that there would be a number of potential difficulties with regular use of this station as a refuelling location for flights between Davis and Casey or the Bunger Hills.

The major problem relates to the availability of a reliable and safe landing area for fixed wing aircraft. While it was possible for the Twin Otter to land on the sea-ice on this occasion, the sea-ice in this area apparently cannot be relied upon after about mid-December each summer. In addition, even when the sea-ice is suitable, the experience this summer demonstrated that the presence of coastal tide cracks can make it very difficult and time-consuming to move fuel from the station to the sea-ice runway site.



Figure 18: A crevasse discovered during attempts to prepare a skiway at Mirny for the Twin Otter

Due to the problems with getting fuel to the sea-ice runway, the potential for establishing a skiway on the ice plateau surrounding Mirny was also investigated. The skiway previously used by the Russians had apparently been abandoned due to problems with crevassing, so an alternative site was examined which was reasonably level and avoided the worst of the sastrugi in the area. Attempts at preparing a skiway at this site (about 2km south-west of the station) were however abandoned when one of the vehicles broke through a snow bridge to expose a one metre wide (and very deep) crevasse in the middle of the planned strip (see Figure 18). As a result of this experience, and subsequent discussions with the station personnel, it appears that crevassing in the Mirny area may prevent any safe and reliable skiway being developed at this station.

In addition to the problems presented for development of a skiway in the area, the presence of many crevasses even in the immediate vicinity of the station buildings creates a hazard for any other operations at Mirny (one crevasse for example is known to be within 20 metres of the main station building). All helicopter crews and other Australian personnel visiting Mirny should be warned of the requirement for great care and also not to stray from marked routes when moving around the station.

On the basis of the lessons learned this season, future intracontinental fixed-wing aircraft operations should be planned so that they are not dependent on use of Mirny as a refuelling location, except at those times when the sea-ice is likely to be reliable.

5.3 INFRASTRUCTURE REQUIREMENTS

5.3.1 Introduction

As noted in the 1999 Scoping Study (Section 4.2.8), there are differing views on the extent of infrastructure required to support an air transport system and also on the most appropriate means of providing the required capacity. While determining the right approach for an Australian air transport system will still require a number of detailed cost-benefit and risk assessments (many of which should be undertaken in consultation with the selected aircraft operator and other appropriate experts), it is possible to make a number of observations on the basis of the experience gained this season. These observations should be read in conjunction with Section 4.2.8 of the Scoping Study as they are intended to supplement rather than replace the Study's discussion of infrastructure issues.

5.3.2 Accommodation

The operations this season reinforced the suggestions in Section 4.2.8.1 of the Scoping Study regarding the suitability and desirability of portable facilities as a means of providing the additional accommodation that would be required by an Australian air transport system.

For example, Polarhaven-type structures were used at Patriot Hills to provide all required kitchen/mess, ablution, storage and workshop facilities, while personnel accommodation was provided in smaller 'clam' tents. All of these structures were comfortable and very functional for these purposes (see Figures 19 and 20). Similar structures were also used to provide excellent dormitory-style accommodation at the Italian/French base at Dome C.



Figure 19: The kitchen/mess and ablutions facilities at Patriot Hills

Given that both Patriot Hills and Dome C experience much colder summer conditions than any of Australia's proposed airstrip locations (for example, it was -37 C when the Twin Otter visited Dome C in January), it is strongly suggested that these or an equivalent type of temporary structure would be more than adequate to provide the accommodation facilities required at remote airfield sites used by Australia. The benefits of these structures, which have withstood winds of 100 knots at Patriot Hills, include that they are light, air-transportable, and easy to erect and remove. All required facilities can therefore be established without any reliance on heavy vehicles or sleds.



Figure 20: Interior of the kitchen/mess at Patriot Hills

Most of the short-term accommodation provided at Australia's stations for the Twin Otter aircrew and passengers was in converted shipping containers. This form of accommodation was completely adequate for the purpose, but would need to be supplemented by additional equivalent structures for transiting passengers at Casey and Davis if regular air operations occur.

5.3.3 Communications

During the 1999/2000 season, HF radio was used for all communications between Australia's stations and the Twin Otter, other than the occasional use of air-band VHF radio when the aircraft was very close to the stations. Excellent support was received from the communications officers at all of Australia's stations and no technical problems were experienced with any aspect of these air-ground communications. The additional demands imposed on Casey and Davis as a result of regular and lengthy air operations to these sites did, however, confirm the value of having dedicated communications operators at these sites. This practice should be continued if regular operations are planned in future seasons.

While the full requirements for air-ground communications will need to be resolved in discussions with the selected aircraft operator, Section 4.2.8.2 of the Scoping Study suggests a number of items of equipment that are likely to be needed at any regularly used airfield site. In addition to this airfield-based equipment, the experience of landing the Twin Otter at a number of remote sites, both during its delivery flight and when undertaking science support tasks, demonstrated the need for the intracontinental aircraft to carry communications equipment for use when the aircraft is not in the air. In particular, these aircraft should carry a satellite phone plus a separate HF radio and power supply for use when the aircraft are on the ground at remote locations.

5.3.4 Meteorological requirements

The Twin Otter operations during the 1999/2000 season received excellent support from the meteorological personnel at all of Australia's stations. The observations and forecasts received, plus the satellite weather pictures available at our stations, were at least as good as anything obtained elsewhere in Antarctica.

While it was possible with current facilities and staffing levels to provide this high quality meteorological service for the relatively small number of intracontinental flights undertaken this season, it was recognised in the Scoping Study that the introduction of regular intercontinental and intracontinental flights would impose additional demands. In this regard, Section 4.2.8.3 of the Study includes a number of suggestions from the Bureau of Meteorology for additional equipment and facilities that it considers would be necessary to support these expanded operations, particularly at remote airfield sites. The final requirements should be determined in consultation with the Bureau and the selected aircraft operator, but also taking into account the experience of a range of established Antarctic fixed-wing aircraft operators.

As recommended by the Scoping Study, some additional meteorological facilities have already been installed in Antarctica as part of this project. These three automatic weather stations were erected during the summer at the blue-ice runway sites used by the Twin Otter near Davis, Mawson and the Bunger Hills. While analysis of the data from these automatic stations will greatly assist in developing an understanding of the weather conditions that are likely to affect any future flying operations to these sites, these stations will not eliminate the requirement for on-site human observers during actual flying operations to these locations.

In addition to equipment and personnel issues, use of the Twin Otter this season highlighted the fact that fixed-wing aircraft operations may have a number of specific information requirements that differ from our current helicopter operations. For example, a major factor affecting flights this season was the amount of cloud cover, and therefore the quality of the surface definition, at destination locations. While the extent to which this is a factor may depend on individual pilots, it is clear that adequate surface definition at the actual runway site is desirable for safe fixed-wing aircraft operations to snow and ice surfaces and will therefore need to be included as a feature in observations and forecasts for these operations.

Even though no major problems were experienced this season, it would be highly desirable for the Bureau of Meteorology to meet with the senior pilot in advance of any future fixed-wing aircraft operations to determine exactly what type and format of meteorological information will be required. These requirements should then be disseminated to all relevant meteorological and operational personnel.

5.3.5 Navigational and landing aids

As envisaged in the 1999 Scoping Study (Section 4.2.8.4), the Twin Otter operations this season used a satellite Global Positioning System as the primary means of navigation, with Non-Directional Beacons being used as a back-up when available at some stations.

With the exception of McMurdo and Amundsen-Scott stations, very simple but effective landing aids were used at all ice and snow runways visited by the Twin Otter. For example, snow-filled black plastic bags placed every 100 metres down either side of the runway were used as the standard form of runway marking. In addition to being cheap and easy to install and remove, these runway markers have the advantage that they pose no danger to the aircraft if it accidentally hits one. A simple windsock was also provided at each of these sites.

The only other landing aids used to support intercontinental aircraft operations to the Patriot Hills blue-ice runway were two hand-held signalling mirrors. These proved to be a simple but very effective means of indicating the threshold and half-way point of the runway. The simplicity of this set-up is in marked contrast to the facilities available at McMurdo station, which include precision approach radar and runway landing lights. The benefit of these more elaborate facilities is that they allow aircraft to land safely in conditions of restricted visibility - which can be a problem at McMurdo due to low cloud and fog.

As recommended in the 1999 Scoping Study, discussions will be needed with the selected aircraft operator and the Civil Aviation Safety Authority (CASA) to determine what

aircraft navigation and landing aids would be most appropriate for an Australian Antarctic air transport system.

5.3.6 Fire-fighting

The fire-fighting equipment at Antarctic airfields also varies greatly, ranging from quite sophisticated facilities at McMurdo to none at all at many remote sites. As suggested in the Scoping Study (Section 4.2.8.5), a risk assessment should be undertaken in consultation with the selected aircraft operator, other experienced Antarctic operators and CASA to determine what approach and facilities would be most appropriate for an Australian Antarctic air system.

5.3.7 Aircraft service and support equipment

Because it was operating on its own, and at a long distance from any source of spare parts, the Twin Otter involved in the 1999/2000 investigations needed to carry a considerable volume and weight of spare parts, lubricants and other service equipment (including, for example, a 70 kg cylinder of nitrogen gas). To reduce this payload penalty in the future, it would be useful if (as envisaged in Section 4.2.8.6 of the Scoping Study) a stock of standard service items and equipment could be held at airfields that are regularly used.

While responsibility for determining and providing aircraft service and support equipment requirements should rest with the aircraft operator, the experience this season suggests that this equipment should include Herman Nelson heaters for engine warming and a Ground Power Unit at the intercontinental airfield. The only associated infrastructure requirement would be to provide some suitable form of storage for this equipment. This could be either in a Polarhaven-type structure as used at Patriot Hills, or a small shipping container as used at Davis.

5.3.8 Cargo handling equipment

The investigations this summer provided the opportunity to observe two very different approaches to cargo handling associated with intercontinental aircraft. The approach taken at Patriot Hills by both Polar Logistics and the Chilean Air Force was to avoid the use of any specialised cargo handling equipment - all items were either unloaded by hand onto small sleds or were rolled out the back of the Hercules aircraft. Where necessary, skidoos and a Snocat were used to tow the sleds to their camps (see Figure 21). In comparison with the Patriot Hills experience, the US and New Zealand approach to cargo handling at McMurdo is highly mechanised, with all cargo being palletised and moved by trucks and front-end loaders.



Figure 21: Snocat and sleds being used to unload commercial Hercules aircraft at Patriot Hills

The different approaches are probably largely due to the fact that McMurdo is a vastly bigger operation and handles both a much greater number of flights and a much larger volume of cargo. In addition to increasing the efficiency with which this cargo is unloaded in Antarctica, the use of mechanised cargo handling equipment at McMurdo also means that the size and weight of individual items can be, and is, much larger than items delivered to the Patriot Hills. This issue of likely cargo unit size will be a key factor in determining what type of cargo handling arrangements and equipment are most appropriate for an Australian air transport operation.

Unlike the US Antarctic Program which has the capacity with its ski-equipped Hercules to move relatively large items from McMurdo to more remote stations and field sites, an Australian air transport system would have to rely on smaller aircraft (such as the Twin Otter) to move most incoming personnel and their equipment between its intercontinental airfield and its other stations. As a result, the limiting factor for the size and weight of cargo carried on an Australian system is likely to be the capacity of its intracontinental aircraft rather than the capacity of its airfield cargo handling equipment. This suggests that cargo items carried by an Australian operation will need to be limited to those items that are capable of being loaded by hand or ramp into a Twin Otter. While this also suggests that no specialised mechanical cargo handling equipment would be needed at the intercontinental airfield, the availability of such equipment could increase the efficiency of some aspects of the operation. Discussions should be held with the selected aircraft operator when determining the most appropriate approach and any associated equipment requirements.

5.3.9 Medical

A number of medical issues relating to an air transport system were raised in the Scoping Study (Section 4.2.8.7). These issues will need to be discussed with any selected operator and taken into account in making decisions about the final design of any air transport system and its associated infrastructure requirements.

5.3.10 Fuel storage and handling

As suggested in the Scoping Study (Section 4.2.8.8), a risk assessment and cost-benefit analysis is needed of the various alternatives for storing and handling the large quantities of aviation fuel that would be required by an Australian Antarctic air transport system. Fuel movement and handling is a significant issue in relation to any airfield, but even more so for remote airfields (such as the Bunger Hills or, to a lesser extent, the blue-ice sites near Davis) that do not have easy vehicle access from a wharf or other depot where fuel can be delivered by ship.

While the operations this season confirmed the previous experience of Polar Logistics that it is feasible to move drummed fuel over considerable distances using ski-equipped aircraft, these operations also highlighted that the movement of a large quantity of fuel in this way would be labour-intensive, time-consuming and expensive. This experience reinforces the need for a thorough examination of all potential fuel storage and handling options, including options such as the use of different means of transport or types of container for moving fuel to remote airfields.

In the case of airfield sites that have easy vehicle access from the closest station, it is likely in the longer term that bulk storage tanks would be used. However, to maximise flexibility and minimise impacts during the initial trial stages, no decisions should be taken to construct such permanent facilities until the air system has been tested and proved to be successful.

5.3.11 Control and coordination

The Twin Otter operation this season highlighted the fact that a fixed-wing aircraft operation, with its ability to move people and equipment relatively quickly over a large area of Antarctica, presents both opportunities and challenges. Among other things, new procedures and systems for controlling and coordinating the use of the logistical opportunities are likely to be required.

For example, while it is appropriate that the helicopters based at an Antarctic station are generally tasked by the leader at that station, it would be unrealistic to expect any single station leader to coordinate and control the operations of the aircraft involved in an intracontinental air system. Given that these aircraft would be constantly moving between stations, remote field sites and the intercontinental airfield, it would probably be more appropriate for these operations to be coordinated by a dedicated air transport coordinator based at the intercontinental hub. Direct control of the aircraft could however be passed to station or field leaders when the aircraft were tasked to support activities originating from their locations.

Given the speed with which people can be moved by air, and the rapid changes that will inevitably occur to any plans that are made in advance, it is also likely that new procedures and mechanisms will be required to enable continuous tracking of the location of all aircraft and the names of the personnel travelling on these aircraft at any point in time.

5.4 POTENTIAL AIRCRAFT

5.4.1 Intercontinental aircraft

The investigations during 1999/2000 provided the opportunity to witness and experience the operation of civil and military versions of the Hercules aircraft. In addition to being impressed by the obvious professionalism of the civil and military crews, the experience also clearly demonstrated the ability of the Hercules aircraft to operate to unprepared blue-ice runway sites with minimal infrastructure.

Some questions do, however, remain over the ability of the Hercules aircraft (and the other likely contender for the intercontinental transport role - the Russian-built Ilyushin IL-76) to satisfy all of the current safety and regulatory requirements of Australia's Civil Aviation Safety Authority. While it is possible to make some limited observations, such as that the seating and emergency exit arrangements in the civil Hercules appear to be considerably superior to the military version for passenger use, detailed discussions will need to be held with CASA regarding the whole issue of applicable safety standards. These discussions should include matters such as CASA's requirements relating to emergency exits, supplemental oxygen, life rafts and immersion suits.

As recommended in the Scoping Study (Section 4.3.2), the final decision regarding the type of aircraft to be used should be made in the context of a competitive commercial tender process which specifies what services are required rather than exactly how they are to be provided. Potential operators need to be free to propose the use of any aircraft that they believe to be suitable - but with the significant condition that all proposed aircraft must be acceptable to CASA for the type of operations planned.

In accordance with Recommendation 4 of the Scoping Study, further discussions have been held with the US Government in an attempt to resolve issues relating to whether and under what terms its surplus ski-equipped Hercules aircraft would be available for use by the Australian Antarctic program. While the initial indications were positive, more recent advice from the US Government suggests that it may not now be possible for these aircraft to be released for use directly by commercial operators. Further discussions would be useful with the US Government to resolve this question and, if there is any chance that the aircraft could become available, to also clarify the age, model and current condition of these aircraft. For example, it would be useful to confirm informal advice received during talks at McMurdo that the surplus aircraft were originally LC130F models but over time have been virtually rebuilt to the newer, more efficient LC130R standard. Similarly, if any further consideration is given to use of these aircraft, the discussions with CASA would need to cover the requirements that would potentially apply to this type of aircraft.

5.4.2 Intracontinental aircraft

Use of a Twin Otter aircraft to support the investigations this season provided the opportunity to gain contemporary first-hand experience of the operation of a ski/wheel-equipped fixed-wing aircraft in support of Australia's Antarctic program. In addition to demonstrating the usefulness of this type of aircraft as a means of moving personnel between Australia's Antarctic stations and to directly support scientific projects at remote locations, this experience will be invaluable when planning the effective use of similar aircraft in the future. Some of the key lessons that have not already been mentioned in previous sections are set out in the following paragraphs.

5.4.2.1 *Runway requirements*

The basic runway requirements for the Twin Otter this season were:

- a strip 20 metres wide and up to 1000 metres long (although usually less than half this length was actually used);
- aligned into the prevailing wind - if more than 15 knots crosswind, an alternative runway orientation is required;
- surface must be as level and smooth as possible (any sastrugi should be less than 15cm high);
- no obstructions or sensitive environmental areas on approach or departure paths; and
- sea-ice must be at least one metre thick and cored regularly to check thickness and condition.

While the ski/wheel-equipped Twin Otter proved itself capable of operating to a range of unprepared snow and ice surfaces, the operations this season also indicated that the safety and the efficiency of the flights was enhanced by even limited preparation work. For example, the placement of black plastic garbage bags along the sides of an airstrip improved the safety of the operation not only by clearly marking an area that was known to be safe to land but also by providing a visual reference to the pilot when landing in conditions of poorer surface definition. Similarly, the removal of surface bumps and undulations to produce the smoothest possible surface increased the efficiency of the operation by enabling the aircraft to safely take off and land with a larger payload (e.g. the payload flown over a given distance varied by as much as 500kg depending on the surface condition of the airstrips used).

5.4.2.2 *Aircraft equipment requirements*

As well as demonstrating what the Twin Otter was capable of carrying (such as two fully assembled quads or at least six drums of fuel), the operations this season also confirmed the need for any intracontinental aircraft to carry some basic equipment and supplies. This equipment includes standard survival items such as tents, sleeping bags, sleeping mats and cooking equipment, plus at least two weeks food for all people on board. As suggested in Section 5.3.3, the aircraft also needs to carry a satellite telephone plus a separate HF radio, antenna and power supply for use when the aircraft is on the ground at remote locations.

Other items that would be usefully carried by any intracontinental aircraft include a lightweight sled for moving full fuel drums, equipment and baggage over snow and ice at remote locations; a couple of aluminium ramps for loading fuel drums, skidoos and quads into the aircraft; and a hand-auger plus extension to enable checking of sea-ice and lake-ice thickness at remote locations. On a related issue, it was also found that the process of loading the Twin Otter at remote sites was made easier if the equipment to be loaded was stacked no higher than a 200 litre drum so that the aircraft could taxi directly alongside it.

In addition to the items to be carried by the aircraft, the operations this season demonstrated that all personnel travelling on the aircraft need to be issued with boot chains or crampons to enable safe movement on blue-ice surfaces. Ear plugs and a personal pee bottle were also found to aid comfort on long flights.

5.4.2.3 *Delivery arrangements for intracontinental aircraft*

Lengthy and frustrating weather-related delays were experienced by the Twin Otter during its twelve-day delivery flight from the Patriot Hills to Davis. These delays were largely a result of the need to wait for slow-moving low pressure systems to clear ahead of the aircraft before it could continue its eastwards flight around the Antarctic coast. In comparison, the aircraft's seven-day return trip was considerably quicker due to the fact that, with the generous assistance of the US, French and Italian programs, it was able to use the inland route via Dome C, McMurdo and the South Pole, and thus avoid much of the poorer coastal weather.

As a result of the intercontinental distances involved, it is likely that any intracontinental aircraft to be used in the future will also have to travel to the AAT via South America and the Antarctic Peninsula. If this is the case, it would be desirable for these aircraft to be able to use the more efficient (inland) route as their standard delivery route between the Antarctic Peninsula and the AAT. For this to occur, appropriate arrangements will need to be made with the US, Italian and French Antarctic programs. These arrangements would need to cover issues such as the provision of fuel, communications and meteorological support for the transit flights, plus short-term accommodation for the aircrews.



Figure 22: Twin Otter and ski-equipped Hercules aircraft at Williams Field, McMurdo

Regardless of the route taken by the aircraft in getting from their home bases to the AAT, these aircraft are only of benefit to the Australian Antarctic program during the time that they are where we need them. To provide an strong incentive to aircraft operators to ensure their timely delivery, contracts for intracontinental aircraft should be negotiated such that charter payments are based on the number of days that the aircraft are actually available in the AAT to support Australian programs.

5.4.2.4 *Selection of future intracontinental aircraft*

It is important to note that, even though a Twin Otter was used to support the operations this season, no decision has yet been taken regarding the type of aircraft to be used in the future for the intracontinental component of any Australian Antarctic air transport system. As recommended in Section 4.3.3 of the Scoping Study, the final decision regarding the type of aircraft to be chartered will be made in the context of a competitive commercial tender process which specifies the services required rather than how they are to be provided. All proposed aircraft must however be acceptable to CASA for the type of operations planned.

A significant consideration is likely to be the ability of the intracontinental aircraft to safely carry useful payloads over the required distances. Given that fixed wing aircraft operations between Casey and Davis cannot rely on the use of Mirny as a refuelling location throughout the season (see Section 5.2.6.2), at least one component of an efficient intracontinental system will need to have the capacity to fly 540 nautical miles (the distance between Davis and the Bunger Hills) with a reasonable payload. This is consistent with many of the preferred air system options identified in the Scoping Study which, in addition to use of a Twin Otter-type aircraft, also included use of a larger aircraft with the payload-range performance of the ski/wheel-equipped Basler turbine DC3 (see Figure 23).



Figure 23: Basler turbine DC3 at Patriot Hills

5.4.3 Issues requiring resolution with CASA

In addition to questions relating to infrastructure requirements (see Section 5.3) and the potential acceptability of particular aircraft types, further discussions are required with CASA on a number of general operational issues (such as aircrew duty time limits, the types of cargo that can be carried with passengers and whether internal fuel tanks can be used). More importantly though, there are several broader regulatory issues that need to be resolved with CASA because they could have a significant impact on the feasibility of commercial fixed-wing aircraft operations within Australian Antarctic Territory (AAT).

Firstly, in recognition of the special conditions in Antarctica and the limited choice of aircraft that are suitable for use in those conditions, further discussions are needed with CASA with a view to including ‘air operations in support of national Antarctic programs’ as a special restricted category of operation. Secondly, given that no ski-equipped aircraft are on the Australian aircraft register, it is likely to be important that a workable solution is found to the current problems associated with foreign-registered aircraft being used on a regular basis within the AAT. The temporary exemptions granted to enable the investigations to proceed this season are clearly not an appropriate long-term solution.

6. IMPLICATIONS FOR AIR SYSTEM OPTIONS

6.1 INTRODUCTION

This chapter discusses the implications of the results set out in the previous chapter for the overall feasibility of the four preferred air system options identified in the 1999 Scoping Study report. Taking into account all of the results and issues raised, a possible approach to the establishment of a workable and efficient Australian Antarctic air transport system is also suggested.

6.2 ANALYSIS OF OPTIONS

6.2.1 Option 1: Ski-equipped Hercules aircraft flying to a skiway at Casey, with smaller ski/wheel-equipped aircraft providing the link from Casey to skiways and sea-ice runways at Davis and Mawson.

Between 1978 and 1981, ski-equipped US Hercules aircraft successfully operated from McMurdo to a skiway about 12 nautical miles from Casey. On the basis of this experience, there is little doubt that a suitable skiway for any future flights by these aircraft could again be relatively easily established near Casey.

Similarly, as a result of the Twin Otter's operations this summer, there is no doubt that suitable landing areas are available at Davis and Mawson for use by the smaller ski/wheel-equipped aircraft that would provide the necessary intracontinental links under this option. Specifically, the investigations confirmed that areas of sea-ice at Davis and Mawson would provide excellent and very convenient locations for early to mid-season flights to these stations, and that suitable blue-ice runway sites are also available near both stations for use when required (e.g. later in the summer when the sea-ice is no longer useable).

While the operations this season did highlight some problems with aircraft using Mirny as a refuelling location for the long intracontinental flights between Casey and Davis (see Section 5.2.6.2), they also demonstrated that the Bunger Hills would provide a dependable alternative refuelling location that could be used throughout the summer.

In summary, the investigations this season and previous experience have confirmed that it would be feasible to establish and operate all of the infrastructure and the intracontinental links required by this system. However, there are now major doubts that it will be possible to acquire the ski-equipped Hercules aircraft that are essential for providing the intercontinental link under this option (see Section 5.4.1).

While further discussions should be held with the US Government to finally resolve this question of availability, current indications strongly suggest that the required aircraft will not be released for use by the Australian Antarctic program. Significant questions also remain as to whether these aircraft would be able to meet CASA's requirements for civilian operations. Overall, therefore, it is very unlikely that this option will provide a workable Antarctic air transport system for Australia.

6.2.2 Option 2: Wheeled Hercules aircraft (or equivalent) flying to a blue-ice runway at the Bunger Hills, with smaller ski/wheel-equipped aircraft providing the link from Bunger Hills to skiways, sea-ice and blue-ice runways at Casey, Davis and Mawson.

As was the case with the previous option, the investigations this season confirmed that it is possible to establish suitable skiways and runways at Casey, Davis and Mawson for use by ski/wheel-equipped intracontinental aircraft. The Twin Otter's operations this season also confirmed that it is possible for ski/wheel-equipped aircraft to move personnel and equipment between the Bunger Hills and these stations.

Unlike the previous option, there is also little doubt that suitable aircraft would be available to operate the intercontinental component of this system. For example, commercial Hercules and Ilyushin IL-76 aircraft have already proven their capacity to undertake intercontinental flights to blue-ice runway sites in Antarctica, and are known to be available for similar operations in the future. While these and any other types of aircraft proposed by operators will need to be acceptable to CASA for the type of operations planned, it is not anticipated that CASA's requirements would rule out the use of all potential intercontinental aircraft.

Even though a need has been identified for ongoing monitoring of ice and weather conditions, and for on-site confirmation of conditions prior to each flight, the investigations undertaken during 1999/2000 did confirm that a suitable area of blue-ice is currently available in the Bunger Hills for use by intercontinental aircraft. Similarly, while a full environmental evaluation would be required before regular intercontinental flights were to occur to this site, initial indications are that it should be possible to conduct these operations in an environmentally acceptable manner provided that appropriate safeguards and practices are put in place. In summary, the investigations this season indicate that it would be feasible to establish and operate all of the basic components of this air system.

While this option would provide a means to trial the major components and benefits of an intercontinental air system, a number of factors suggest that, on its own, it would not provide the most desirable long-term Antarctic air transport system for Australia. These factors include: the difficulties associated with transport and storage of the large quantity of fuel that would be required in the Bunger Hills to support a full season of flights; the disadvantages associated with the intercontinental airfield being remote from the support infrastructure available at established stations; and the desirability of providing a suitable alternative landing area for use by intercontinental aircraft in emergencies. These factors are discussed further in the following paragraphs.

As noted in Section 5.2.1.1, the operations this season did confirm that it was possible to transport drummed fuel over considerable distances using ski-equipped aircraft but they also highlighted that the movement of large numbers of fuel drums in this way would be labour-intensive, time-consuming and expensive. While a thorough study should be made of all possible fuel transport and storage options, it appears likely that the need to move large quantities of fuel to the remote blue-ice runway at the Bunger Hills would remain a major drawback of this option. The most practical means of reducing the extent of this drawback is likely to be by designing an alternative air system that significantly reduces the quantity of fuel that needs to be delivered to the Bunger Hills.

The operations this season also highlighted that, in addition to greatly simplifying fuel delivery, there are other advantages in having easy vehicle access between an established station and a runway site. These advantages include access to sophisticated communications and meteorological facilities and to a wide-range of engineering, medical and other support facilities and personnel that are available at our stations. While the basic facilities required for normal operations could be provided as part of the infrastructure at a remote intercontinental airfield such as the Bunger Hills, it would not be practical or efficient to replicate everything that is already at our stations. There is no simple way of reducing the extent of this drawback, other than to use a site closer to an established station as the major intercontinental terminus.

The third factor - the availability of a suitable alternative landing area for intercontinental aircraft - applies equally to all air systems considered. Due to the long intercontinental distances involved, intercontinental aircraft would have to proceed several hours beyond their Point of No Return on flights from Australia to the Bunger Hills or to any other potential Antarctic airfields. As there is always a risk that conditions could dramatically worsen after the aircraft has committed to continuing its flight, the lack of a suitable alternative landing area is a significant drawback of this and similar options. This drawback can only be overcome by identifying and maintaining two separate landing areas for possible use by the intercontinental aircraft.

An alternative air system design that seeks to overcome the drawbacks of this option, while also taking advantage of its benefits, is suggested at Section 6.3.

6.2.3 Option 3: Wheeled Hercules aircraft (or equivalent) flying to a blue-ice runway at the Bunger Hills and then continuing to a Davis blue ice runway, with smaller ski/wheel-equipped aircraft providing the links from Bunger Hills to a skiway at Casey, and from Davis to sea-ice/blue-ice runways at Mawson.

Many of the observations regarding the previous system also apply equally to this option. In particular, investigations have confirmed that it is possible to establish the necessary intracontinental skiways and runways and also that suitable intracontinental aircraft are available. Similarly, there is little doubt that suitable aircraft would be available to operate the intercontinental component of this system.

The major difference compared to the previous option relates to the availability of the required intercontinental airfields. While the investigations this season did confirm that a suitable blue-ice runway site is available in the Bunger Hills, a comprehensive survey of possible blue-ice sites near Davis was forced to conclude that none of those sites were suitable at the time for heavy wheeled aircraft operations. Even though it is possible that suitable areas of blue-ice may be available near Davis for opportunistic use in more favourable seasons, it was concluded that these unidentified areas could not be relied upon at this time as a key component of an intercontinental air transport system.

To some extent it is unfortunate that a suitable area of blue-ice was not found at Davis because the combination of such a site and the blue-ice runway at Bunger Hills would have provided an air system option that successfully addressed the need for an alternative landing site for intercontinental flights. On the other hand, this option would not have eliminated the disadvantages associated with transporting large quantities of fuel to remote runway sites. While use of intercontinental airfields at both Davis and the Bunger Hills would have reduced the distance that some fuel needed to be moved, neither of these airfields are easily accessible by vehicle and the total amount of fuel required by such a system would actually be greater than for an intercontinental option based only on use of the Bunger Hills.

6.2.4 Option 4: Wheeled Hercules aircraft (or equivalent) flying to a blue-ice runway at Davis, with smaller ski/wheel-equipped aircraft providing the link from Davis to skiways, sea-ice and blue-ice runways at Casey and Mawson.

As with the previous option, it must be concluded at this time that this option does not provide the basis of a reliable Antarctic air transport system for Australia. While suitable areas of blue-ice may be available near Davis for opportunistic use by intercontinental aircraft in more favourable seasons, no such sites were identified by the survey conducted in 1999/2000.

Even if a suitable blue-ice runway site had been identified at Davis, its distance from Australia creates concerns about its use as the sole intercontinental terminus for operations. As discussed in Section 5.2.2.2, a blue-ice runway at Davis would be an extra 530 nautical miles and about two additional flying hours from Australia compared to a runway in the Bunger Hills. The difference in distance and times is even greater if compared to a potential runway at Casey. Given the lack of alternative airfields under this option, the resulting increase in the intercontinental aircraft's Point of No Return (PNR) would clearly not be desirable.

6.3 A SUGGESTED ALTERNATIVE AIR TRANSPORT SYSTEM

Taking into account all of the results of the 1999/2000 investigations and the other factors discussed in this chapter, it is suggested that none of the four investigated options would provide a completely desirable long-term Antarctic air transport solution for Australia. While Option 2 (based on an intercontinental blue-ice runway in the Bunger Hills) is feasible and would provide a useful interim means to trial many of the major components of a long-term system, several significant drawbacks have been identified with use of the Bunger Hills as the sole intercontinental terminus for a full-scale air system. The following paragraphs therefore suggest an alternative long-term solution that seeks to overcome the drawbacks of the Bunger Hills option while also taking advantage of its benefits.

As discussed in the previous sections, the only real means of addressing the desire for a suitable alternative landing area for intercontinental aircraft is to identify or establish two separate runway sites. Unfortunately, the investigations this season were unable to identify any areas of blue-ice near Davis or elsewhere that would provide a realistic alternative for an intercontinental runway in the Bunger Hills. Similarly, while the frozen surface of Beaver Lake may be suitable for landings by intercontinental aircraft, it is too distant from the Bunger Hills (750 nautical miles) and too remote from Australia's other stations to be useful as a standard alternative for intercontinental flights to the Bunger Hills.

Other potential options for establishing a second intercontinental landing site in the region include the proposed Russian compressed snow runway at the Larsemann Hills or a similar Australian runway at Casey. A major drawback with the Larsemann Hills option is that, due to its location, the Russians do not expect it to be available for operations during the 'warmest' six to eight weeks each summer. Given the delays that have already occurred with the construction of this proposed facility, it is also not clear when this runway will become operational.

Of all the available options, the construction of a compressed snow runway at Casey appears to offer the greatest long-term potential. Previous trials undertaken at Casey have been successful in proving the technical feasibility of constructing a suitable intercontinental compressed snow runway at that location. While the establishment of such a runway may require two year's effort, in combination with the Bunger Hills blue-ice runway it would guarantee the availability of a suitable primary and alternative landing site for intercontinental air operations from Australia.

In addition to solving the need for an alternative landing site, a combined system involving the establishment of a compressed snow runway at Casey would have the potential for phased introduction and would provide a solution to the problems associated with moving large quantities of fuel to the Bunger Hills blue-ice runway. Under this option, the Bunger Hills blue-ice runway would be used for a limited number of intercontinental trial flights to gain experience of these operations during the two seasons that the compressed snow runway was being constructed at Casey. Following its establishment, the Casey runway would then be used as the primary intercontinental airfield, with the Bunger Hills runway being operated as a secondary intercontinental runway and as the required transit and refuelling location for intracontinental flights to Davis and Mawson.

By refuelling the majority of intercontinental flights at Casey, this proposed system would dramatically reduce the quantity of fuel that would need to be transported to the Bunger Hills each season. Use of an intercontinental runway at Casey would also provide the additional benefits arising from easy vehicle access to the wide range of established support facilities at our stations, while significantly reducing the intercontinental flight times and distances from Hobart.

Taking all factors into account, the combined Casey-Bunger Hills system proposed above appears to provide the most desirable long-term Antarctic air transport solution for Australia. To maximise the efficiency and effectiveness of this system, its detailed design and implementation should reflect the range of other lessons learned during the course of the 1999/2000 investigations.

7. RECOMMENDATIONS

On the basis of the analysis and findings presented in this paper, this chapter sets out a number of recommendations relating to the design and implementation of a long-term Antarctic air transport system for Australia. Recommendations and a timetable for future action are also included.

7.1 THE RECOMMENDED SYSTEM

1. In accordance with the analysis presented in Chapter 6, implementation of a long-term Australian Antarctic air transport system should include the following core components:

- Construction and use of a compressed snow runway at Casey as the primary long-term destination for wheeled intercontinental aircraft flights from Hobart;
- Initial use of the blue-ice runway site at the Bunger Hills to gain experience of intercontinental flights from Australia;
- Following construction of the Casey runway, continued operation of the Bunger Hills blue-ice runway as a secondary intercontinental runway and as the required transit and refuelling location for intracontinental flights to Davis and Mawson;
- Use of ski/wheel-equipped aircraft to provide the intracontinental link from Casey via the Bunger Hills to Davis and Mawson; and
- Operation of sea-ice skiways/runways at Davis and Mawson for early to mid-season intracontinental flights, followed by use of local blue-ice runways when the sea-ice deteriorates later in the season.

2. An environmental impact evaluation should be undertaken in accordance with Australian and Antarctic Treaty requirements, and appropriate environmental safeguards and practices put in place, prior to any intercontinental air operations to the Bunger Hills or Casey.

3. As recommended in the 1999 Scoping Study, the final decision regarding the type of intercontinental and intracontinental aircraft to be used should be made in the context of a competitive tender process which specifies the services required rather than exactly how they are to be provided. A condition of this process should be that any aircraft offered must be acceptable to the Civil Aviation Safety Authority (CASA) for the type of operations planned.

4. Also as recommended in the Scoping Study, a number of detailed cost-benefit and risk assessments should be undertaken to determine the type of infrastructure that would be most appropriate for an Australian air transport system - these assessments should be undertaken in consultation with experienced operators and should take into account the various detailed observations included in this paper.

5. To maximise flexibility and minimise impacts, a guiding principle for the consideration of infrastructure options should be to avoid the creation of additional fixed infrastructure wherever practicable - in particular, no decisions should be taken to construct permanent aviation fuel storage facilities at any location until the air system has been tested and proved to be successful.

6. Implementation of the system should also take into account the range of detailed suggestions and observations in this paper regarding airfield and station-based support facilities and personnel, aircraft equipment requirements, and the planning and conduct of operations.

7.2 RECOMMENDED FUTURE ACTIONS

Implementation of the recommended system will require the following initial actions over the next year:

1. Prepare a detailed plan, budget and timetable for construction and testing of a compressed snow runway at Casey, taking into account all of the lessons learned from previous trials.
2. Conduct detailed cost-benefit and risk assessments to determine the type of supporting infrastructure that would be most appropriate for an Australian Antarctic air transport system. These assessments should cover the range of infrastructure requirements discussed in this paper and should take into account the experience of a range of established Antarctic operators, and the views and requirements of relevant authorities.
3. Undertake further consultations with the Civil Aviation Safety Authority to resolve a number of issues (such as the suitability of particular aircraft types, the certification of foreign-registered aircraft for use in Australian Antarctic Territory, and the granting of a special restricted category status to flights in support of Australia's Antarctic program).
4. Consult with the US Government to resolve the issue of potential availability of its surplus ski-equipped Hercules aircraft.
5. Call and short-list commercial expressions of interest for providing the flights and other services required under the recommended air system option.
6. Consult with other national programs regarding options for undertaking trial flights to the Bunger Hills.
7. Prepare an initial environmental impact evaluation in accordance with Australian legislation and Australia's Antarctic Treaty obligations prior to any trial flights to the Bunger Hills or snow compaction trials at Casey.
8. Plan the potential trial flights to the Bunger Hills - including arranging for inspection of the site by the short-listed operators.
9. Arrange delivery of equipment required for snow compaction trials at Casey.
10. Make appropriate arrangements with the Bureau of Meteorology to ensure ongoing monitoring and analysis of the data obtained from the automatic weather stations installed at blue-ice runway sites near the Bunger Hills, Davis and Mawson.
11. Arrange for regular monitoring of snow and ice conditions on the blue-ice areas near Davis to obtain a better understanding of the changes that occur at these sites, and to assess the potential for future opportunistic or regular use of these sites by intercontinental aircraft.

12. Develop formal arrangements with the US, French and Italian Antarctic programs to enable the delivery flights for the intracontinental aircraft involved in an Australian air transport system to occur via the South Pole, McMurdo and Dome C stations.

13. Subject to a favourable assessment of the results of the initial trial flights and other investigations, call and assess tenders for the longer-term delivery of all the services required under the recommended air system option.

14. Prepare a comprehensive environmental impact evaluation in accordance with Australian legislation and Australia's Antarctic Treaty obligations, prior to establishment or operation of a full-scale Antarctic air transport system.

7.3 TIMETABLE FOR FUTURE ACTIONS

The recommended timetable for undertaking the required future actions over the next year is as follows:

