DEVELOPMENT AND IMPLEMENTATION OF SURFACE TRAVERSE CAPABILITIES IN ANTARCTICA COMPREHENSIVE ENVIRONMENTAL EVALUATION

DRAFT (15 January 2004)
FINAL (30 August 2004)

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1.0 INTRODUCTION

1.1 Purpose

This Comprehensive Environmental Evaluation (CEE) has been prepared by the Director of the Office of Polar Programs (OPP) of the National Science Foundation (NSF) to enable a decision to develop and implement surface traverse capabilities in Antarctica (i.e., the proposed action). The NSF manages and funds United States activities in Antarctica, and is responsible for the U.S. Antarctic Research Program (USAP) as well as the operation of three active U.S. research stations, numerous outlying facilities, and related logistical systems in support of scientific research activities in Antarctica.

This CEE contains information to permit informed consideration of reasonably foreseeable potential environmental effects of the proposed action and possible alternatives. Because the scope of individual traverse activities that may be performed by the USAP as a result of the proposed action will be dependent on the specific needs of each mission and cannot be accurately predicted in this CEE, representative examples of a re-supply and a science traverse have been used to identify and evaluate potential environmental and operational impacts. In addition, the affected environment described in this CEE (i.e., Ross Ice Shelf, Transantarctic Mountains, Polar Plateau) includes areas in Antarctica where surface traverse activities have been conducted in the past and represents areas where traverses may be reasonably expected to be performed by the USAP in the future. Should surface traverses be conducted in environmental settings that are substantively different than those as described in this CEE or involve different potential environmental receptors, supplemental environmental reviews would be performed.

1.2 Comprehensive Environmental Evaluation (CEE) Process

Proposed USAP actions in Antarctica are subject to the environmental impact assessment requirements of Annex I, Article 3 of the Protocol on Environmental Protection to the Antarctic Treaty, Environmental Impact Assessment, and the implementing regulations in the United States, Environmental Assessment Procedures for National Science Foundation Actions in Antarctica (45 CFR §641) (Code of Federal Regulations). These requirements specify that, for actions expected to have a *more than minor or transitory impact* on the Antarctic environment, a Comprehensive Environmental Evaluation (CEE) will be prepared.

In making this determination, the NSF must consider whether and to what degree the proposed action:

- Has the potential to adversely affect the Antarctic environment;
- May adversely affect climate and weather patterns;
- May adversely affect air or water quality;
- May affect atmospheric, terrestrial (including aquatic), glacial or marine environments;
- May detrimentally affect the distribution, abundance or productivity of species, or populations of species of fauna and flora;
- May further jeopardize endangered or threatened species or populations of such species;
- May degrade, or pose substantial risk to, areas of biological, scientific, historic, aesthetic or wilderness significance;
- Has highly uncertain environmental effects, or involves unique or unknown environmental risks; or
- Together with other actions, the effects of any one of which is individually insignificant, may have at least minor or transitory cumulative environmental effects.

Based on the preliminary environmental review of the scope of activities that may be performed as a result of the proposed action, and using the representative traverse examples and the above criteria, NSF has determined that the development and implementation of surface traverse capabilities in Antarctica may have a more than minor or transitory impact on the Antarctic environment, and has prepared this CEE accordingly. This CEE is consistent with the Protocol and U.S. implementing regulations including 45 CFR §641.18(b) which states that a CEE shall be a concise and analytical document, prepared in accordance with the range of relevant issues identified in the scoping process. It shall contain sufficient information to permit informed consideration of the reasonably foreseeable potential environmental effects of a proposed action and possible alternatives to that proposed action. Such base-line information shall include the following:

(1) A description of the proposed action (preferred alternative) including its purpose, location, duration and intensity;
(2) A description of the initial environmental state with which predicted changes are to be compared, and a prediction of the future environmental state in the absence of the proposed action;
(3) A description of the methods and data used to forecast the potential impacts of the proposed action;
(4) An estimate of the nature, extent, duration and intensity of the likely direct potential impacts of the proposed action;
(5) A consideration of the potential indirect or second order impacts from the proposed action;
(6) A consideration of potential cumulative impacts of the proposed action (preferred alternative) in light of existing activities and other known planned actions and available information on those actions;
(7) A description of possible alternatives to the proposed action, including the alternative of not proceeding, and the potential consequences of those alternatives, in sufficient detail to allow a clear basis for choice among the alternatives and the proposed action;
(8) Identification of measures, including monitoring, that could be employed to minimize, mitigate or prevent potential impacts of the proposed action, detect unforeseen impacts, provide early warning of any adverse effects, and carry out prompt and effective response to accidents;
(9) Identification of unavoidable potential impacts of the proposed action;
(10) Consideration of the potential effects of the proposed action on the conduct of scientific research and on other existing uses and values;
(11) Identification of gaps in knowledge and uncertainties encountered in compiling the information required by this paragraph (b);
(12) A nontechnical summary of the information included in the CEE; and
(13) The name and address of the person and/or organization which prepared the CEE, and the address to which comments thereon should be directed.

Where possible, the procedures and evaluation criteria described in the Guidelines for Environmental Impact Assessment in Antarctica (1) were also used in the preparation of this CEE. In addition, this document has been prepared consistent with the policies of the National Environmental Policy Act (NEPA) described in 40 CFR §1500-1508 and with National Science Foundation’s implementing regulations for NEPA contained in 45 CFR §640. Applicability to NEPA is further defined by 45 CFR §641.14(e), which states that a CEE shall serve as an Environmental Impact Statement for purposes of Executive Order 12114, Environmental Effects Abroad of Major Federal Actions (44 FR 1957) (Federal Register).

1.3 Document Organization

Chapter 2 of this Comprehensive Environmental Evaluation provides the background information of surface traverses that have been conducted throughout the Antarctic continent. Chapter 3 provides a summary of the proposed action and possible alternatives. Chapter 4 describes the purpose and need of the proposed action and provides a description of typical traverse activities that may be performed including a discussion of the nature and intensity of the activities associated with re-supply and scientific traverses. Chapter 5 describes the affected environment (i.e., initial environmental state). Chapter 6 provides a detailed description of potential environmental impacts caused by the proposed action and addresses the following:

- A description of the methods and data used to forecast the potential impacts of the proposed action (45 CFR §641.18(b)(3))
- Consideration of the potential effects of the proposed action on the conduct of scientific research and on other existing uses and values (45 CFR §641.18(b)(10))
- Consideration of the potential indirect or second order impacts from the proposed action (45 CFR §641.18(b)(5))
- Consideration of potential cumulative impacts of the proposed action in light of existing activities and other known planned actions and available information on those actions (45 CFR §641.18(b)(6))
- Identification of unavoidable potential impacts of the proposed action (45 CFR §641.18(b)(9))

Chapter 7 identifies mitigating measures, including monitoring, that could be employed to “minimize, mitigate, or prevent potential impacts of the proposed action, detect unforeseen impacts, provide early warning of any adverse effects, and carry out prompt and effective response to accidents”. Chapter 8 identifies gaps in knowledge and uncertainties encountered in compiling the information presented in the CEE.

Chapter 9 summarizes the conclusions derived in this Comprehensive Environmental Evaluation of the development and implementation of surface traverse capabilities. Chapter 10 contains a nontechnical summary of the information included in this CEE and provides the name and address of the person and/or organization which prepared the CEE and who will address comments. Chapter 11 provides references to information and other documents used to prepare the CEE, and Chapter 12 includes appendices containing data that were used in the development of this CEE.

2.0 BACKGROUND OF SURFACE TRAVERSES IN ANTARCTICA

2.1 Introduction

The use of surface traverses is a major component in the history of Antarctic exploration for re-supply and science-related purposes. It continues to be a valuable tool to support research and various facilities on the continent.

Numerous traverses have been performed in Antarctica dating back to the earliest part of the 20th century, including the explorations performed by Robert Scott, Douglas Mawson, and Wilhelm Filchner. As technology progressed, mechanized transport was utilized and aircraft support resources were used to supplement and partially replace traverse activities. In recent years, numerous improvements in vehicle technologies, including features specifically designed or adaptable for polar conditions, have become available allowing surface transport to be a safe and reliable mode of travel.

2.2 Re-supply Traverses

Surface traverses were used extensively in the 1957-1958 International Geophysical Year (IGY) to establish and re-supply numerous Antarctic stations and large field camps. The surface traverses were often used to transport fuel, food, building materials and other supplies from coastal areas to remote facilities in the interior of the continent.

Table 2-1 identifies the characteristics of surface traverses that have been performed by seven nations for logistical support purposes for which documentation is available. Several of these nations routinely conduct traverses to re-supply facilities that operate on a long-term basis. For example, since the 1950s the Russians have routinely conducted 1,429 km traverses from Mirny Station to re-supply Vostok on the Polar Plateau. Re-supply traverses are also performed each year by South Africa to support station Vesleskarvet (i.e., SANAE IV) (see Figure 2-1) and by France and Italy to support the activities at the jointly-operated Antarctic station at Dome C (Concordia) (see Figure 2-2).

Table 2-1. Summary of Re-supply Traverses in Antarctica

Locations	Country	Region	Description
Casey - AWS	Australia	Wilkes Land	In April 2002, Caterpillar D7G, D6, and D5 tractors were used to install automatic weather stations at various locations in East Antarctica over a 600 km roundtrip
Moore Pyramid, Farely Massif, Mount Cresswell	Australia	Mac Robertson Land	During the 1970s a series of traverses, supplemented with fixed wing aircraft and helicopters, established field bases in the Prince Charles Mountains to support remote field programs in the region.
Mount King	Australia	Enderby Land	Similar to the program in the Prince Charles Mountains, traverse resources were used to establish a base to support nearby field operations.
Wilkes- Vostok	Australia	Wilkes Land	A 3,000 km roundtrip traverse from Wilkes to the abandoned Vostok station and return, using two Caterpillar D4 tractors, was performed in 1962.
Mawson – Prince Charles Mountains	Australia and Germany	Mac Robertson Land	In support of the Prince Charles Mountains Expedition of Germany-Australia (PCMEGA), a traverse over an established route was performed during 2002 with the specific purposes of placing a fuel depot at LGB6, located 250 km from Mawson. The traverse comprised three tractors towing two support modules and three sledges containing over 300 drums of fuel.

Table 2-1. Summary of Re-supply Traverses in Antarctica

Locations	Country	Region	Description
			The traverse was staffed by 6-8 people and took six weeks to complete.
Mawson – Mount Cresswell	Australia and Germany	Mac Robertson Land	A second PCMEGA traverse was conducted during the 2002-03 austral summer and comprised a 1,000 km roundtrip conducted to deliver 90,000 liters of fuel to the base at Mount Cresswell. A crew of five personnel operated three Caterpillar D7s and one Haaglund towing two support modules and six cargo sledges. The last 200 km of this traverse were over an uncharted route.
Cape Prudhomme - Dome C (Concordia)	France and Italy	Polar Plateau	Traverses have been conducted to Dome C over a period of eight years. Up to seven Caterpillar Challengers, two each Kassbohrer PB330, and one Kassbohrer PB270 and up to seven associated sleds and trailers per tractor were used to support construction of the new Concordia station from Dumont d'Urville station located 1,100 km away, and continue to be used to re-supply the facility. Up to three traverses per year have been conducted, with up to 120 tonnes of cargo transported in each traverse while consuming approximately 80,000 liters of fuel. Each roundtrip takes approximately 25 days.
Neumayer - EPICA	Germany	Queen Maud Land	Up to eight Kassbohrer Pisten Bully tractors towing living containers and sledges were used to transport 325 tonnes of supplies for drilling activities at field camp and remote field locations. Since 2000, up to two traverses per season have been conducted.
Suyowa - Dome Fuji	Japan	Queen Maud Land	In conjunction with International Trans Antarctic Science Expedition (ITASE) activities in 1997, a re-supply traverse was conducted to Dome Fuji Station, covering a distance of 1,000 km.
Mirny-Vostok	Russia	Wilkes Land	Two inland bases were established using traverse resources in 1957 and 1958; the Vostok station near the Geomagnetic Pole and the other, the former Sovietskaya station, at the Pole of Inaccessibility. Regular re-supply of Vostok Station has been performed using tracked vehicles.
EBase/SANAE III - SANAE IV	South Africa	Queen Maud Land	The Vesleskarvet (i.e., SANAE IV) base was constructed from 1993 to 1998 using Caterpillar Challengers and Caterpillar D6 tractors to transport 800 tonnes of construction materials 160 km from EBase (i.e., SANAE III). Up to five tractors are used to conduct one or two annual re-supply traverses per season. Refueling of traverse equipment is supported by a field cache consisting of a 3,000-liter fuel tank.
Little America – Byrd	United States	Marie Byrd Land	Caterpillar D8 tractors were used to transport supplies to Byrd Station from the former coastal station at Little America during the 1957-1958 austral summer.

Figure 2-1. Re-supply Traverse for SANAE IV

Source: South African National Antarctic Expedition (http://www.geocities.com/sanaeiv/index.html)

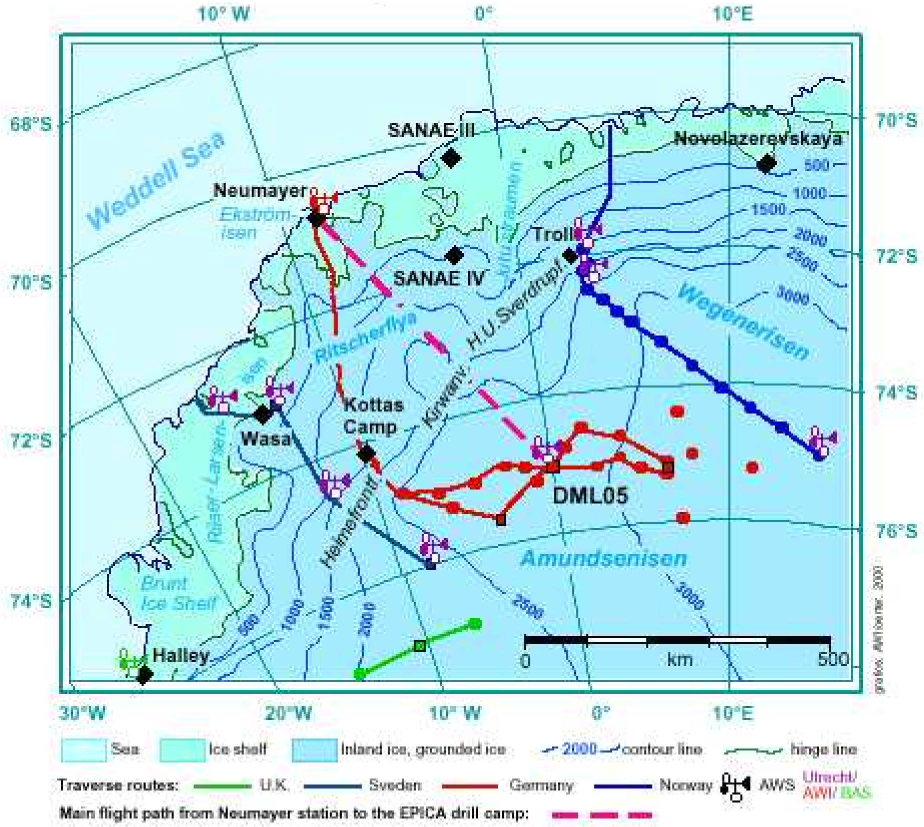
Figure 2-2. Re-supply Traverse for Concordia Station

Source: Antarctic Sun

Traverses have been used by the Australian National Antarctic Research Expeditions (ANARE) since Australia set up its first Antarctic station at Mawson in 1954, although most of the earlier traverses were comprised of dog sledges and were supported by airlift. In 1962, ANARE conducted a 3,000 km roundtrip traverse between the former U.S. Wilkes Station in Vincennes Bay (near modern-day Casey Station) and Vostok Station. This was the earliest traverse to demonstrate the potential of mechanized transport for remote, long-range, field travel. During the 1970s, ANARE established field bases in the Prince Charles Mountains and Enderby Land using a series of traverses supplemented with support by fixed wing aircraft and helicopters. More recently, ANARE conducted a traverse from Casey Station to establish various field research locations in East Antarctica and completed a 1,000 km roundtrip traverse in conjunction with Germany from Mawson Station to the Prince Charles Mountains to deliver fuel as part of the Prince Charles Mountains Expedition of Germany – Australia (PCMEGA).

Surface traverse resources were recently used to support a multinational research effort in Dronning Maud Land known as the European Project for Ice Coring in Antarctica (EPICA). The project included a series of traverses to transport bulk materials from coastal facilities (e.g., Neumayer Station) along shelf and inland ice sheets to the drilling sites (Figure 2-3).

Figure 2-3. Re-supply Traverse Routes for EPICA

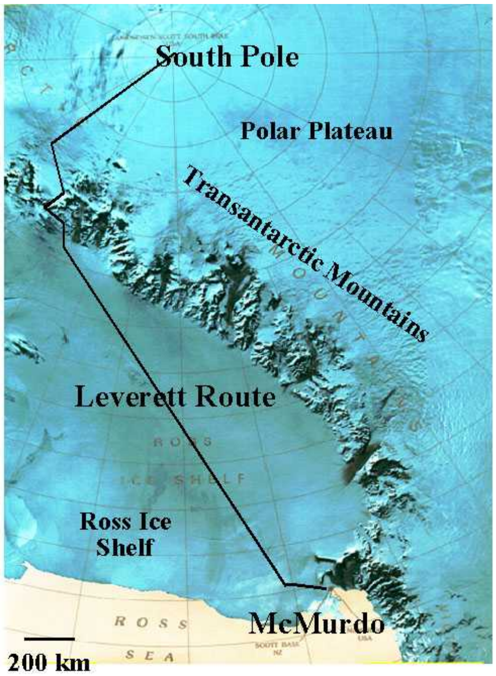


Source: Comprehensive Environmental Impact Evaluation for Recovering a Deep Ice Core in Dronning Maud Land, Antarctica (reference 18)

The United States used traverses during the 1950s through the 1970s for scientific and exploratory research applications but did not develop the resources for major re-supply missions. In recent years, the USAP has used small-scale surface traverses to transport supplies to various outlying facilities near McMurdo Station including the Pegasus Runway (25 km), the Black Island Telecommunications facility (35 km), and the Marble Point Refueling Facility (100 km). The USAP conducts these smaller traverses using existing heavy equipment and sleds and trailers.

While the USAP does not have the resources to perform more complex or longer distance re-supply traverses, a feasibility and engineering study is underway to evaluate a surface route and equipment requirements to transport cargo from McMurdo Station to the Amundsen-Scott Station at the South Pole (Appendix A). A potential traverse route crossing the Ross Ice Shelf and ascending Transantarctic Mountains at the Leverett Glacier to the Polar Plateau (Figure 2-4) is currently being evaluated by the USAP as a “proof of concept” demonstration. This effort is expected to take place over the next several austral summer seasons. Based on experience gained from the proof of concept study and from previous traverses conducted in Antarctica, the USAP intends to develop a more robust traverse capability to supplement current airlift resources and thus enhance research opportunities in Antarctica.

Figure 2-4. Proof of Concept Traverse Route from McMurdo Station to the South Pole



2.3 Scientific Traverses and Surface-Based Surveys

Traditionally, most surface traverses conducted in Antarctica have been specifically designed for science-related and data collection purposes. Over 90 years ago, the earliest surface traverses focused on exploration and mapping goals and were performed by expeditions from Britain, Norway, Germany, and Australia. At that time, the traverses were comprised of dog-sleds and human-drawn sledges. The first use of a flagged route over snow-covered terrain is believed to have occurred in 1912 by Douglas Mawson leading the Australasian Antarctic Expedition during the survey and mapping of George V Land.

The first documented use of mechanized equipment such as tractors for a science-related surface traverse was performed by Richard Byrd during the 1933-1934 austral summer. The traverse involved ground-based geology, meteorology, biology, and atmospheric studies throughout Marie Byrd Land. Because of the emergence of aircraft to support Antarctic exploration and the occurrence of World War II, few science-related traverses were performed during the 1930s and 1940s. One series of science-related traverses which was performed between 1935 and 1937 included the British Graham Land Expedition that involved aerial and sledge surveys on the Antarctic Peninsula.

Major science-related traverse and surface-based survey activities began in earnest during the 1950s. Between February 1950 and January 1952, a Swedish-British-Norwegian scientific expedition based at the temporary Maudheim Station conducted surface-based glaciological and geological surveys in the interior of Queen Maud Land. The International Geophysical Year (IGY) from 1 July 1957 to 31 December 1958 was a great cooperative endeavor by the world's scientists to improve their understanding of the earth and its environment. Much of the field activity during the IGY took place in Antarctica, where 12 nations established some 60 research stations. A notable investigation involved the British Commonwealth Trans-Antarctic Expedition, a joint British-New Zealand project, led by Sir Vivian Fuchs and Sir Edmund Hillary. This investigation was designed to complete an entire cross-section of the continent and collect seismic and magnetic data. In late 1957, two teams began at different ends of the continent (Weddell Sea, Ross Sea), met at the South Pole, and then returned to Scott Base on Ross Island.

During the IGY, the United States established six research stations: Little America, Hallett, South Pole, Byrd, Wilkes (on the coast of Wilkes Land, East Antarctica) and Ellsworth (on the Filchner Ice Shelf). Naval Air Facility, McMurdo Sound (now McMurdo Station), was set up as a logistics base that was used to re-supply the South Pole. The United States contributed to the IGY by making several long scientific traverses to collect data for research in glaciology, seismology, gravimetry, and meteorology.

Table 2-2 identifies science-related surface traverses and ground-based surveys that have been performed between 1950 and 1999 by 10 countries, including the United States. Several of these traverses were multi-year efforts between several locations, circular routes, or spurs from a central location. At least six of these expeditions utilized the South Pole as an endpoint. One of the most extensive science-related traverses was conducted by the Australians in the Lambert Glacier Basin traveling over 4,500 km.

A recent and extensive series of science-related traverses was conducted throughout East and West Antarctica between 1999 and 2003 for the International Trans Antarctic Scientific Expedition (ITASE). The ITASE traverses were designed to build upon the existing coverage of glaciological traverses conducted since the 1950's and were conducted jointly by 14 different nations (Figure 2-5).

Although the United States conducted various surface traverses during the 1950s and 1960s (Table 2-2), the USAP has conducted few science-related traverses since this period. There were many reasons for the shift from the traverse mode of operation, the most significant being the availability of ski-equipped airlift resources to support field camps in remote areas. However, the USAP’s participation in the recent ITASE traverse activities has reaffirmed the value of surface-based scientific research supported by mobile facilities.

Table 2-2. Summary of Scientific Traverses and Surface-based Surveys in Antarctica

Mission ID	Region	Description	Data Type	Country
TRAVERSES				
RIS-5760	Ross Ice Shelf	US seismic reflection shooting over the Ross Ice Shelf between October 1957 and March 1960. Three traverses undertaken by United States parties including the Ross Ice Shelf traverse Oct 1957 - April 1958, Victoria Land traverse Oct 1958 - Jan 1959, Discovery Deep traverse Feb and March 1960.	Seismic reflection & gravity	US
LAMBERT-8995	Lambert Glacier basin	ANARE Lambert Glacier Basin traverse 1989/90 to 1994/95. Study of the mass budget and dynamics of the interior basin. Traverses were conducted from Davis to Mawson, around the top of Lambert Glacier Basin, and back to Davis. The 1994/95 traverse completed a 4,500 km journey.	Ground-based RES	AU
WESTANT-5759	Marie Byrd Land and the Ellsworth Mountains	US seismic reflection shooting, Marie Byrd Land, Ellsworth Land and the Horlick Mountains at 30 nautical mile (55.5 km) intervals, during three traverses in West Antarctica between January 1957 and January 1959.	Seismic reflection & gravity	US
MARIEBYRD-5960	Marie Byrd Land	US northwest Marie Byrd Land traverse 1959-60, ice thickness from combined gravity and seismic observations.	Seismic reflection & gravity	US
MCMPOLE-6061	Victoria Land, Plateau, South Pole	US seismic soundings carried out in a traverse from McMurdo Station to the South Pole in 1960-61.	Seismic reflection & gravity	US
SPQMLT-6468	Queen Maud Land	US seismic, gravimetric and electromagnetic observations in three reconnaissance traverses from South Pole to Queen Maud Land (1964/65, 1965/66, 1967/68).	Seismic reflection & gravity	US
VLT1-5859	Victoria Land	US seismic observations, Victoria Land traverse No. 1, made on oversnow traverse from the head of the Skelton Glacier to 132E.	Seismic reflection	US
VLT2-5960	Victoria Land	US seismic observations, Victoria Land traverse No. 2, made on oversnow traverse in the Victoria Land plateau.	Seismic reflection	US
PENINSULA-6162	Ellsworth Land, Antarctic Peninsula	US seismic and gravity measurements obtained during the Antarctic Peninsula oversnow traverse of 1961-62.	Seismic reflection & gravity	US
JARE-6971	West Enderby Land	JARE 10-11 oversnow traverse in the Mizuho Plateau-West Enderby Land, 1969-71. Observations of ice thickness obtained using a radio echo sounder. Additional measurements obtained from seismic soundings and gravimetric methods. Includes seven routes A,B,C,S,W,X,Y.	Ground-based RES	JP
JARE-8283	Queen Maud Land	JARE 23 oversnow traverse in East Queen Maud Land along line of Shirase Glacier, Yamamoto Mountains, 1982-83. Observations of ice thickness obtained using a radio echo sounder. Includes routes IM, YM,SS,SY,H,Z	Ground-based RES	JP
JARE-8384	Queen Maud Land	JARE 24 oversnow traverse in East Queen Maud Land extending work or East Queen Maud Land Glaciological project, 1983-84. Includes route KR.	Ground-based RES	JP
JARE-8586	Queen Maud Land	JARE 26 oversnow traverse in East Queen Maud Land toward the inland plateau and Sor Rondane Mountains, 1985-86. Includes routes ID, DF.	Ground-based RES	JP
JARE-8687	Queen Maud Land	JARE 27 oversnow traverse in East Queen Maud Land extending work or East Queen Maud Land Glaciological project, 1986-87. Includes routes SZ,NY,YG6,RY,L.	Ground-based RES	JP
RONNE-9495	Ronne Ice Shelf	BAS 2300 km traverse across part of the Ronne Ice Shelf during the 1994-95 season. Seismic reflection stations at 15 km intervals.	Seismic reflection	UK

Table 2-2. Summary of Scientific Traverses and Surface-based Surveys in Antarctica

Mission ID	Region	Description	Data Type	Country
TAE-5758	Upper Plateau - West Antarctica, South Pole, Victoria Land	Seismic reflection survey conducted by Commonwealth Trans-Antarctic Expedition, 1955-58. Surface traverse from Shackleton Base on the Filchner Ice Shelf through the South Pole and on to Scott Base.	Seismic reflection	UK
GEORGEVI-8485	George VI Ice Shelf, Antarctic Peninsula	Seismic measurements across George VI Ice Shelf supplemented by ground base RES measurements, 1984/85. Traverses were run perpendicular to the regional geology. 101 seismic stations and 210 RES measurements.	Seismic reflection & RES	UK
ANARE-5759	Kemp Land	ANARE seismic and gravity survey during the period of the IGY (1957-59) inland of Mawson Station, Kemp Land. Ice thickness measurements made on two regional traverses.	Seismic reflection & gravity	AU
BELGE-5960	Dronning Maud Land	1959-60 Belgian Antarctic Expedition seismic traverse in Dronning Maud Land from the King Baudouin base to the Sor Rondane Mountains.	Seismic reflection	BE
SOUTHPOLE-6263	South Pole traverse	Seismic investigations on a US oversnow traverse between South Pole and the Horlick Mountains during the 1962-63 season.	Seismic reflection	UK
BELGEDUTCH-6566	Sor Rondane Mountains, Dronning Maud Land	Oversnow gravity traverses carried out in the major glaciers draining the Sor Rondane Mountains in 1966 by the Belgian-Dutch expedition. 17 traverses carried including 138 measurements of ice thickness.	Gravimetric measurements	BE
SAE-5859	Inland Plateau - East Antarctica	Soviet Antarctic Expedition (SAE3) seismic survey along a traverse from Mirny to the Pole of Relative Inaccessibility and between Komsomolskaya and Vostok (1958-59). 27 seismic shots made. Traverse distance 2300 km.	Seismic reflection	RU
SAE-5960	Inland Plateau - East Antarctica	Soviet Antarctic Expedition (SAE4) seismic survey along a traverse from Komsomolskaya to Vostok and on to the South Pole (1959-60). 12 seismic shots made. Traverse distance 1832 km.	Seismic reflection	RU
SAE-6364	Inland Plateau - East Antarctica	Soviet Antarctic Expedition (SAE9) seismic survey along a traverse from Vostok to the Pole of Relative Inaccessibility and on to Molodezhnaya (1963-64). 21 seismic shots made. Traverse distance 3323 km.	Seismic reflection	RU
SAE-5658	Queen Mary Land	Soviet Antarctic Expedition (SAE1 & 2) seismic survey along a traverse from Mirny to Pionerskaya (1956-58).	Seismic reflection	RU
SAE-6061	Queen Mary Land, Wilhelm II Land.	Soviet Antarctic Expedition (SAE5) seismic survey along a traverse from a point approximately 100 km north of Pionerskaya south-west for 500 km then south-east to Komsomolskaya (1960-61).	Seismic reflection	RU
MIRNYDOMEC-7886	Wilkes Land	ANARE ground based RES survey in Wilkes Land, 1978-86. Traverse from Mirny to Pionerskaya to Dome C.	Seismic reflection & gravity	AU
NBS-5152	Queen Maud Land	Seismic shooting in Queen Maud Land by Norwegian-British-Swedish Antarctic Expedition, 1951-52. Oversnow traverse inland from Maudheim station.	Seismic reflection	UK
JARE-9294	Dronning Maud Land	JARE 33 (1992-94) oversnow traverse between Mizuho Station and Dome F, Dronning Maud Land.	Ground-based RES	JP
JARE-9597	Queen Maud Land	JARE 37 oversnow traverse in Dome F region. 150 km long traverse from the Dome to the south, and 130 km long traverse from the Dome region to east.	Ground-based RES	JP
SIPLE-97	Siple Coast, Marie Byrd Land	USAP 60 km oversnow traverse at the head of Ice Stream C. Ice thicknesses determined by reflection seismic shooting and the surface elevation by GPS.	Seismic reflection	US

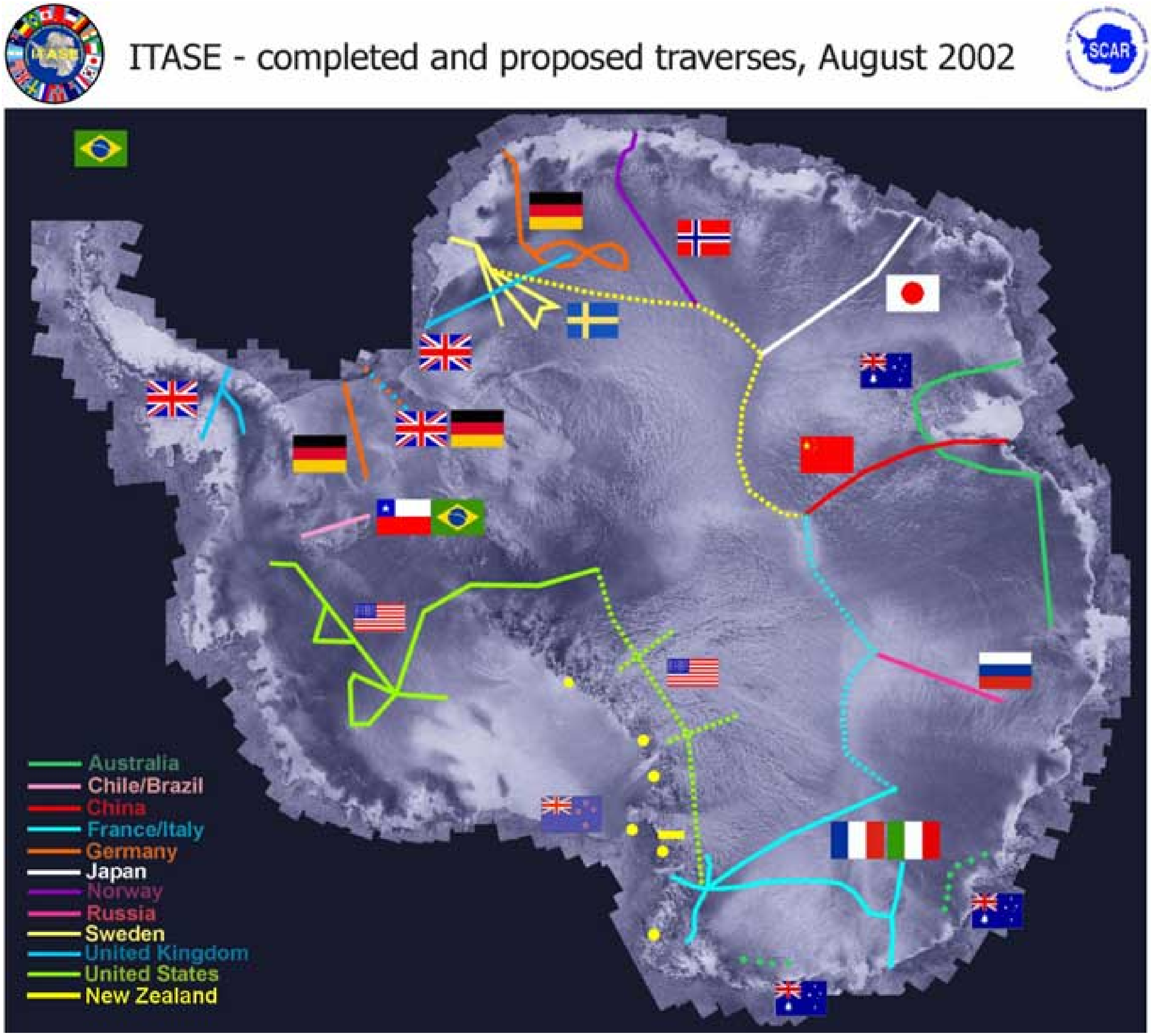
Table 2-2. Summary of Scientific Traverses and Surface-based Surveys in Antarctica

Mission ID	Region	Description	Data Type	Country
LARSEN-90	Larsen Ice Shelf, Antarctic Peninsula	BAS seismic traverse on the Larsen Ice Shelf in the 1990/91 season. Profile length 21.6 km, surface of ice shelf at 34 m above mean sea level.	Seismic reflection	UK
PATRIOT-9798	Patriot Hills, Ellsworth Land	Chilean oversnow RES traverse in the Patriot Hills area conducted under a Chilean Antarctic Institute (INACH) sponsored program. The logistic support was provided by the Chilean Air Force. The data were collected by a radio echo sounding profiling system mounted on sledges and pulled by snowmobiles.	Ground-based RES	CL
ARGEN-8891	Larsen Ice Shelf	Instituto Antartico Argentino (IAA) glaciological and geophysical traverse carried out in two seasons between 1988 and 1991covering about 80 km between Gray Nunatak and Jason Peninsula. nine seismic shots and three RES stations	Seismic reflection & RES	AR
SIPLEDOME-9596	Siple Dome, Siple Coast	US oversnow RES traverse across Siple Dome collected in the 1996/97 season. Sixteen-hundred and ten xy points corresponding to the location of radar waveforms points were derived by interpolation at intervals of ~ 100m from a set of 69 static GPS surveys of markers located along the traverse route.	Ground-based RES	US
	Wilkes Land	The geophysical traverse extended from the Taylor Dome drill site in the Transantarctic Mountains to the center of the Wilkes subglacial basin.	Seismic reflection	US/NZ
	Enderby Land	Japanese Antarctic Research Expedition (JARE) 12 and 13 1972-1973	Glaciology	JP
	Enderby Land	Japanese Antarctic Research Expedition (JARE) 15	Glaciology	JP
	Enderby Land, Queen Maud Land	Syowa-South Pole Traverse 1968-69	Glaciology	JP
	Dronning Maud Land	Norwegian Traverse of 1996-97. EPICA pre-site survey	Glaciology	NW
	Marie Byrd Land	Byrd Station to South Pole Traverse 1960-61	Glaciology	US
LAND BASED SURVEYS				
RUTFORD-8586	Ellsworth Land & Ronne Filchner Ice Shelf	BAS ground based RES of Rutford Ice Stream, 1985/86 season	Ground-based RES	UK
FILCHNER-5758	Filchner Ice Shelf	US seismic soundings carried out in the Filchner Ice Shelf area during 1957-58 (IGY).	Seismic reflection	US
AMERY-6871	Amery Ice Shelf	ANARE Amery Ice Shelf Expedition 1968 and 1970/71. Includes 22 individual traverses.	Ground-based RES	AU
WILKES-7886	Wilkes Land	ANARE ground based RES survey east inland of Casey Station with data at two km spacing.	Ground-based RES	AU
ELLSBYRD-5859	Ellsworth Land	US seismic soundings carried between Ellsworth and Byrd Stations during 1958-59.	Seismic reflection	US
130WEST-5859	Marie Byrd Land	US seismic soundings carried out along meridian 130W in 1958-59	Seismic reflection	US
88WEST-5960	Ellsworth Land	US seismic soundings carried out along meridian 88W in 1959-60.	Seismic reflection	US
RIGGS-7378-1	Ross Ice Shelf	US Ross Ice Shelf Geophysical and Glaciological Survey using seismic and radio wave velocities to determine ice thickness in 1974-1978.	Seismic reflection	US
WALGREEN-6061	Walgreen Coast, Marie Byrd Land	US seismic reflection shooting along the Walgreen coast, Marie Byrd Land in 1960-61.	Seismic reflection	US
ELLSWORTH-6061	Ellsworth Land	US seismic and gravity observations in the Ellsworth Highlands in 1960-61	Seismic reflection & gravity	US
ROOSEVELT-6263	Roosevelt Island, Ross Ice Shelf	US seismic measurements obtained on Roosevelt Island 1962-63	Seismic reflection	US
SAE-7584	Coats Land, Ronne-	Soviet Antarctic Expedition (SAE21-29) seismic reflection surveys carried out in Coats Land	Seismic reflection	RU

Table 2-2. Summary of Scientific Traverses and Surface-based Surveys in Antarctica

Mission ID	Region	Description	Data Type	Country
	Filchner Ice Shelf	and the Ronne-Filchner Ice Shelf between 1974/75 and 1983/84, total area surveyed 583,000 km.		
WISCONSIN-6364	Whitmore Mountains, Marie Byrd Land	US oversnow seismic survey north of Horlick Mountains in Whitmore Mountains in 1963/64.	Seismic reflection	US
BELGE-6768	Jutulstraumen, Western Dronning Maud Land	Gravity survey across the 50 km wide Jutultraumen Ice Stream by the 1967-68 Belgian Antarctic Expedition.	Gravimetric measurements	BE
PENSACOLA-6566	Pensacola Mountains	USGS seismic reflection survey in the Pensacola Mountains during the 1965-66 season.	Seismic reflection	US
SORROND-8692	Sor Rondane Mountains, Dronning Maud Land	Glacier valley cross-section profiles in the central Sor Rondane Mountains gathered by gravimeter and radio-echo sounding measurements during the Japanese Antarctic Research Expeditions JARE-28 and JARE-32.	Ground-based RES & gravimetric	UK
RUTFORD-9193	Rutford Ice Stream, Ellsworth Land	BAS seismic surveys on the Rutford Ice Stream during the 1991-92 and 1992-93 seasons. Surveys were concentrated above the grounding line using three different seismic sources depending on time and resources.	Seismic reflection	UK
DOMEC-9293B	Dome C, Wilkes Land	Italian Antarctic Program (PNRA) ground based RES survey at Dome C, Wilkes Land. Twenty one profiles were carried out from a snocat (rover) in a 50 km x 50 km square grid (line spacing 10 km).	Ground-based RES	IT
WILKES-6163	Wilkes Land	ANARE seismic reflections obtained on route from Wilkes Station to Vostok in 1961/62 and 1962/63 seasons. Data restricted to stations within 300 miles of the coast.	Seismic reflection	AU
ROOSEVELT-9697	Roosevelt Island, Ross Ice Shelf	US ground based radar echo sounding survey on Roosevelt Island undertaken by the Geophysics Dept. University of Washington in the 1996/97 season. Included eight profiles.	Ground-based RES	US
RONNE-8284	Ronne Ice Shelf	BAS geophysical expedition across the Ronne ice Shelf in the 1982/83 and 1983/84 seasons. Three hundred and eighty-four seismic and RES measurements of ice thickness made over 3500 km of ice shelf.	Seismic reflection & RES	UK
ELLSW-PEN-8587	Ellsworth Land & James Ross Island	BAS geophysical expedition in Ellsworth Land and James Ross Island in the 1985/86 and 1986/87 seasons. One hundred and eighty-five seismic and RES measurements of ice thickness made.	Seismic reflection & RES	UK
BERKNER-9899	Ronne Ice Shelf	BAS seismic surveying around the south-west tip of Berkner Island, Ronne Ice Shelf made during the 1998-99 season.	Seismic reflection	UK
SAE-7075	Enderby Land	Soviet Antarctic Expedition (SAE16-20) seismic reflection survey in Enderby Land. Two hundred and ninety stations along the Prince Olaf Coast.	Seismic reflection	RU
SAE-7174-2	Lambert Glacier, Amery Ice Shelf	Soviet Antarctic Expedition seismic surveys - East Antarctica (1970/71 - 1983/84).	Seismic reflection	RU
KGI-9597	King George Island	Russian-Brazilian ground-based RES in December 1995 and December 1996-January 1997 using a monopulse radar with acentral frequency 40 MHz and GPS for navigation. Radar data were recorded on film using an oscilloscope C1-73 and a photo camera.	Ground-based RES	RU

Figure 2-5. International Trans Antarctic Scientific Expedition (ITASE) Traverses



3.0 ALTERNATIVES

3.1 Introduction

Several options were analyzed for the development and implementation of USAP surface traverse capabilities. Additionally, the option of “no action” or maintaining the status quo, is discussed here as are several alternatives that were identified but not considered and thus eliminated from detailed analysis.

The primary goal of the proposed action is to develop surface traverse resources that could be used in conjunction with existing USAP airlift capabilities to re-supply USAP facilities and provide a platform for scientific research or advanced surface-based survey activities in Antarctica. Each year, logistical support is needed to re-supply existing facilities, establish or decommission temporary scientific field camps, or provide other specialized support to scientific research at numerous field sites. Because surface traverse and airlift transport mechanisms offer different advantages, they are both expected to serve as essential components in meeting the annual logistical support needs and research requirements of the USAP. The use of surface traverse mechanisms in conjunction with airlift support will provide a number of additional benefits including reduced reliance on aircraft resources, increased opportunities to expand science at USAP facilities (including the South Pole), and resource savings (the example logistics traverse presented here shows as much as a 40% reduction in fuel usage compared to aircraft deliveries of materials to South Pole).

In order to evaluate potential environmental impacts associated with surface traverses used for re-supply missions for this CEE, a surface traverse route between McMurdo Station and the South Pole was selected as the first example. An analysis of the specific operating characteristics (e.g., route, transport configuration) for an optimally configured re-supply traverse to the Amundsen-Scott South Pole Station is presented in Appendix A. Based on the finite quantity of airlift available to support the Amundsen-Scott Station, and the expanding scientific endeavors pursued at the geographic South Pole, the development of a surface traverse capability for re-supply missions is a priority for the USAP.

To evaluate potential impacts associated with scientific traverses and surface-based surveys, the International Trans Antarctic Scientific Expedition (ITASE) traverse conducted by the USAP was selected as a representative example, although future scientific traverses will be customized to meet the specific objectives of the intended research. Appendix B provides a detailed description of a recent ITASE traverse mission.

Sections 3.2 through 3.7 identify various alternatives considered in this CEE for the operation of surface traverses for re-supply (Table 3-1). This exercise is straightforward to accomplish for the first example of a logistics traverse (between McMurdo Station and the South Pole). However, because the technical scope of future research proposals may be specifically designed to employ the use of science-related traverse activities or surface-based surveys, there are no relevant alternatives for science traverses, other than performing the research as proposed or not doing it at all. Therefore, the only science-related traverse alternative under consideration is Alternative A, that is conducting the traverse under the optimal conditions described in the experimental design of the research proposal. Section 3.8 describes alternatives that were identified but were not analyzed.

Table 3-1. Alternative Actions Considered in this Evaluation

Alternative	Description
A	Optimally Configured
B	Minimum Frequency

Table 3-1. Alternative Actions Considered in this Evaluation

Alternative	Description
C	Reduced Intensity
D	Minimal Field Support
E	Use of Existing Routes Only
F	No Action Condition (Status Quo)

3.2 Alternative A – Develop Traverse Capability and Implement Under Optimal Configuration Conditions (Preferred Alternative)

Re-supply Traverses

In this alternative, surface traverse capabilities would be developed to provide logistical support to selected USAP facilities by configuring the components and operation of the traverse to achieve maximum efficiency when used in combination with airlift support. An optimally configured re-supply traverse will provide a practical balance between surface transport and airlift depending upon the specific types of cargo to be transported. To achieve this balance, the traverse route, the timing and frequency of each traverse, and the configuration of the transport equipment, will be customized to suit the cargo transport needs. It is expected that optimally configured re-supply traverses will be conducted on a relatively routine basis (several roundtrips per austral summer) using appropriately designed and sized equipment over improved and marked (e.g., GPS coordinates, flagged) routes.

In order to identify and evaluate potential environmental and operational impacts, the design characteristics and specifications were reviewed for the use of an optimally configured re-supply traverse transport mechanism to the South Pole (Appendix A). Using the conditions described in this study, an optimally configured re-supply traverse (Alternative A) would consist of a convoy of tractors towing cargo sleds from McMurdo Station to the Amundsen-Scott Station several times each austral summer season (Table 3-2). For the South Pole re-supply scenario, each 3,200 km roundtrip (or swing) would require approximately 30 days to complete and would occur during the South Pole's austral summer operating season, typically from late October to mid-February.

Table 3-2. Estimated Statistics for an Optimally Configured Surface Re-supply Traverse from McMurdo Station to the Amundsen-Scott Station (Alternative A)

Number of Swings per Season (i.e., year)	Number of Tractors Towing Cargo Sleds per Swing	Cargo Delivered per Swing [per year] (kg)	Volume of Fuel Consumed for Traverse (liters per year)
6	6	133,000 [800,000]	750,000

The specifics of other optimally configured re-supply traverses will depend upon the destination, the type and quantity of cargo to be transported, and the desired or necessary route. Routes which traverse areas where environmental conditions are substantially different than those evaluated in this CEE (i.e., Ross Ice Shelf, Transantarctic Mountains, Polar Plateau) would require supplemental environmental review.

An optimally configured traverse may require the temporary storage of fuel or cargo at designated areas along the traverse route for use by the swing on the return leg of the trip. For the McMurdo to South Pole re-supply traverse example, a portion of the fuel for the traverse vehicles would be temporarily stored at one or more caches along the route. Alternatively, fuel could be deposited at these caches by airdrops. To facilitate redeployment for subsequent swings, it is expected that traverse equipment will be returned to a supporting station or outlying facility. Supplies temporarily staged or cached in the field would typically be recovered at the end of each summer season and returned to the supporting station. However, in some cases, it may be practical to leave selected equipment or caches in the field over the austral winter using established procedures to ensure their recovery and prevent the release of these materials to the environment (reference 1). In addition, a traverse route may require periodic maintenance (e.g., surface grooming, crevasse detection and mitigation) either by a swing or a support team to ensure safe traverse operations.

Scientific Traverses

The proposed USAP surface traverse capability may be used as a platform for in-field scientific research activities. An optimally configured (Alternative A) research traverse would be based on the types of research to be conducted, the number of personnel performing the research, and the duration and routing of the traverse. To enhance mobility and efficiency, fuel or other supplies may be temporarily cached in the field either by airdrops, delivery by aircraft, or separate re-supply traverses. Optimally configured surface-based surveys as well as science traverses will typically be conducted along one or more specific routes using equipment designed and configured for the intended research. It is expected that traverses used for science applications would typically follow undeveloped routes in the areas intended for the research but may also use routes established for re-supply purposes, if available.

The 2002-2003 International Trans Antarctic Scientific Expedition (ITASE) traverse conducted by the USAP (Appendix B) is an example of an optimally configured traverse used for research purposes. This traverse was one in a series of multinational research traverses conducted on the Polar Plateau. The 2002-2003 ITASE traverse covered the 1,250 km distance between Byrd Field Camp and the South Pole in 40 days while performing glaciological and atmospheric research at eight designated sites. The 2002-2003 ITASE traverse proceeded on an undeveloped route using two tractors towing 10 trailers and staffed by 13 scientists and support personnel. To optimize efficiency, the ITASE utilized a series of fuel caches placed at strategic locations along the traverse route.

3.3 Alternative B – Develop Surface Traverse Capability and Implement Under Minimum Frequency Conditions

Re-supply Traverses

In this alternative, surface re-supply traverses would be configured similar to those described in Alternative A but each individual traverse would occur on a less frequent basis each austral summer season. Using the McMurdo Station to South Pole re-supply mission as an example, Table 3-3 summarizes the details of the use of three surface traverses per year as opposed to the optimum number of six.

Table 3-3. Estimated Statistics for a Surface Re-supply Traverse to the Amundsen-Scott Station from McMurdo Station Operating Under Minimal Frequency Conditions (Alternative B)

Number of Swings per Season (i.e., year)	Number of Tractors Towing Cargo Sleds per Swing	Cargo Delivered per Swing [per year] (kg)	Volume of Fuel Consumed for Traverse (liters per year)
3	6	133,000 [400,000]	375,000

Scientific Traverses

Reducing the frequency of science-related traverses on a project or annual basis may severely compromise the quality of the intended research and therefore may not be feasible. No further analysis will be pursued in this CEE pertaining to the reduction in the frequency of scientific research traverses.

3.4 Alternative C – Develop Surface Traverse Capability and Implement Under Reduced Intensity Conditions

Re-supply Traverses

In this alternative, surface re-supply traverses would transport cargo on the same frequency as described in Alternative A but would use only three tractors per swing instead of the six if optimally configured. Based on the McMurdo Station to South Pole re-supply mission as an example, Table 3-4 summarizes the details associated with this operating configuration.

Table 3-4. Estimated Statistics for a Surface Re-supply Traverse to the Amundsen-Scott Station from McMurdo Station Operating Under Reduced Intensity Conditions (Alternative C)

Number of Swings per Season (i.e., year)	Number of Tractors Towing Cargo Sleds per Swing	Cargo Delivered per Swing [per year] (kg)	Volume of Fuel Consumed for Traverse (liters per year)
6	3	67,000 [400,000]	375,000

Scientific Traverses

The configuration of science-related traverses (number and size of science-related cargo modules and tractors) would be based on the experimental design of the intended research. Reducing the number of tractors or cargo modules for research traverses may severely compromise the quality of the research and therefore may not be feasible. No further analysis will be pursued in this CEE pertaining to the reduction of resources for scientific research traverses.

3.5 Alternative D – Develop Surface Traverse Capabilities and Implement Using Minimal Field Support Resources

Re-supply Traverses

Alternatives A, B, and C will likely involve the use of field caches, depots, or camps to optimize the effective cargo carrying capacity of the re-supply traverse. For example, fuel intended to be consumed on the return leg of the mission, or empty fuel containers or wastes, may be temporarily stored along the traverse route for subsequent pickup on the return to the base station. If field caches, depots, or camps are not used for this purpose, the useful load (i.e., quantity of deliverable cargo) may be reduced. Using the McMurdo Station to South Pole re-supply mission as an example, Table 3-5 summarizes the conditions if no intermediate storage facilities are used. In this example, the quantity of cargo delivered would be reduced by four percent.

Table 3-5. Details of a Surface Re-supply Traverse to the Amundsen-Scott Station from McMurdo Station Operating With Minimal Field Support (Alternative D)

Number of Swings per Season (i.e., year)	Number of Tractors Towing Cargo Sleds per Swing	Cargo Delivered per Swing [per year] (kg)	Volume of Fuel Consumed for Traverse (liters per year)
6	6	128,000 [768,000]	750,000

Scientific Traverses

Research-related traverses could function without the use of field caches, depots, or camps but this could adversely affect the efficiency of the mission. For example, the tractors towing the science and personnel support equipment could transport all of the fuel and other supplies needed for the entire mission from the onset but this would essentially result in the transport of dead weight for a portion of the trip, especially an out-and-back route. Alternatively, fuel or other supplies could be airlifted to the traverse team in the field on an as-needed basis but this would require precise planning and coordination of resources which could easily be compromised by adverse weather or mechanical problems. As a result, the elimination of the use of field caches, depots, or camps by scientific traverses is not a practical alternative and will not be analyzed further in this CEE.

3.6 Alternative E – Develop Surface Traverse Capabilities and Implement Using Existing Routes Only

Re-supply Traverses

In this alternative, the USAP would develop and conduct optimally configured re-supply traverses as described in Alternative A but would only utilize existing routes in Antarctica. Assuming that the ongoing proof of concept traverse evaluation is successfully completed by 2007, the only USAP surface traverse route available will be from McMurdo Station to the Amundsen-Scott Station via the Ross Sea Ice Shelf and the Leverett Glacier. Table 3-2 summarizes the details of an optimally configured re-supply traverse which would exclusively use this route to the South Pole.

Scientific Traverses

Theoretically scientific traverses could be limited to established traverse routes in Antarctica either maintained by the USAP or other nations but this restriction could severely inhibit research opportunities on the continent. As a result, no further analysis on restricting the routes of scientific research traverses will be pursued.

3.7 Alternative F – Do Not Develop Surface Traverse Capability and Continue to Use Air Support Only (No Action Alternative)

The no action alternative suggests that the USAP would not develop surface traverse capabilities and aircraft would continue to be used exclusively as the primary logistical transport mechanism providing support to selected USAP facilities and research sites. Traverses for science-related research would either be curtailed completely or would require separate environmental reviews on a case-by-case basis.

3.8 Alternatives Identified But Not Analyzed

Several additional alternatives were identified but were eliminated from further consideration in this CEE due to technical reasons. The following alternatives included variations on the traverse location, equipment, and operational characteristics.

3.8.1 Surface Re-supply Traverse to the South Pole from Dumont d'Urville via Concordia Station

The French and Italians have jointly developed and are currently operating a surface traverse capability to transport supplies from a coastal facility at Cape Prudhomme (near Dumont d'Urville) to the Dome C Station (Concordia) on the Polar Plateau. As an alternative for the re-supply of the Amundsen-Scott Station, the USAP could potentially use this existing traverse route to Concordia and develop a new route from Concordia to the South Pole. Implementation of this alternative would involve transporting supplies to Cape Prudhomme by vessel, offloading and temporarily storing the materials for subsequent transport by traverse to the South Pole. Neither Cape Prudhomme nor Dumont d'Urville currently has the infrastructure to support this type of operation without substantial expansion. Additionally, the "Dome C" route is twice the overall distance of the "Leverett" route, resulting in a much higher environmental exposure as well as cost per kilogram delivered. For these reasons this alternative was eliminated from further consideration.

3.8.2 Develop and Implement Surface Traverse Capability Using Low Exhaust Gas Emission Equipment

The types of equipment proposed for use on re-supply or scientific traverse missions (e.g., Caterpillar Challenger models 55 and 95; Case Quadtrac STX450) are currently used in the USAP (and in other national Antarctic programs) for various field and station operations. These vehicles have been shown to be suitable for these types of applications and operate reliably under polar conditions. The USAP has a substantial number of trained mechanics and parts inventories needed to support and maintain these types of vehicles. Consistent with the acquisition practices for the existing fleet of USAP vehicles, tractors procured for surface traverse uses would be acquired in the United States and built to meet U.S. emissions standards which are increasingly stringent for construction and off-road vehicles. Although vehicles with lower exhaust gas emissions may be potentially available, equipment which is underpowered or has not been proven to operate reliably and effectively under polar conditions could jeopardize safety and the completion of the mission. As a result, the equipment described in this CEE represents the optimum combination of functionality for the intended application and fuel combustion efficiency. Potential environmental benefits derived from the selection of other types of equipment were deemed to be negligible and were eliminated from further consideration in the CEE.

3.8.3 Minimize the Transport of Fuel

Each year, the USAP transports a considerable volume of petroleum hydrocarbon fuels, principally diesel fuel (JP-8, AN-8) to remote locations for use in generators, heating devices, heavy equipment, and vehicles. Nearly all of this fuel is currently transported by aircraft. Fuel represents a commodity which has a significant potential to adversely impact the environment because it is a liquid and under certain conditions may migrate (i.e., diffuse, disperse) in the environment. The risk of adverse environmental impacts caused by fuel spills or related releases can be reduced by several means, including minimizing the quantity of fuel transported into the field either by surface traverse or aircraft.

Fuel is essential for the operation of all USAP facilities. Using the equipment and procedures described in the CEE, fuel transport by surface traverse is expected to be as secure as transport by aircraft. Use of the surface traverse capability for fuel as well as other supplies would provide the USAP with the ability to optimize a combination of transport mechanisms to efficiently suit the specific needs of the mission and resources available. Since minimization of the amount of fuel transported by surface transport would not reduce potential environmental hazards (while at the same time reducing the ability to optimize transport mechanisms), this alternative has been eliminated from further consideration.

4.0 DESCRIPTION OF PROPOSED ACTIVITES

4.1 Introduction

The proposed activities associated with the development and implementation of surface traverse capabilities for both re-supply and scientific research applications in the USAP are discussed here. The purpose and need for the proposed action is presented in Section 4.2 and includes a description of the goals and benefits of potential traverses. Section 4.3 provides a description of the typical components of a surface traverse including the route, resources (e.g., personnel, equipment), operating factors (e.g., loads, schedules), field logistical support, and off-season activities. Finally, Section 4.4 contains a detailed description of the nature and intensity of anticipated traverse activities.

Whether the proposed surface traverse is for re-supply or scientific research (while the purpose and scale may be significantly different), both types of surface traverses will involve the use of multiple motorized tracked vehicles towing sleds or trailers containing living and working modules for the traverse crew, fuel for the traverse equipment, as well as payload or cargo. The scope of a traverse performed by the USAP will be dependent of the specific needs of the mission and cannot be definitively stated in this CEE. However, examples of re-supply and science traverses have been presented in order to identify and evaluate potential environmental and operational impacts. The example of a re-supply traverse was recently the subject of a proof of concept study (Appendix A) and involves the transport of fuel and other cargo to the Amundsen-Scott Station from McMurdo Station. The 2002-2003 USAP ITASE traverse is part of a multi-year research effort by several nations and was used as an example to characterize the potential environmental and operational impacts associated with this type of traverse activity. A technical description of the recent ITASE traverse is provided in the activity’s end-of-season report (Appendix B).

4.2 Purpose and Need

In support of the United States Antarctic Program (USAP), the National Science Foundation (NSF) proposes to develop and implement enhanced surface traverse capabilities in Antarctica. The successful development and use of surface traverses will enable the USAP to meet several logistical and scientific goals.

The primary purpose of developing a surface traverse capability will be to enhance the USAP’s current logistical support mechanism for the re-supply of facilities in Antarctica, specifically to provide a more capable alternate transportation method to complement the existing airlift resources. The development and use of surface traverse resources would allow logistical planners to optimize the transportation of fuel, cargo, and supplies to various USAP facilities through the implementation of a combination of airlift and surface traverse mechanisms as conditions warrant. The surface traverse capability would also allow the USAP to efficiently transport cargo to locations where airlift may not be possible or practical.

An equally important purpose for the development of a surface traverse capability relates to the use of the traverse as a platform to perform advanced surface-based scientific studies in Antarctica. Recent traverse activities conducted by the USAP as a partner in the International Trans Antarctic Scientific Expedition (ITASE) demonstrate the value of surface-based scientific research supported by mobile facilities.

The need to develop and implement surface traverse capabilities hinges on limitations inherent to the USAP’s heavy reliance on the existing airlift support mechanism. The current airlift support system has a limited number of aircraft, crews, and suitable operating days available each year. As a result, the airlift system typically operates near capacity levels each year with little flexibility or opportunity for expansion. Most of the USAP’s heavy-lift, long-range airlift capability is provided by ski-equipped LC-130 Hercules aircraft.

The Amundsen-Scott Station is approximately 1,600 km from McMurdo Station and is supported exclusively by LC-130 aircraft. Each LC-130 flight has the capacity to deliver up to 11,800 kg of cargo and personnel to the South Pole. Much of the available LC-130 airlift capacity for the entire field season is consumed by re-supply of Amundsen-Scott Station, in particular, the delivery of fuel. When delivering fuel the LC-130 actually consumes more fuel with each trip than it deposits at the station. Using the example re-supply traverse, compared to a single aircraft, each tractor would deliver to South Pole significantly more material (approximately twice as much) per roundtrip for approximately the same amount of consumed fuel. The delivery of fuel and other cargo to the South Pole represents a significant use of the limited aircraft resources, particularly when rapid delivery of these re-supply materials is often unnecessary.

Because surface traverse and airlift transport mechanisms each offer different advantages, they are both expected to serve as essential components in meeting logistical and scientific goals of the USAP depending upon the specific needs of the mission and environmental conditions. The following provides additional details regarding the purpose and need for the USAP to develop and implement a robust surface traverse capability.

4.2.1 Description of Current Air Logistical Support Systems

Each year the USAP operates numerous aircraft within Antarctica for logistical support and direct support of scientific research activities. Available aircraft operated within Antarctica by the USAP include ski-equipped LC-130 Hercules for heavyweight and bulky cargo missions as well as ski-equipped DeHaviland Twin Otters. Helicopters are also operated, and are primarily assigned missions in the McMurdo area and the Dry Valleys. All of these aircraft are flown only during the austral summer operating season, typically from October through February.

In general, larger field camps that are used as bases for scientific research activities are established at snow-covered locations which can be safely accessed by ski-equipped aircraft. Smaller field camps (i.e., tent camps) or research sites may be supported by aircraft or surface vehicles, typically small tracked vehicles (e.g., LMC Spryte, Kassbohrer Pisten Bully, snowmobiles) operating from a supporting station or base camp. In addition, some field efforts are periodically resupplied by LC-130 aircraft via airdrops at strategic locations.

For the past several years, the USAP has operated an average of 400 intra-continental LC-130 missions per year, including 280 missions to the Amundsen-Scott Station at the South Pole and 120 missions to support various other field locations, in total representing approximately 3,000 flight hours. Twin Otters typically provide 1,000 hours (or 200 missions) of flight support annually to numerous snow-covered sites, while helicopters generally provide 1,500 hours of flight support primarily in the McMurdo area and locations in the Dry Valleys.

The LC-130 aircraft is the largest ski-equipped aircraft available to the USAP and is the only resource used to annually re-supply the Amundsen-Scott Station. The LC-130 aircraft also provide logistical support to other USAP facilities and science projects at various locations within Antarctica. This support is typically provided to 10 locations annually, including the re-supply of selected field camps and research sites (e.g. Automatic Geophysical Observatories, Long Duration Balloon recovery) and may include the delivery and pickup of personnel, supplies, equipment, and fuel. In addition, LC-130 aircraft routinely airdrop drums of fuel or other supplies to selected locations depending upon the needs of various research or operational projects. Twin Otter aircraft also provide logistical and science support to numerous locations in the field. Because of the Twin Otters' limited transport capacity as compared to the LC-130, the Twin Otter's primary focus is to support smaller facilities or perform various types of aerial monitoring.

4.2.2 Limitations of Air Logistical Support

The USAP's airlift logistical support system is subject to various constraints including operating periods, cargo transport dimensions and capacities, environmental conditions, and personnel (e.g., flight crew, ground support) limitations. The safe load capacity of the LC-130 aircraft is limited to 103 m^3 of cargo space (12.3 m long, 3.1 m wide, 2.7 m high) and 11,800 kg which may include 14,500 liters of fuel stored in the wing tanks of the aircraft.

The annual re-supply of the Amundsen-Scott Station may include the transport of scientific instruments, construction materials, heavy equipment, and station operating supplies. Currently, transport of these materials is subject to the cargo size and weight restrictions of the LC-130 aircraft. Building components used for the ongoing reconstruction of the station were designed to be modular and sized to fit within the LC-130 aircraft. Equipment shipped to the South Pole for scientific research projects must also be designed and configured to fit within the aircraft's size limitations. For example, the equipment needed for the proposed neutrino telescope of Project IceCube or the eight-meter telescope, must be disassembled into units which can be accommodated on the LC-130 aircraft.

Based on recent history, it is estimated that the current fleet of LC-130 aircraft available to the USAP could potentially fly slightly more than 400 missions during an austral summer season but inevitable delays or postponements due to weather or other factors usually lower this number. Because the Amundsen-Scott Station is solely dependent on the LC-130 aircraft for re-supply, a major portion of the available LC-130 resources must be allocated for this purpose. The remaining LC-130 resources available each austral summer season may be used for other scientific support missions but often the demand for these resources exceeds the capacity. As a result, the availability of LC-130 resources can potentially limit the start of new science projects in Antarctica, both at South Pole and elsewhere on the continent.

The majority of LC-130 airlift capacity to the South Pole each year is used to deliver fuel, a vital commodity for the continued safe operation of the Station. The four-engine LC-130 aircraft consumes more fuel in a roundtrip to the South Pole from McMurdo Station (approximately 17,200 liters) than can be delivered (approximately 14,500 liters). Periodically, planned flights to the South Pole may be delayed due to adverse weather, extreme temperatures, or other unexpected conditions (aircraft maintenance). Delayed flights must be made up in order to deliver the minimum quantity of fuel and other materials needed to sustain operations at South Pole, particularly over the inaccessible 250-day austral winter. Although the LC-130 aircraft have always been able to deliver the fuel needed for USAP operations at the South Pole, other types of cargo or missions to other locations have at times been compromised because no alternate transport methods are currently available to re-supply the Amundsen-Scott Station.

4.2.3 Benefits of Surface Traverses

The development and use of a surface traverse capability by the USAP will provide an alternate and viable means to provide logistical support to USAP facilities and scientific research efforts which is not subject to the physical limitations of aircraft. In addition, since the USAP does not currently have a robust traverse capability, new science projects involving mobile surface-based research could be performed using equipment optimally configured for this purpose as opposed to airlift support or traverse capabilities patched together using existing resources. While the proposed development and use of traverse capabilities in the USAP is not intended to replace the existing aircraft logistical support system, it will supplement current airlift resources and allow the benefits of each transport mechanism to be effectively realized.

4.2.3.1 Increased Reliability

The use of surface traverses as part of a diversified logistical support system will provide the USAP with a greater level of reliability than is currently provided with the exclusive use of aircraft. Because a variety of environmental conditions (e.g., wind, snow, extremely low temperatures) may affect the safe operation of aircraft, flights are often delayed or cancelled when adverse weather conditions are encountered at the point of origin, destination, or locations enroute. Because the safe operation of surface traverse equipment is more tolerant of adverse weather conditions than aircraft, traverse activities can be scheduled with a reduced level of risk of significant delay or cancellation. Having a dual mode capacity to make deliveries to the interior of Antarctica greatly reduces the risks posed by a single-point failure in the current system.

4.2.3.2 Resource Savings

The use of surface traverse capabilities in conjunction with airlift support will result in resource savings to the USAP, including fuel, personnel time, and associated support services. Using the South Pole re-supply traverse as an example, it is expected that each tractor towing cargo trailers will be capable of delivering approximately twice the amount of cargo to the South Pole as a single LC-130 aircraft while consuming close to the same amount of fuel. Specifically, for each 100,000 kg of cargo transported to the South Pole from McMurdo Station, traverse equipment would consume approximately 90,000 liters of fuel. Transporting the same quantity of cargo by LC-130 aircraft would require 8.5 flights and consume 150,000 liters of fuel. Although aircraft can transport cargo much more rapidly than traverse, transport by traverse could save fuel.

A surface traverse from the South Pole may also be used to transport wastes generated at the Amundsen-Scott Station back to McMurdo Station for subsequent retrograde and disposition in the United States. Wastes expected to be produced at the South Pole in the near future include heavy bulky debris resulting from the demolition of the old station during the South Pole Station Modernization (SPSM) project. The use of the traverse capability for this application will reduce resources required to dismantle larger components and specially prepare the waste for shipment in LC-130 aircraft. In addition, the use of traverse capabilities to transport supplies or wastes will free-up the resources typically used at Amundsen-Scott and McMurdo Station to handle cargo since this function would be performed by the traverse crew.

4.2.3.3 Reduced Reliance on Aircraft Resources

The development and use of traverse capabilities would reduce the reliance on aircraft resources in the USAP by reducing the number of missions and associated flight hours that must be dedicated to re-supply or scientific support missions. There are a finite number of aircraft and crews available to provide support to locations within the Antarctic continent and these resources are typically operated near capacity.

Supplementing the USAP's airlift resources with a traverse capability could eliminate approximately 8.5 flight missions for each 100,000 kg of cargo delivered either allowing a reduction in the number of missions flown or the reprogramming of LC-130 resources for other applications.

4.2.3.4 Increased Opportunities to Perform Scientific Studies in Antarctica

The availability of surface traverse resources will allow the USAP to reliably support a variety of scientific research projects throughout the Antarctic continent including surface-based surveys. Surface-based data collected in strategic areas of Antarctica can be used to document the spatial and temporal variability of glacial, geological, climatological, and atmospheric characteristics which have been traditionally available only from remote sensing sources (e.g., Radarsat, Landsat, Department of Defense imagery). The scientific community has already expressed an interest in conducting such research in Antarctica (reference 2).

The USAP has been able to support various scientific surface-based surveys or traverse research projects in the past using existing USAP resources. Although these missions have been generally successful, the research activities were often performed using equipment or expertise that was not optimized for the specific application and may have potentially complicated the work that was done. The development of the proposed traverse capability will ensure that the USAP has adequate resources and experience available to efficiently support future surface-based research projects.

4.2.3.5 Increased Opportunities to Expand the Scope of Science at the South Pole

In conjunction with the USAP's existing airlift resources, the availability of a surface traverse capability to the South Pole will provide the opportunity to expand the scope of new scientific research projects that may be conducted at the Amundsen-Scott Station. Currently, all science projects at the South Pole are performed using equipment and facilities transported to the Station on LC-130 aircraft. All cargo must conform to the size and weight restrictions of the aircraft. Potential use of a surface traverse capability will expand the types of cargo that can be transported.

4.2.3.6 Increased Opportunities to Provide Logistical Support to Science at Other Field Locations

In conjunction with the USAP's existing airlift resources, the availability of a surface traverse capability would provide the USAP with the flexibility to select the most efficient transport mechanism available to support scientific research projects at remote field locations. Currently, larger field camps are typically established only at locations which can be safely accessed by available aircraft (LC-130, Twin Otters), while smaller field camps are serviced by helicopters or tracked vehicles (e.g., Tucker Snocat, LMC Spryte, Kassbohrer Pisten Bully, snowmobiles). Based on the specific needs of each new research project, a surface traverse capability may provide a more efficient mechanism to transport needed materials and support science.

4.3 Description of Surface Traverses for Re-supply

It is assumed that a re-supply traverse would generally be conducted between two primary facilities (e.g., stations), perhaps with intermediate stops, would follow an established, marked and improved route (e.g., crevasses mitigated, trail groomed), and would be used more than once. Re-supply traverse activities would include equipment, personnel, operating factors, and field logistics. These traverse characteristics would be customized to meet the specific goals of the traverse.

A detailed engineering evaluation of various characteristics composing a re-supply traverse from McMurdo Station to the South Pole has been completed (Appendix A), and is used as an example of a re-supply traverse in this CEE to identify potential impacts. Using this example, the following summarizes the optimum characteristics of a re-supply traverse.

4.3.1 Traverse Route

In general, it is expected that a route used for re-supply missions would be developed so that the path could be safely and reliably reused on a periodic basis. The development of this type of route could involve the mitigation of crevasse hazards by filling them , the marking of the trail, and the establishment of caches or temporary storage and rest areas. Re-supply traverse routes could also involve the use of established paths developed to different destinations.

A proof of concept study is currently being performed to evaluate a possible traverse route between McMurdo and Amundsen-Scott Stations. The proof of concept route, if deemed successful, is divided into four distinct areas: 1) the “shear zone” between the McMurdo Ice Shelf and Ross Ice Shelf, 2) the Ross Ice Shelf, 3) the Leverett Glacier, and 4) the Polar Plateau. The proof of concept route crosses ice and snow areas but does not intersect dry land, seasonal sea ice (marine), wildlife areas, or Antarctic Specially Protected Areas (ASPA). Potential traverse routes, which would cross environmental settings different than those described in this CEE, would require supplemental environmental review.

To ensure safe operations, each surface traverse route is typically inspected for crevasse hazards using remote sensing (aerial or satellite imagery), ground penetrating radar (GPR), or infrared photography. If crevasses are detected, they are either avoided by rerouting around the area or mitigated by filling them with native snow and ice. Crevasses are mitigated by removing surface snow bridges, sometimes with explosives, filling the void with snow and ice, and constructing a stable path sufficiently wide enough to support the traverse equipment. When a crevasse has been successfully avoided or mitigated, the path is groomed and flagged to mark the safe route. Periodically, traverse routes may require maintenance such as the removal of drifting snow, re-grooming, and re-flagging.

4.3.2 Resources

The resources needed to conduct a surface re-supply traverse include equipment, personnel, support facilities and services, fuel, and supplies. The magnitude of resources utilized for each alternative may alter or impact the effectiveness of traverse operations as well as the nature and extent of environmental impacts.

Equipment

The equipment that will be used in a re-supply traverse will comprise, in general, a convoy of tractors towing a series of trailers. The type of tractors to be used on a traverse would be based on the requirements of the mission but each must be able to tow fully laden sleds in a low-traction environment. If the route for a particular traverse has not been fully developed and marked, it is expected that a traverse team would be equipped with GPR crevasse detection equipment and trail maintenance equipment such as groomers or land planes.

The ongoing proof of concept evaluation of a surface re-supply traverse capability between McMurdo and Amundsen-Scott Stations is currently assessing the effectiveness of several types of tractors, including the Caterpillar Challenger 95 and the Case Quadtrac STX450. It is estimated that either of these rubber-track agricultural tractors could leave McMurdo Station towing trailers with a total payload (gross load less tare weights) of about 43,000 kg and deliver in excess of 20,000 kg of cargo to the South Pole.

Each trailer on an optimally configured traverse would be specifically designed to accommodate the types of cargo such as fuel in tanks, cargo in intermodal containers, and bulk cargo. To reduce unnecessary tare weight, the trailers would have a skeletal design allowing secure transport of both modular and loose loads. Modular loads would include intermodal cargo containers that would serve as support facilities for traverse personnel.

Trailers used to transport fuel will be constructed to minimize the height of the trailer's center of gravity and allow modular or loose loads to be placed on the trailer as well. Fuel tanks and other hazardous material containers would be constructed with materials suitable to protect the contents against handling and transportation stresses. Fuel tanks would be regularly inspected to detect leaks or potential weaknesses in the containers and empty vessels would be available if emergency transfers were necessary.

The use of slaved or remote control technology may also be a feasible option whereby the lead tractor would be driven by an operator with the one or more of the remaining tractors unmanned and linked electronically.

Personnel

Skilled personnel will be needed to operate the tractors and support traverse activities including equipment preventive maintenance and refueling. The number of people operating a traverse swing would depend on the specific needs of the mission such as the loads to be transported, the number of tractors, or the distance. It is assumed that a re-supply traverse may be staffed at a ratio of one person per tractor, with additional support camp operational skills supplemented by available or additional staff. It is assumed that some of the traverse equipment operators would be skilled mechanics to handle preventive maintenance and emergency breakdown situations. In addition, some traverse personnel will possess other contingency skills such as emergency first aid, life-saving, mountaineering, communications expertise, and spill response training.

Personnel Support Modules

Each re-supply traverse swing would include the necessary support modules containing facilities needed for the duration of the traverse. For example, one unit would serve as the primary living module with berthing, food preparation and dining areas. A second, back-up living module would be physically separated from the primary unit to minimize the risk of the loss of both in a single mishap. The primary and backup living modules would be capable of berthing and feeding the entire swing team and would contain redundant sets of communications equipment. The back-up module would have its own electrical power generator and a snow melter for production of potable water. A third utilities module would contain the primary power plant (approximately 30 kW), potable water generation facilities, sanitary facility (i.e., bathroom), and workshop area. A supplies and spare parts module may also be required.

Fuel and Supplies

Each series of tractors and trailers deployed on a roundtrip mission would be called a swing and would be self-sufficient. Each swing would carry the supplies needed to operate the traverse, including food, fuel, lubricants, maintenance supplies, and waste containers. Cargo containers would be compatible with their contents and structurally able to withstand the physical and environmental conditions encountered during the traverse. Food stores and critical medical supplies would be divided between two berthing modules to minimize the loss of all supplies in the event of a mishap. Other supplies that would be needed for the traverse equipment or maintenance activities such as gasoline, lubricants, and coolants would be transported and stored in containers supplied by the manufacturer or in 208-liter (55-gal) drums. Each swing would also be equipped with the containers needed to collect and manage all wastes generated during the traverse, including solid wastes, sanitary wastes (e.g., human solid waste, urine, greywater), and hazardous wastes, which will be returned to McMurdo for proper processing and disposal.

Support Facilities and Services

During each austral summer operational period, traverse activities would utilize the facilities and services of one or more supporting stations or outlying facilities to provide equipment storage, cargo management, temporary personnel berthing, equipment maintenance and repair, and waste management services. For the austral winter season, it is anticipated that all traverse equipment would be brought to McMurdo Station for maintenance and storage. McMurdo Station is the USAP's largest facility and central supply hub.

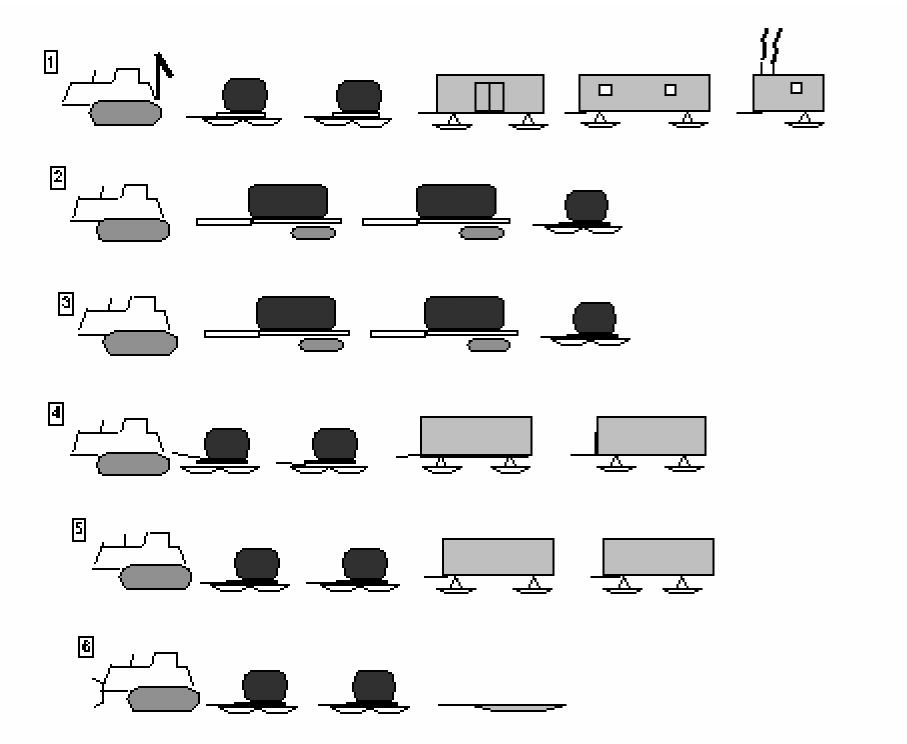
4.3.3 Operating Factors

The performance of re-supply traverse operations may be defined by a series of operating factors including swing configuration, cargo load, and travel time.

Swing Configuration

The configuration of a traverse swing includes the number and type of tractors, trailers, sleds and other specialized equipment used to transport cargo. Each swing would be configured to accommodate the type and quantity of cargo scheduled to be transported as well as the personnel modules, fuel, and supplies needed to support the operation of the traverse. Because of transport efficiencies and safety considerations, it is expected that a minimum of three tractors would be used in any given traverse swing. Figure 4-1 provides a schematic diagram of an example six-tractor swing configuration for a re-supply traverse.

Figure 4-1. Typical Re-supply Traverse Swing Configuration



Cargo Load

Each tractor departing on a re-supply mission would haul an optimally configured payload based on the cargo's weight and volume and the tractor's performance capabilities. Using the surface traverse from McMurdo Station to the South Pole as an example, the maximum payload of each tractor leaving McMurdo would be approximately 43,000 kg excluding the tare weights of the tractor, sleds, and cargo containers. Considering the volume of fuel that would be consumed on a roundtrip traverse mission between McMurdo Station and the South Pole, each tractor could deliver approximately 20,000 to 27,000 kg of cargo.

Travel Time

The travel time required to complete a roundtrip re-supply traverse mission would depend on a number of factors including the distance traveled, equipment power and traction, cargo load, environmental conditions such as crevasses, snow characteristics, slope over the traverse route, and tractor performance. The number of hours each day that the traverse personnel are able to transport cargo would also influence the total duration of a traverse mission.

In the example of the re-supply traverse from McMurdo Station to the South Pole (Appendix A), a 12-hour driving day was assumed resulting in a one-month roundtrip between McMurdo and South Pole.

4.3.4 Field Logistics

Efficient traverse operations require the use of various logistical support mechanisms including the operation of personnel support modules and resources to refuel and maintain the equipment. In addition, the use of fuel caches and supply depots provide the traverse team with resources which do not have to be transported over the entire route but only have to be accessed when they are needed.

Operation of Personnel Support Modules

Personnel support modules for the operating crew would be an integral part of each traverse mission. These modular facilities would provide needed personnel support facilities when the traverse has stopped for the day. Unless delayed by weather or mechanical problems, it is expected these facilities would be operated at a different location along the traverse route each day.

The support modules would contain kitchen, berthing and sanitary facilities, space heating equipment, water production equipment, a portable power plant with approximately 30 kW capacity, and waste storage containers. One set of backup facilities will be available. The modules would also be equipped with a workshop and resources for equipment maintenance.

All wastes generated during operations of the traverse equipment would be handled in accordance with 45 CFR §671 and documented for *USAP Master Permit* (reference 3) reporting purposes. All nonhazardous and Antarctic Hazardous wastes generated during the traverse activities would be containerized and returned to a supporting station or outlying facility for further processing and disposition. Sanitary wastes would be either containerized or discharged to snow covered areas as allowed by 45 §CFR 671 and the *USAP Master Permit*.

Equipment Refueling, Maintenance, and Repair

Each swing would contain the resources and equipment to refuel the tractors and to perform limited but essential maintenance in the field. Based on the type of equipment expected to be used and expected fuel consumption rates, it is anticipated that the tractors would be refueled at least daily. To prevent accidental releases (spills) to the environment, the traverse crew would follow specific refueling and maintenance fluid handling procedures and will use fuel distribution equipment and containment devices (drip pans, absorbents) appropriate for the conditions.

Depending upon the length of a particular traverse mission, it is expected that minor equipment maintenance activities will be necessary in the field. Although it is unlikely based on the proven reliability of the proposed equipment, it is possible that some equipment may fail and repair would be beyond the capability of the traverse team. In these instances, the disabled equipment could be repaired using parts and mechanics deployed to the field via aircraft; the equipment could be loaded onto a trailer and towed to a supporting facility; or the failed equipment could be secured in the field for subsequent retrieval by another traverse team.

Field Caches

To optimize operational efficiency, it may be useful to temporarily deposit critical supplies for the traverse in field caches and access these materials when they are needed. For example, to support a re-supply traverse to the South Pole, it may be practical to reduce the payload of each tractor by staging fuel for the traverse equipment along the route. These caches could be established by other traverse operations or airlift support. Similarly, it may be practical to leave some fuel and other supplies at strategic locations along the traverse route so that these items could be accessed when needed on the return leg of the traverse as opposed to transporting them for the entire trip.

All supplies temporarily cached along the traverse route would be positioned and marked so that they can be easily located and recovered without damage to the containers. It is expected that all staged or cached supplies would be recovered at the completion of traverse activities each austral summer, although it may be beneficial to pre-stage some materials in the field for the following austral summer season. All field caches would be deployed and managed as specified in the *Standard Operating Procedure for Placement, Management, and Removal of Materials Cached at Field Locations* (reference 1).

4.3.5 Off-season Activities

Most re-supply traverse activities are expected to be conducted during the austral summer, typically October through February. During the off-season (austral winter), it is anticipated that all equipment would be stored at or in the immediate vicinity of McMurdo Station and mechanical equipment maintained at the Vehicle Maintenance Facility (VMF). Personnel support modules would be inspected, winterized, maintained, and restocked for subsequent use.

At the beginning of each operating season, traverse equipment, including the tractors, trailers, and personnel support modules would be mobilized, prepared for use, and staged accordingly. Williams Field, located ten kilometers from McMurdo Station on the permanent ice sheet, would be a practical staging area for re-supply cargo being transported to the Amundsen-Scott Station.

4.4 Description of Surface Traverses for Scientific Research

A fully developed USAP traverse capability could provide the resources including the equipment, trained personnel, and logistical procedures needed to perform various types of scientific research in Antarctica. In general, it is assumed that a traverse used for scientific research would cover an area or undeveloped route that was selected to achieve specific research goals. Unlike a re-supply traverse mission, a research traverse would only need to transport the cargo needed to perform the intended research and support the personnel and traverse equipment while in the field. Variable characteristics which can be used to describe science-related traverse activities include the route or area to be surveyed, resources to be used, operating factors, and field logistics. These characteristics would be optimized to meet the specific goals of the research.

The entire range of research activities that may be performed on science-related traverses is dependent on the goals of future researchers and cannot be projected and analyzed in this CEE. The scope of this environmental review is intended to focus on the mechanics of conducting a traverse used for scientific research purposes. Potential impacts resulting from the scientific aspects of the research performed on a traverse would be evaluated, if they have not been addressed elsewhere, in additional environmental reviews supplementing this CEE. The recently completed International Trans Antarctic Scientific Expedition (ITASE) is an example of a science-related traverse used to identify potential impacts associated with this type of traverse activity (Appendix B). The following describes typical characteristics of a science-related traverse.

4.4.1 Traverse Route

Traverse activities for science applications would utilize a route designed to meet the particular objectives of the research. The traverse route may consist of transects between defined points, circular routes, or series of branches from a central location. A science-related traverse may be conducted on a new route, a route previously used for research, or a route used for a re-supply mission. Summaries of the past scientific traverses that have been conducted by numerous Treaty nations, including the United States, in virtually every region of Antarctica was presented in Section 2. Under the proposed action, science-related traverse routes that extend into environmental settings which are different than those characterized in this CEE (e.g., Ross Ice Shelf, Polar Plateau) would require supplemental environmental review.

It is assumed that most traverses conducted for scientific research activities would utilize an unimproved and unmarked route, which may only be used once. It is anticipated that each science-related traverse route would be inspected for crevasse hazards using ground penetrating radar, infrared photography, or other remote sensing methods. Given the resources that may be typically available on a science-related traverse, crevasses would be avoided when practical as opposed to mitigation through exposure and fill.

4.4.2 Resources

The resources needed to conduct a science-related traverse include equipment, personnel, support infrastructure system, fuel, and supplies. The magnitude of resources utilized may alter or impact the effectiveness of traverse operations as well as the nature and extent of environmental impacts.

Equipment

The equipment that would be used in a science-related traverse will comprise, in general, two or more tracked vehicles towing a series of trailers or other equipment. The size of the powered equipment may be large (e.g., Caterpillar Challenger) if heavy loads are anticipated or small (e.g., Tucker Snocat, Kassbohrer Pisten Bully, LMC Spryte, snowmobiles) if suitable for the intended purpose. Tracked trailers or sled-mounted trailers may be used as well as containers modified for specialized purposes (e.g., ice core storage).

The ITASE traverse activities conducted during the 2002-03 austral summer season provides an example of the type of equipment that may be used on a science-related traverse. The ITASE traverse used two Caterpillar Challenger 55 tractors towing more than ten trailers consisting of modules for personnel support, science equipment, and mechanical workspace, and containers for food, fuel, and related supplies. Each of the Challenger 55 tractors was capable of hauling approximately 20,000 kg of material.

Personnel

The number of personnel and skills used to perform scientific traverses and surface-based surveys would be based on the scientific goals of the mission and the operational needs of the traverse itself such as equipment operators, mechanics, support camp operations, first aid, mountaineering, communications, and spill response. For example, the recent ITASE traverse utilized a total of 13 staff, including the field team leader, nine scientists and technicians, mechanic, camp manager, and cook.

Personnel Support Modules

Personnel support modules for the research and operating crew would be an integral part of each traverse mission. Each traverse is expected to transport at least two personnel modules containing the life support facilities needed for the staff (e.g., berthing, food service, lounge). Separate primary and backup modules would be available to prevent the loss of both in a single accident. The primary and backup modules would be capable of berthing and feeding the whole traverse team, and will include power generation, potable water production, heating, and communications equipment. Unless delayed by weather or mechanical problems, it is expected these facilities would be operated at a different location along the traverse route each day.

Fuel and Supplies

In addition to science-related materials, each traverse would require fuel, lubricants, maintenance supplies, spare parts, food, other expendables, and waste containers. To optimize operations, scientific traverses may be designed to minimize the amount of fuel and supplies that are transported over the entire traverse route by periodically utilizing airlift support or pre-staged field caches for re-supply.

The cargo and liquid containers used on the traverse would be structurally compatible with their contents and able to withstand the physical and environmental conditions to be encountered during the traverse. Fuel tanks would be regularly inspected to detect leaks or potential weaknesses in the containers and empty vessels would be available if emergency transfers were necessary. Other supplies needed for the traverse equipment or maintenance activities such as gasoline, lubricants, and coolants would be transported and stored in 208-liter (55-gal) drums. Each traverse or surface-based survey party would be equipped with the containers needed to collect and manage all wastes generated during the traverse, including solid and hazardous and sanitary wastes.

Support Facilities and Services

Scientific traverses and surface-based survey parties may utilize the facilities and services of a supporting station or outlying facility to facilitate the management of supplies, equipment, or scientific samples. These services may include equipment storage and maintenance, cargo management, interim personnel berthing, and waste management services. As the USAP's largest facility and central supply hub, McMurdo Station is expected to serve as the primary traverse staging and resource facility although other sites may be used as secondary support facilities as well. For example, the recent ITASE traverse used the Byrd Surface Camp as a base of operations for traverse staging and preparation.

4.4.3 Operating Factors

Traverse Configuration and Equipment Load

Each tractor would haul the facilities and materials needed to conduct the intended research as well as personnel support modules, fuel, and supplies needed to support the traverse itself. The load hauled by each tractor would depend on the quantity of equipment and materials to be transported, the terrain to be encountered, and the tractor's performance.

For the recent ITASE traverse from Byrd Surface Camp to the South Pole, each Caterpillar Challenger 55 tractor had the capacity to tow a load of approximately 20,000-kg while consuming fuel at a rate of 29.1 liters per hour.

Schedule

The schedule of scientific traverse activities and surface-based surveys would be designed to meet the specific goals of the project and must be compatible with the schedule for logistical resources needed to support the research efforts. Science-related traverse activities may include periods of travel interspersed between data gathering (e.g., field measurements, sample collection) activities. The travel schedule would be affected by the equipment operating speed and daily operating hours.

In the recent ITASE, a total 1,250 km of terrain was traversed over a 40-day period including stops at several sites occupied for 2-3 days each. Along some sections of the ITASE traverse, snow conditions caused a slower operating speed (5 km per hour) compared to usual travel speeds of 10-12 km per hour.

4.4.4 Field Logistics

Efficient science-related traverse operations require the use of various logistical support mechanisms including the operation of personnel support modules and resources to refuel and maintain the equipment. In addition, the use of fuel caches and supply depots provide the science traverse team with resources which do not have to be transported over the entire route but only have to be accessed when they are needed.

Operation of Personnel Support Modules

Personnel support modules for the science and traverse operating crew would be an integral part of each traverse mission. These modular facilities would provide living facilities for the personnel when the traverse has stopped for the day. When moving, it is expected these facilities would be operated at a different location along the traverse route each day; when stopped for weather or mechanical problems, or for data collection, a several-day occupation can be expected.

The support modules would contain kitchen, berthing and sanitary facilities, space heating equipment, water production equipment and power generation equipment necessary to support the proposed staff. Backup facilities would be available. The modules would also be equipped with a workshop and resources to perform equipment maintenance and minor equipment repair as needed.

All wastes generated during operations of the traverse equipment would be handled in accordance with 45 CFR §671 and documented for the *USAP Master Permit* (reference 3) reporting purposes. All nonhazardous and Antarctic Hazardous wastes generated during the traverse activities would be containerized and returned to a supporting station or outlying facility for further processing and disposition. Sanitary wastes would be either containerized or discharged to snow covered areas as allowed by 45 §CFR 671 and the *USAP Master Permit*.

Equipment Refueling, Maintenance, and Repair

Each science-related traverse or surface-based survey would contain the resources and equipment to refuel the tractors and to perform limited but essential maintenance in the field such as the addition of lubricants and coolants. Based on the type of equipment expected to be used and associated fuel consumption rates, it is anticipated that the tractors would be refueled daily. To prevent accidental releases such as spills to the environment, the traverse crew would follow specific refueling procedures and will use fuel distribution equipment and containment devices (e.g., drip pans, absorbents) appropriate for the conditions.

Depending upon the length of a particular traverse mission, it is expected that minor equipment maintenance activities may be necessary in the field. Although it is unlikely based on the proven reliability of the proposed equipment, it is possible that some equipment may fail and repair would be beyond the capability of the traverse team. In these instances, the disabled equipment could be repaired using parts and mechanics deployed to the field via aircraft; the equipment could be loaded onto a trailer and towed to a supporting facility; or the failed equipment could be secured in the field for subsequent retrieval by a recovery team.

Field Caches

To optimize operational efficiency, it may be useful to temporarily deposit critical supplies for the traverse in field caches and access these materials when they are needed. For example, to support a science-related traverse or surface-based survey, it may be practical to reduce the payload of each tractor by staging fuel for the traverse equipment along the route. These caches could be established by other traverse operations or airlift support. Similarly, it may be practical to leave some fuel and other supplies at strategic locations along the traverse route so that these items could be accessed when needed on the return leg of the traverse as opposed to transporting them for the entire trip.

All supplies that would be temporarily cached along the traverse route will be positioned and marked so that they can be easily located and recovered without damage to the containers. It is expected that all staged or cached supplies would be recovered at the completion of traverse activities each austral summer, although it may be beneficial to pre-stage some materials in the field for the following austral summer season. All field caches would be deployed and managed as specified in the *Standard Operating Procedure for Placement, Management, and Removal of Materials Cached at Field Locations* (reference 1).

4.4.5 Off-season Activities

Most science-related traverse activities are expected to be conducted during the austral summer, typically October through February. During the off-season (austral winter), it is anticipated that all equipment would be stored at or in the vicinity of McMurdo Station and mechanical equipment maintained at the VMF. During the austral winter and in preparation for science-related traverse activities planned for the future, equipment would be selected and customized as needed. In addition, supplies for future field caches would be assembled and prepared for transport to the field.

4.5 Nature and Intensity of Proposed Activities

Surface traverse activities intended to be used for re-supply or scientific research missions would generally include motorized tracked vehicles towing sleds or trailers which contain fuel for the tractors, living and working modules for the traverse personnel, cargo, and other materials as needed. The following describes the nature and extent of the traverse activities used for re-supply and science-related purposes.

4.5.1 Re-supply Traverse

The USAP intends to develop and implement a surface re-supply traverse capability to supplement existing airlift resources and optimize the transportation of fuel, cargo, and supplies to selected USAP facilities. In general, re-supply traverses would consist of a convoy of tractors operating on a routine basis along a marked, improved route.

In order to identify and evaluate potential environmental and organizational impacts associated with the performance of re-supply traverses, the re-supply of the Amundsen-Scott Station has been selected as an example for analysis. Appendix A provides an engineering analysis of the use of the traverse capability to re-supply the Amundsen-Scott Station from McMurdo Station thereby supplementing existing airlift resources. In this analysis, each roundtrip of a traverse team is called a swing. Table 4-1 summarizes various practical alternatives for the re-supply of the Amundsen-Scott Station by surface traverse operations.

Table 4-1. Projected Re-supply Traverse Operations

Alternative	No. of Roundtrips per Season	No. of Tractors Towing Cargo Sleds	Typical Quantity of Cargo Transported per Traverse (kg)	Cargo Delivered per Season (kg)
A (optimal configuration)	6	6	133,000	800,000
B (minimal frequency)	3	6	133,000	400,000
C (reduced intensity)	6	3	67,000	400,000
D (minimal field support)	6	6	128,000	768,000
E (existing routes only)	6	6	133,000	800,000
F (no action)	0	0	0	0

Alternative A – Develop Traverse Capability and Implement Routine Use and Optimal Configuration

The surface re-supply traverse that would be conducted in Alternative A would be optimally configured to be used in conjunction with existing airlift support resources. The South Pole re-supply traverse would utilize the route developed by the proof of concept effort and would consist of six swings per year comprising six tractors per swing. It is expected that the traverse in this alternative will be capable of delivering up to 800,000 kg of cargo and fuel per year to the South Pole.

Based on the traverse distance and route, anticipated equipment operating speed, and 12-hour operating shift per day, each roundtrip from roundtrip from McMurdo Station to the South Pole would require approximately 30 days to complete. The frequency of each traverse would be designed to efficiently accommodate the austral summer operating period of the Amundsen-Scott Station. It is anticipated that the re-supply traverse swings to the South Pole could depart McMurdo Station from 20 October through 15 January while still allowing sufficient time for the complete roundtrip.

Each swing would be configured to accommodate the specific type and quantity of materials scheduled for delivery to the South Pole. It expected that each optimally configured swing would be capable of delivering approximately 133,000 kg of cargo or fuel to the South Pole as well as transporting equipment, fuel, and supplies needed to sustain the operation of traverse. Cargo loads may be increased slightly by using field caches or depots of fuel and supplies strategically placed along the traverse route.

In the optimal configuration for the South Pole re-supply traverse, each swing would be staffed by six people, one operator per tractor. The team would be trained to provide specialized operations and emergency skills. Remote control technology could potentially be used to operate one or more tractors slaved together thereby allowing fewer personnel to operate the traverse.

Alternative B – Develop Surface Traverse Capability and Implement at a Minimal Frequency

Alternative B re-supply traverse activities would occur on the same route and operating conditions as described in Alternative A but would transport less cargo since there would be only three traverse swings per year using six tractors per swing. This alternative would not provide the optimum use of personnel and equipment needed to develop a traverse capability in the USAP.

Alternative C – Develop Surface Traverse Capability and Implement at a Reduced Intensity

Alternative C re-supply traverse activities would occur on the same route and operating conditions as described in Alternative A but would transport less cargo since there would be only three tractors per swing and six swings per season. This alternative may be practical if only a limited amount of traverse equipment was available but it would not be optimal since the re-supply needs of the Amundsen-Scott Station far exceed the amount of cargo that could be delivered.

Alternative D – Develop Surface Traverse Capability and Implement With Minimal Use of Field Support Resources

Re-supply traverse activities that will be conducted in Alternative D would be optimally configured but would be restricted from using field support resources such as field caches, depots, or support camps. The potential benefit in reducing the use of field resources is that hazardous materials ultimately spend less unattended time outside of USAP stations. Each swing that would be conducted in this alternative would need to be configured to transport at all times all of the fuel and materials needed to sustain itself for the entire roundtrip and; therefore, may not realize maximum efficiencies.

Alternative E – Develop Surface Traverse Capability and Implement Using Only Existing Routes

In this alternative, re-supply traverses would be performed using the optimal configuration, but would be limited to using only existing traverse routes in Antarctica. A potential route between McMurdo Station and the Amundsen-Scott Station is being evaluated as part of the ongoing proof of concept study. If this traverse route is determined to be successful, it, as well as existing traverse routes used by other nations, could be utilized for re-supply missions.

Alternative F – The USAP Does Not Develop a Traverse Capability (No Action Alternative)

For the no action alternative, the USAP would not develop a surface traverse capability and would continue to exclusively use airlift resources for re-supply missions. All materials that would be delivered to the Amundsen-Scott Station and other USAP facilities would be subject to the same airlift transport limitations (e.g., size, weight, schedule, weather, flight availability) that must be currently considered for logistics planning. In this alternative, airlift resources currently programmed for re-supply missions could not be reprogrammed to support new surface-based scientific research activities.

4.5.2 Scientific Traverses and Surface-Based Surveys

The USAP as well as other nations currently use science-related traverses or surface-based surveys to support in-field research activities. Since the USAP does not have a fully-developed traverse capability, research proposals requesting traverse support must be addressed on an ad hoc basis using existing resources. The proposed action would provide the USAP with enhanced traverse capabilities to support new research opportunities. In addition, the development and implementation of a USAP capability to support new science-related needs may reduce the reliance on airlift resources.

Because the technical scope of some future research proposals would be specifically designed to employ the use of science-related traverse activities or surface-based surveys, there are no relevant alternatives other than performing the research as proposed or not doing it at all. As such, this environmental review will focus on the identification and evaluation of the potential environmental and organizational impacts associated with the mechanical aspects (e.g., terrain disturbance, exhaust gas emissions, releases of substances to the environment) of performing traverses and surface-based surveys for science-related purposes. Potential impacts associated with the performance of the science-related activities such as ice coring, sample collection, or installation of monitoring equipment would be evaluated in separate environmental reviews, as needed.

As an example, the 2002-03 ITASE traverse (Appendix B) conducted glaciological and atmospheric research along a 1,250 km route and eight designated monitoring locations between Byrd Surface Camp and the South Pole. The traverse comprised two tractors towing more than ten trailers containing science equipment, workspaces, personnel support modules, fuel, and supplies. The 2002-03 ITASE traverse proceeded for approximately 40 days and was staffed by 13 scientists and support personnel.

It is expected that most scientific traverses would be designed to operate with a minimal cargo load by incorporating the strategic use of pre-staged field support resources. The 2002-03 ITASE traverse utilized airlift support to provide field caches of fuel and other supplies at key locations along the traverse route. In this way, the science-related traverse did not have to transport all of the fuel and other supplies needed for the entire expedition. If appropriate to support future research activities, field caches containing fuel, equipment, or supplies may remain in the field for multiple operating seasons.

As needed for the research, workspaces and personnel support modules may be operating while moving and when stopped at temporary camps or monitoring locations. Facilities needed to support these operations include power generators, heaters, a snowmelter, and communication equipment. All wastes would be collected and managed consistent with 45 CFR §671 and procedures for field camp operations describe in the *USAP Master Permit* (reference 3).

Equipment maintenance would be performed as needed during science-related traverse activities available resources. In general, only minor routine or preventative maintenance would be performed. Should the failure of a piece of mechanical equipment be beyond the repair capabilities of the traverse team, either a repair crew will be flown to the site; the equipment would be towed to a supporting facility; or the equipment would be secured in the field and identified for subsequent recovery.

5.0 AFFECTED ENVIRONMENT

5.1 Introduction

The affected environment includes the physical conditions on the Ross Ice Shelf (Section 5.2), Transantarctic Mountains (Section 5.3), and Polar Plateau (Section 5.4). Since traverse activities may have broader impacts, the affected environment also includes the operations at McMurdo Station (Section 5.5) and other USAP Facilities (Section 5.6), scientific research conducted in the USAP (Section 5.7), and social conditions in the Antarctic (Section 5.8) including the historical resources, cultural resources and heritage, and wilderness values. This description of the affected environment represents the initial environmental state (i.e., existing conditions).

The exact locations of surface traverse activities that may be conducted as a result of the proposed action cannot be predicted in this CEE. The scope of this environmental review focuses on potential routes which may traverse ice and snow-covered inland areas (e.g., Ross Ice Shelf, Transantarctic Mountains, Polar Plateau). The scope of this review specifically excludes traverse routes crossing or in proximity to dry land, areas covered by temporary sea ice, areas which support wildlife, and Antarctic Specially Protected Areas (ASPAs). Traverse routes that are planned in areas not specifically addressed by this CEE will require supplemental environmental review.

5.2 Ross Ice Shelf

The Ross Ice Shelf is a large snow-covered body of floating glacial ice located between 155^0 and 160^0 E longitude and 78^0 and 86^0 S latitude in Antarctica and bordered by the Transantarctic Mountains, the McMurdo Ice Shelf, Marie Byrd Land, and the Ross Sea (see Figure 2-4). The ice shelf is approximately 965 km long and covers an area of 540,000 square km. The shelf was formed by inputs from ice streams and glacier flows and is grounded along coastlines and on shallow parts of the Ross Sea. Thickness of the ice shelf ranges from 100 to 900 meters.

The McMurdo Ice Shelf is adjacent to the Ross Ice Shelf near McMurdo Station on Ross Island. The "shear zone" is a four-kilometer long area approximately 35 km from McMurdo Station between the slow, generally westward-moving McMurdo Ice Shelf and the faster, northward-moving Ross Ice Shelf. The shear zone is a heavily-crevassed area that must be crossed to reach areas west of McMurdo Station. As part of the South Pole traverse proof of concept study, a total of 32 crevasses were mitigated in the shear zone during the 2002-03 austral summer to allow safe passage by equipment.

The annual mean temperature recorded at McMurdo Station is -18^0C with temperature extremes of -50^0C and 8^0C. The prevailing wind direction is from the east with an average velocity of 5.1 meters per second (m/sec). The annual average snow accumulation on Ross Island is 17.6 cm (water equivalent). Drifting snow can result in accumulations of 1.5 m or more per year.

5.3 Transantarctic Mountains

The Transantarctic Mountains provide a natural division of Antarctica. They are approximately 3,000 km long, dividing the continental into West Antarctica (30°E to 165°W longitude, moving in an anti-clockwise direction) and East Antarctica (30°E to 165°W longitude, moving in a clockwise direction). The glacier-mantled peaks of the Transantarctic Mountains rise high above the western shore of McMurdo Sound and the Ross Sea, 90 km from Ross Island. Several large valley glaciers flow from the Polar Plateau through gaps in the range, some joining the Ross Ice Shelf and some flowing directly into McMurdo Sound. Nearly 20 glaciers connect the Polar Plateau to the Ross Ice Shelf; many of the largest, including the Beardmore and the Skelton, have been used as surface traverse routes in the past.

Prevailing winds in the Transantarctic Mountains are downslope katabatic (gravity driven), in contrast to the easterly winds of the Ross Ice Shelf. Snow cover in the mountainous areas is variable and is influenced by localized wind and weather patterns.

5.4 Polar Plateau

The interior of Antarctica is composed of two major, geologically distinct parts (i.e., East and West Antarctica) buried under a vast ice sheet (i.e. the Polar Plateau). East Antarctica, the larger of the two, is roughly the size of the United States and is composed of continental crust covered by an ice sheet that averages 2,160 m in thickness. The ice sheet is also composed of two distinct parts. The larger portion, the East Antarctica Ice Sheet, rests on land that is mostly above sea level, while the smaller West Antarctica Ice Sheet is grounded below sea level, in places over 2.5 m below sea level. These two ice sheets cover all but 2.4 percent of Antarctica's 14 million square kilometers. Nearly 90 percent of the ice flowing across West Antarctica converges into ice streams that are the most dynamic, and perhaps unstable, components of the ice sheet. At the South Pole, the ice sheet is approximately 3 km in depth and is constantly shifting, at the rate of about nine meters per year.

Temperatures in the interior of the continent are extremely cold. Earth's lowest surface temperature (-88°C) was recorded at Russia's Vostok Station, and the mean annual temperature at the South Pole is –49.3^{0}C. Temperatures recorded at the South Pole have ranged from a minimum of –80.6 ^{0} C to a maximum of -13.6^{0}C. Mean monthly temperatures range from –60^{0}C in July and August to about –28^{0}C in December and January.

Annual snowfall in much of the interior is less than five centimeters. As the snow accumulates on the surface of the Polar Plateau in the extremely dry and cold atmosphere, it forms what is referred as a “firn”, a very dry form of snow with a mean density near the surface of approximately 0.3 to 0.4 g per cubic centimeter (g/cm^3). The snow compacts with depth until, at approximately 100 m below the surface, it attains a density of about 0.8 g/cm^3 where it has become glacial ice. As the depth of the polar ice sheet increases, density increases and many voids are compressed, forming a very clear and uniform mass of ice relatively free of fissures and cracks.

On the Polar Plateau, the high elevation and the gradually sloping ice sheet provide for a physical environment that yields persistent and predictable winds. The South Pole is located within a persistent polar anticyclone anchored by the elevated continental ice sheet. The average wind speed at the South Pole is typically less than six meters per second, with peak winds rarely over 10 m/sec, and a predominant wind direction of approximately 40 degrees E longitude. Winds that flow down the surface of the ice sheet toward the coast (katabatic winds) commonly reach speeds of 35 m/sec, and maximum measured wind speeds have exceeded 80 m/sec.

5.5 McMurdo Station

McMurdo Station is the largest facility in Antarctica, and is located on the Hut Point Peninsula on Ross Island. The station includes over 100 buildings, comprising research facilities and associated infrastructure. The station operates year-round and can support a peak population of approximately 1,200 people during the austral summer. McMurdo Station serves as the primary logistical support hub for the USAP, and the station resources would be used, as needed, to develop re-supply and scientific traverse capabilities.

The primary resources that McMurdo Station would provide to support a surface traverse capability include equipment and vehicle maintenance services using the Vehicle Maintenance Facility (VMF) and Science Support Center (SSC). The VMF is responsible for maintaining and repairing a fleet of over 140 large- and medium-sized vehicles based in the McMurdo area which cumulatively operate 130,000 hours per year. The SSC maintains and repairs the fleet of smaller vehicles (e.g., snowmobiles, LMC Sprytes, Kassbohrer Pisten Bullies) and powered equipment (e.g., generators, ice drills). Other McMurdo Station resources that would be used to support traverse operations include:

- Temporary personnel support (e.g., berthing, food service)
- Supplies (e.g., food)
- Fuels (e.g., diesel, gasoline)
- Waste management (e.g., containers, handling)
- Weather support
- Communications support
- Airlift support (e.g., airdrops, cargo transport)
- Equipment storage (austral winter)

5.6 Other USAP Facilities

In addition to McMurdo Station, the USAP operates other facilities in Antarctica, including one permanent station at the South Pole (Amundsen-Scott Station), one permanent coastal station on the Antarctic Peninsula (Palmer Station), and permanent support facilities, outlying facilities (e.g., major and minor field camps), unmanned instrumentation sites, and field caches located throughout the continent. Depending on the needs of the USAP, re-supply or scientific traverse missions may be conducted to, or supported by, any of these facilities.

The Amundsen-Scott Station is located on the Polar Plateau at the Geographic South Pole (90^0S) and could be serviced by re-supply traverses or involved in the performance of science-related traverse activities. The station supports a variety of scientific activities, and is occupied year round. Depending on the extent of research and station operations, the austral summer season population may be 150 while the winter population would normally be less than 50 people. The station includes over 60 buildings and various types of towers, antennas, and related structures placed on the snow surface. A 3,000-meter skiway is maintained for ski-equipped aircraft. Logistical support to the station is provided exclusively by ski-equipped LC-130 Hercules aircraft. Most of the LC-130 airlift support resources operated by the USAP each year are used to service the South Pole. Construction of a new primary facility at South Pole has required considerable aircraft support for the delivery of building materials. The new facility is nearing completion, when it is expected that delivery needs will drop to a lower level.

Williams Field, a skiway located 16 km from McMurdo on the snow-covered Ross Ice Shelf, may also be used to support traverse operations during the austral summer. Williams Field comprises a series of ski-mounted structures, facilities, and equipment used for runway maintenance, aircraft support, and logistical support, such as fuel distribution and cargo handling. In addition, Williams Field has several semi-permanent structures and the Long Duration Balloon (LDB) Camp, which is operated each austral summer to support atmospheric science projects. Because the facilities at Williams Field are located on the Ross Ice Shelf and separate from McMurdo Station, it would be a practical location to base a majority of the traverse staging activities such as cargo loading, unloading, and equipment storage.

Each austral summer season, the USAP operates numerous outlying facilities to support scientific research performed at field sites throughout the Antarctic continent. These outlying facilities include:

- Major Field Camps in snow/ice covered areas (typically five per season and occupied more than 400 person-days per year)
- Minor Field Camps in snow/ice covered areas (typically 26 per season and occupied less than 400 person-days per year)

- Minor Field Camps in dry land areas (typically 16 per season and occupied less than 400 person-days per year)
- Minor Field Camps on the seasonal sea ice or coastal areas (typically six per season and occupied more than 200 person-days per year)
- Field Caches (typically 61 per season and unmanned)
- Unmanned Instrumentation Sites (typically 123 per season and unmanned)

Most of the field camps operated by the USAP each year are minor camps possessing few structures (e.g., tents) and are used on a temporary basis (i.e., one or two seasons). Unmanned field caches and instrumentation sites are typically maintained for multiple years. The locations of these outlying facilities will depend on the specific goals of the research to be performed or supported.

5.7 Scientific Research in the USAP

Each year, surface-based scientific research is performed at two of the three U.S. year-round stations (McMurdo, Amundsen–Scott), outlying facilities, and remote field locations, while marine-based research is conducted primarily at Palmer Station and from research vessels operating in the Southern Ocean. Projects supported in Antarctica by the USAP include research in aeronomy and astrophysics, biology and medicine, ocean and climate studies, geology and geophysics, glaciology, and long-term ecological research (LTER). During the 2002-03 austral summer, nearly 700 researchers and special participants conducted 141 projects, including surface traverse-based studies of the International Trans-Antarctic Scientific Expedition (ITASE) in West Antarctica (reference 4).

Scientific traverses may be used to provide a platform for specialized scientific research or advanced surface-based studies in one or more of the research fields. The nature of future surface-based science projects is dependent on the goals of each researcher and cannot be predicted; however, using results derived from recent satellite-based work (e.g., Radarsat, Landsat) and airborne geophysics, the science community has identified the need for the collection of specific data that can allow for the interpretation of the variability of glaciological, geological, climatological, atmospheric, and other parameters on short distance scales (reference 2).

5.8 Social Conditions

Social conditions in Antarctic represent the human environment and include a rich cultural history, as well as the aesthetic resources such as the wilderness value of the vast continent. The historical and cultural resources of Antarctica date back to the early explorations of the continent performed on behalf of many nations. Section 2 provided a description of prominent surface traverse efforts which have contributed both to the cultural history of Antarctic exploration as well as the scientific knowledge gained through the collection of data in the Antarctic environment. While reaching the Geographic South Pole was a primary goal of early 20th century explorers, efforts to map areas of the continent and collect scientific data were also important objectives. As technology and efficient transportation mechanisms progressed, many parts of Antarctica were visited and subsequently became available for study. The human experience in each area of the continent has contributed to the cultural history of the Antarctic, and maps, photographs, journals, and other publications have all played an important role in documenting this history. In recent years, this documentation has expanded through the use of the Internet, and has even incorporated the experience of individual participants involved in specialized activities such as surface traverses. It is expected that these efforts will continue in the future.

Some human activities commemorate Antarctica's exploration. At the Seventh Antarctic Treaty Consultative Meeting it was agreed to create a list of historic sites and monuments. To date, a total of 74 sites have been identified as documented in the *Antarctic Conservation Act of 1978* (Public Law 95-541) and referenced in Article 8 of *Annex V to the Protocol on Environmental Protection to the Antarctic Treaty*. All of the current historic sites and monuments are related to human experiences, and some are located in proximity to scientific stations. In addition, the historical resources of the Ross Island area have been described in the *Historic Guide to Ross Island, Antarctica* (reference 5).

Aesthetic resources of Antarctica are not readily defined, but can generally be characterized as the wilderness value, or an area without permanent improvements or visible evidence of human activity. The remote areas of Antarctica that exist in locations away from established stations, field camps, and infrequently visited terrain allow visitors to experience the remoteness of the continent and the unique Antarctic environment.

6.0 DESCRIPTION OF ENVIRONMENTAL IMPACTS

6.1 Introduction

This portion of the Comprehensive Environmental Evaluation (CEE) identifies potential impacts that may occur as a result of, or in association with, the proposed action to develop and implement surface traverse capabilities in Antarctica. Section 6.2 discusses the methods and sources of data used to identify, quantify, and evaluate the potential impacts. Section 6.3 describes the nature and extent of activities that have the potential to yield impacts to the Antarctic environment resulting from the proposed performance of surface re-supply traverses. Similarly, Section 6.4 identifies potential environmental impacts associated with the performance of science-related traverse activities.

Potential impacts to the environment that are described in Sections 6.3 and 6.4 include operational impacts that may be realized at McMurdo Station, other USAP facilities, including the Amundsen-Scott Station, and potential impacts to scientific research in the USAP and to the social conditions in the Antarctic, including historical, cultural heritage, and wilderness values. Additional impacts that may result from the use of surface traverses include indirect or second-order impacts, cumulative impacts, and unavoidable impacts; they are described accordingly. Section 6.5 presents a summary of all foreseeable potential impacts caused by the development and use of surface traverse capabilities in the USAP.

6.2 Methodology and Data Sources

The proposed action in this CEE involves the development and implementation of surface traverse capabilities by the USAP. A specific purpose or route for future traverse activities cannot be definitively stated at this time. In order to identify and assess potential environmental and operational impacts associated with the use of surface traverse capabilities, two representative traverse examples were selected for analysis. The first involves the re-supply of the Amundsen-Scott Station at the South Pole by surface traverse from McMurdo Station. The second involves the performance of a science-related traverse such as the 2002-03 International Trans Antarctic Scientific Expedition (ITASE). Data available from these two examples serves to characterize typical traverse operations, including equipment and personnel resources, operating factors, field logistics, and other support needs that may have environmental and operational impacts. The methods used to evaluate potential environmental and operational impacts associated with re-supply traverse activities are similar to those described in the Environmental Document and Finding of No Significant and Not More Than Minor or Transitory Environmental Impact entitled *Develop Proof of Concept Traverse from McMurdo Station, Antarctic to the South Pole* (reference 6).

The initial environmental state presented in chapter 5 described the conditions currently existing at the Ross Ice Shelf, Transantarctic Mountains, and Polar Plateau, and selected USAP facilities, in the absence of the proposed action. Potential environmental impacts resulting from operation of USAP facilities and logistical support systems, including aircraft, have already been evaluated in the *U.S. Antarctic Program Final Supplemental Environmental Impact Statement* (reference 7). The USAP provides further continuous monitoring and assessment of potential environmental impacts using data compiled for the *USAP Master Permit* (reference 3). These assessments noted that there are more than minor or transitory impacts associated with land use, air quality, waste management, wastewater discharge, fuel spills, or ecological resources, that these impacts are localized and do not result in a major adverse impact to the environment, and that there are no significant long-term and widespread impacts to human health or the environment resulting from operation of USAP facilities.

Potential impacts of the proposed action were identified and evaluated for the following environmental and operational aspects using data characterizing the examples of re-supply and science-related traverses:

- Physical Disturbance to the Snow/Ice Environment
- Air Quality
- Releases to the Snow/Ice Environment
- Impacts to McMurdo Station Operations
- Impacts to Other USAP Facilities
- Impacts to Scientific Research in the USAP
- Impacts to Social Conditions
- Second Order and Cumulative Impacts

6.2.1 Physical Disturbance to Snow/Ice Environment

The extent of physical disturbances that will result from traverse activities was estimated based on traverse route development activities documented for the Proof of Concept study (reference 6) and traverse operations documented in the US ITASE 2002-2003 Field Report (Appendix B). Additional data characterizing disturbances caused by surface traverse activities performed by other Antarctic Treaty Nations were derived from Comprehensive Environmental Evaluations (CEEs) and preliminary environmental assessment documents (references 18-21).

6.2.2 Air Emissions

Air emissions resulting from the operation of equipment (tractors, electrical power generation, heating, ancillary equipment) were calculated using factors compiled by U.S. EPA (references 8 and 9). These calculations, including emissions factors, are presented in Appendices C and D. Data characterizing the fuel consumption rates for traverse equipment operating under Antarctic conditions were derived from the traverse examples (Appendices A and B). Emission rates from the use of explosives were based on factors compiled by U.S. EPA (reference 8). Logistical support aircraft air emissions were derived from U.S. EPA emissions factors (reference 8), the number of hours flown, and the number of takeoff/landing cycles.

6.2.3 Releases to the Snow/Ice Environment

Releases to the snow/ice environment such as the discharge of wastewater were quantified using various models. The volume of wastewater that would be released by a traverse activity was assumed to be equivalent to the volume of water produced and consumed and was estimated using the average per capita water consumption rate for remote field operations (reference 3) and the projected population. Wastewater pollutant loadings (e.g., BOD, total suspended solids) were calculated based on per capita loading factors (reference 3) and the projected population. Minor releases of irretrievable operational materials expected during route development and maintenance activities (e.g., flags, poles) occur on a random basis and could not be quantified.

Accidental releases may include spills or leaks from containers primarily involving liquids, the unrecoverable loss of equipment, or the dispersal and loss of materials and wastes due to high winds. Since accidental releases are not planned, their frequency, magnitude, and composition cannot be projected in advance. Records of previous USAP spills will be compiled and reviewed to identify the types of equipment and operations that pose the greatest risk for accidental releases. Using this failure analysis information, the USAP will design and specify equipment and procedures for use on surface traverses which minimize the potential for accidental spills. In the event of an accidental release, specific procedures and resources will be available to facilitate cleanup and removal of contaminated media (e.g., snow, ice) to the maximum extent practical (see Chapter 7, Mitigating Measures).

6.2.4 Impacts to McMurdo Station Operations

The projected impacts to McMurdo Station operations were evaluated based on a qualitative review of the proposed traverse activities and potential inter-relationships or conflicts with ongoing station operations such as vehicle maintenance, cargo handling and storage.

6.2.5 Impacts to Other USAP Facility Operations

Projected impacts to other USAP facility operations, including Williams Field and the Amundsen-Scott Station, were evaluated based on a qualitative review of the proposed traverse activities and potential inter-relationships or conflicts with station and facility operations.

6.2.6 Impacts to Scientific Research in the USAP

The impact to other science projects in the USAP was evaluated on a qualitative basis by identifying the potential benefits of traverse capabilities to conducting science in the field and by reviewing the needs of current science projects and identifying potential conflicts with the proposed traverse operations.

6.2.7 Impacts to Social Conditions

The impacts to the social conditions in Antarctica were evaluated by examining the historical development and use of surface traverses in Antarctica, the cultural heritage of Antarctic exploration using surface traverse mechanisms, and the wilderness values of the Antarctic environment that may be affected by such actions. Although comprehensive lists of documented re-supply and science –related traverses have been compiled, see Tables 2-1 and 2-2 respectively, the assessment of potential impacts to social conditions in Antarctica is primarily qualitative.

If the USAP proceeds with the development and implementation of surface traverse capabilities, it is possible that other international entities or nongovernmental organizations (NGOs) may choose to use the traverse routes established by the USAP. There are no sources of information available to definitively suggest the extent to which non-USAP entities may use surface traverse mechanisms or USAP routes. Nonetheless, the recent rise in Antarctic tourism suggests that if tour operators have access to the diverse variety of resources needed to transit the surface in Antarctica, they may use USAP traverse routes as well as those developed by other signatory nations.

6.2.8 Second Order and Cumulative Impacts

Quantitative and qualitative indicators were used to evaluate potential second-order impacts. Quantitative characteristics included the estimated number of logistical support flights that would be deferred as a result of traverse activities. Qualitative indicators were used to identify potential conflicts associated with the addition of more equipment, fuel, and other supplies needed to support the development of traverse capabilities into existing USAP systems. Cumulative impact analysis was performed on a qualitative basis, and took into consideration activities expected to occur at the South Pole and other field sites.

6.3 Environmental Impacts Associated with a Re-supply Traverse

The evaluation of potential environmental impacts associated with surface traverses used for re-supply missions are based on the example of modeled traverse activities between McMurdo Station and the South Pole. The analysis of environmental impacts focuses on physical disturbance, air quality, releases to the environment, and impacts to McMurdo Station operations, other USAP facilities, scientific research, and social conditions (i.e. the human environment). Additional impacts that are addressed include indirect or second-order impacts, cumulative impacts, and unavoidable impacts.

The existing environmental conditions in the areas that could potentially be impacted by the proposed action include the Ross Ice Shelf, Transantarctic Mountains, and Polar Plateau. Impacts to flora and fauna in these areas are not expected since the extremely dry, cold, snow-covered terrain in any of these areas does not support local biota. In addition, these inland areas of the continent are not located near any Antarctic Specially Protected Areas (ASPAs) including marine areas, lakes, or ice-free areas where localized impacts could affect nearby receptors. However, if the traverse capabilities developed as a result of the proposed action are used for re-supply missions in other environmental settings, supplemental environmental reviews would be required to identify potential impacts.

The assessment of the potential environmental and operational impacts described below assumes that selected mitigating measures detailed in Chapter 7 would be implemented as part of re-supply traverse activities. If feasible, additional mitigating measures may be developed that would further reduce potential environmental impacts. Certainly, mitigation techniques and protocols will be validated and perhaps modified as a result of monitoring results.

6.3.1 Physical Disturbance to Snow/Ice Environment

Traverse activities will only occur on snow and ice covered areas. Physical disturbance (i.e., terrain alteration) of the snow and ice environment will be a certain outcome resulting from the use of traverse capabilities along any route. An existing traverse route that may be of practical benefit to the USAP includes the 1,600-km route between McMurdo Station and the South Pole that will be a consequence of the recent Proof of Concept evaluation. All traverse activities involving the development and use of routes in areas different than the environmental conditions characterized in this CEE (i.e., Ross Ice Shelf, Transantarctic Mountains, Polar Plateau) would require subsequent supplemental environmental review.

The specific routes that may be used for re-supply purposes are dependent upon the specific needs of the mission and cannot be defined at this time. Nonetheless, it is assumed that any route will require minimal terrain alteration by grooming the surface to create a drivable path which would be approximately five meters wide. In addition, crevasses would either be avoided where practical, or exposed and filled to mitigate potential human and equipment hazards. The terrain would therefore be altered either through the filling of crevasses or the creation of level surfaces or ramps over low areas. Additional physical disturbances along improved routes may occur during required periodic maintenance (e.g., surface grooming) to ensure continued safe and efficient traverse operations.

If needed, crevasses would be mitigated using snow moved from the surrounding area to fill the opening and provide a stable path across the crevasse at an elevation matching the surrounding surface contour. The area of the crevasse to be filled will be tapered upward to yield a path at the surface sufficiently wide enough to accommodate the traverse equipment. Since many of the crevasses would be covered on the surface by snow bridges, it is anticipated that explosives would be used to collapse the bridges and thoroughly expose the underlying crevasses for subsequent mitigation. In general, it is anticipated that snow bridges would be removed for up to 20 m along the length of each crevasse to ensure that the limit of the crevasse is visible and can be safely mitigated. The area and volume of snow that would be moved from the surrounding area to fill the crevasse and create the path would depend on the depth and width of each crevasse.

While the number and size of crevasses to be mitigated will depend on the specific route, based on the USAP's experience with a route between McMurdo and Amundsen-Scott Stations, the largest crevasses encountered were approximately six meters wide and 55 m deep. This size of crevasse would require approximately 9,500 cubic meters of snow to fill, and would typically utilize fill taken from an adjacent 5,250 m^2 area to a depth of 1.8 meters.

Because an established re-supply traverse route may be used multiple times during a year, it is expected that the snow's surface would be regularly disturbed. However, snow will continue to accumulate in these areas either as new snow or blowing and drifting snow, thereby minimizing the duration of the time the route visually appears to be disturbed. As a result, physical disturbance would represent a transitory impact.

During the development of a traverse route intended to be used for re-supply purposes, markers consisting of bamboo poles with cloth flags would be installed to identify the borders of the route, crevasses, obstacles, or other significant features. The markers are expected to remain in the field and would eventually either disintegrate or become covered with snow and ice. The markers would result in a minor, temporary alteration of the terrain.

Incorporating the use of the mitigating measures identified in Chapter 7 and realizing that the material used to fill a crevasse would be snow and ice native to the surrounding area, the effects of altering the terrain to develop and implement a traverse capability are expected to be localized along the route and virtually negligible. The nature and extent of any additional physical disturbances that may result from the use of established traverse routes by others (e.g., nongovernmental organizations) may include the use of temporary camps, development of spurs to the route, and the risk of additional hazardous materials releases.

Other types of environmental disturbances that would be expected to occur as a result of the proposed action include the generation of noise and vibrations from the traverse vehicles, generators, and ancillary equipment. Individually or combined, these disturbances are not expected to result in a significant impact because they would occur in extremely remote inland areas, with no receptors, and no ecologically sensitive wildlife habitats and be extremely transitory.

6.3.2 Air Emissions

During the use of the proposed USAP traverse capabilities, emissions from the combustion of petroleum hydrocarbon fuels will be released to the atmosphere. These emissions will originate from the internal combustion engines on tractors used to haul trailers, generators and heaters operated for personnel support, and ancillary equipment such as snowmobiles. Table 6-1 presents the estimated annual operating time and fuel usage for equipment used to transport re-supply cargo to the South Pole from McMurdo Station.

Table 6-1. Projected Annual Operating Time and Fuel Usage for Re-supply Traverse Activities

Equipment	Total Operating Time (hours) [1]	Fuel Combustion Rate (L/hr) [2]	Annual Fuel Consumption (liters)		Possible Number of Equipment Refuelings [3]
			Diesel	Gasoline	
Alternatives A (Optimal Configuration), D (Minimal Field Support), & E (Existing Routes Only)					
6 - Tractors (Challenger 95)	12,000	58	700,000		1,000
2 - Snowmobiles	1,000	1		1,200	110
1 - Generator (30 kW)	2,050	12	25,000		60
2 - Heaters	4,100	1.5	6,600		120

Table 6-1. Projected Annual Operating Time and Fuel Usage for Re-supply Traverse Activities

Equipment	Total Operating Time (hours) [1]	Fuel Combustion Rate (L/hr) [2]	Annual Fuel Consumption (liters)		Possible Number of Equipment Refuelings [3]
			Diesel	Gasoline	
Alternative B (Minimal Frequency)					
6 - Tractors (Challenger 95)	6,000	58	350,000		500
2 - Snowmobiles	500	1		600	55
1 - Generator (30 kW)	1,050	12	13,000		30
2 - Heaters	2,050	1.5	3,400		30
Alternative C (Reduced Intensity, Six Swings per Year)					
3 - Tractors (Challenger 95)	6,000	58	350,000		500
2 - Snowmobiles	1,000	1		1,200	110
1 - Generator (30 kW)	2,050	12	25,000		60
2 - Heaters	4,100	1.5	6,600		60

Notes:

[1] Includes time for weather delays and equipment maintenance.

[2] Fuel consumption rate for tractors based on *Analysis of McMurdo to South Pole Traverse as a Means to Increase LC-130 Availability in the USAP* (Appendix A); fuel consumption rates for other equipment based on manufacturer specifications.

[3] Assumes tractors are refueled daily and all other equipment is refueled every third day.

Table 6-2 provides practical comparison of the quantity of cargo that may be transported to the Amundsen-Scott Station if transported by traverse and airlift mechanisms.

Table 6-2. Projected Cargo Transport Amounts for Re-supply Traverses

Alternative	Projected Cargo Transported by Traverse (kg per year)	Traverse Fuel Consumed (liters)	Equivalent LC-130 Resources		Potential Fuel Savings (liters)
			No. of Flights	Fuel (liters)	
A (optimal configuration) or E (existing routes only)	800,000	750,000	69	1,200,000	450,000
B (minimal frequency)	400,000	375,000	35	600,000	225,000
C (reduced intensity)	400,000	375,000	35	600,000	225,000
D (minimal field support)	768,000	750,000	67	1,150,000	400,000
F (no action)		0	0	0	0

Using models developed by the U.S. EPA (references 8 and 9), Table 6-3 summarizes the annual emissions for characteristic air pollutants [sulfur oxides (SO_2), nitrogen oxides (NO_x), carbon monoxide (CO), exhaust hydrocarbons, and particulate matter (PM)] for each re-supply traverse alternative. Additional air emissions data for other fuel combustion byproducts are provided in Appendix C.

Table 6-3. Annual Air Emissions From Surface Re-supply Traverses

Alternative	Cargo Transported (kg)	Fuel Use (liters)	Fuel Combustion Byproducts (kg)				
			Sulfur Oxides	Nitrogen Oxides	Carbon Monoxide	Exhaust Hydro-carbons	Particulates
A, D, or E	800,000	750,000	49.8	27.0	9.9	1.4	2.2
B	400,000	375,000	25.6	13.7	5.0	0.7	1.1
C	400,000	375,000	47.8	21.7	8.2	1.1	1.9
LC-130 Aircraft Transporting an Equivalent Quantity of Cargo							
A, D, or E	800,000	1,200,000	1,358	10,734	7,208	3,210	2,953
B or C	400,000	600,000	688	5,440	3,653	1,627	1,496

Exhaust emissions resulting from the combustion of fuel during re-supply traverse activities are expected to be transitory and dissipate as minor concentrations along the 2000-km traverse route. The exhaust emissions are not expected to adversely impact human health or the environment. For comparison, McMurdo Station, which uses 10 times more fuel in one year than the optimally configured traverse (Alternative A), was monitored continuously and found to be well below U.S. Ambient Air Quality Standards (reference 10). This suggests that if the stationary sources at McMurdo Station do not adversely impact air quality, the mobile sources on the traverse which use far less fuel would also not create adverse impact air quality. Table 6-3 also presents the estimated air emissions from LC-130 aircraft assuming the aircraft are used to transport the same quantity of cargo as the re-supply traverse. In addition to the fuel savings, traverse activities emit far less quantities of air emissions than LC-130 aircraft.

Although most gaseous fuel combustion emissions dissipate in the atmosphere, carbonaceous aerosols (black carbon) have been detected in Antarctica at very low concentrations downwind of exhaust emission sources (references 11, 12, 13). The potential impacts from the deposition of carbonaceous aerosols and other combustion-related particulates may be realized through alterations of the surface albedo, and modifications of snow and ice chemistry. Because traverse activities are transient, particulate emissions although potentially detectable on a short-term basis are not expected to accumulate to levels which would alter the physical and chemical properties of the terrain and create adverse impacts.

Emissions resulting from the use of explosives (e.g., crevasse mitigation) may also be released to the environment. The primary emission byproducts released from explosives include sulfur dioxide (SO_2), nitrogen oxides (NO_x), carbon monoxide (CO), and hydrogen sulfide (H_2S). The impacts resulting from the projected annual use of 10,750 kg of explosives by the USAP were previously evaluated and found not to have more than a minor or transitory effect on the environment (reference 14). During the most recent reporting period for the *USAP Master Permit* (reference 15), a total of 6,400 kg of explosives were used by the USAP throughout Antarctica, yielding emissions of CO (331 kg), NO_x (165 kg), SO_2 (6.37 kg) and H_2S (12.7 kg). If explosives are needed intermittently to support future traverse activities, it is not expected that the total quantity used in the USAP will exceed 10,750 kg per year.

6.3.3 Releases to Snow/Ice Environment

In addition to air emissions, it is expected that other substances may be released to the snow-covered ice sheet as a result of re-supply traverse activities. These releases may include the discharge of wastewater (greywater) in areas where such discharges are permitted and the release of minor materials such as marker flags that cannot be practically retrieved. Accidental releases such as spills to the environment may also occur during traverse activities.

6.3.3.1 Wastewater Discharge

Based on available resources and if practical, wastewater from personnel support operations would be containerized and transported to a supporting USAP facility for disposition. Wastewater would consist of blackwater (i.e., urine and human solid waste) and greywater containing freshwater (made from melted snow and trace residues of soap, food particles, cleaning materials, and personal care products. If needed, wastewater could be discharged to ice pits in snow accumulation areas along the traverse route as allowed by the Antarctic Treaty and the NSF Waste Regulation (45 CFR §671). Optimum wastewater management techniques would be implemented based on available resources (e.g., storage containers, cargo space) and could include a combination of discharge for greywater and containerization for urine and human solid waste. Wastewater would not be discharged to ice-free areas.

Using a model developed for the *USAP Master Permit*, it is estimated that each person at a remote location in Antarctica generates on average 6.88 liters of wastewater (blackwater and greywater) per day. If it is necessary to discharge wastewater in the field, a hole would be dug in the snow at least one meter deep to ensure the waste is isolated from the surrounding environment. The discharged wastewater would become frozen in the ice sheet and thus immobile. Wastewater contains numerous constituents and several general parameters have been used to characterize the pollutant loadings. Pollutant loadings were calculated using per capita loading factors developed for the *USAP Master Permit* (reference 3) and the traverse population. Table 6-4 summarizes the volume of wastewater that may be generated during re-supply traverse activities and associated pollutant loadings.

Table 6-4. Projected Wastewater Generated During Surface Re-supply Traverse Activities

Alternative	**Population (person-days/yr) [1]**	**Wastewater Generated (liters/yr)**	**Possible Number of Discharge Locations per year**
A, D, or E	1,080	7,430	180
B or C	540	3,715	90
Pollutant Loadings (kg/yr) [2]			
Alternative	**Total Suspended Solids**	**Biological Oxygen Demand**	**Ammonia Nitrogen**
A, D, or E	51	108	6
B or C	25	54	3

Notes:

[1] A person-day represents one overnight stay.

[2] Pollutant Loading Factors - Total Suspended Solids (0.047 kg/person-day); Biological Oxygen Demand (0.100 kg/person-day); Ammonia Nitrogen (0.006 kg/person-day)

The combined volume of wastewater projected to be discharged to snow and ice from all field camps operated by the USAP on an annual basis is 45,800 liters (reference 3). If all of the wastewater generated during traverse activities were discharged, the volume released would be a small fraction (i.e., less than 16 percent) of the total volume discharged from all USAP field camps. The impact is therefore expected to be negligible.

6.3.3.2 Other Materials

Minor releases of other materials to the environment are expected to occur occasionally during the implementation of a re-supply traverse. Flags marking the trail, hazards, and other landmarks will remain in the field and will eventually disintegrate or become lost when covered with snow and ice. The occurrence of these releases will be random and their impact is expected to be negligible. Materials released to the environment will be acknowledged each year in the *Annual Report for the USAP Master Permit*.

6.3.3.3 Accidental Releases

Within the Antarctic Treaty, there are a series of operating agreements under which all Antarctic facilities operate including the Protocol on Environmental Protection, which provides guidelines for spill contingency planning. U.S. activities in Antarctica are not only governed by these treaty provisions, but also by direct U.S. regulations as set forth in the Antarctic Conservation Act. These regulations, which require permitting for all activities conducted in Antarctica, also require specific environmental protection practices including spill response and cleanup. Additionally, the USAP voluntarily has adopted pertinent sections of several other U.S.-based regulatory standards as both a practical and "best management practice" approach. These include the National Environmental Policy Act (NEPA), the Resource Conservation and Recovery Act (RCRA), Occupational Safety and Health Agency (OSHA) regulations, and others. Pertinent U.S. environmental legislation specific to oil spills include both U.S. Environmental Protection Agency and U.S. Coast Guard requirements promulgated in response to the Oil Pollution Act of 1990.

Accidental releases may include spills or leaks primarily involving liquids, the unrecoverable loss of equipment, or the dispersal and loss of materials and wastes due to high winds. Since accidental releases are not planned, their frequency, magnitude, and composition cannot be projected in advance. Existing USAP measures will continue to be implemented to prevent accidental releases to the Antarctic environment. In the event of an accidental release, specific procedures and resources will be available to facilitate cleanup and removal of contaminated media (snow, ice) to the maximum extent practical (see Chapter 7, Mitigating Measures). In addition, traverse operations would utilize procedures contained in the *Field Camp Oil Spill Response Guidebook* (reference 16) for spill response actions. All accidental releases would be documented and reported consistent with the requirements of 45 CFR §671 and the *USAP Master Permit*.

During re-supply traverse missions, it is anticipated that fuel and other hazardous materials identified as Designated Pollutants in 45 CFR §671 would be handled or transferred on a daily basis thereby creating a potential for accidental releases. In general, accidental releases occur most often during equipment refueling activities caused by mechanical failures or operator error. During recent proof of concept traverse activities, comprehensive mitigating measures were applied to refueling procedures successfully preventing spills or other accidental releases.

The risk of an accidental release to the Antarctic environment may also be realized from the catastrophic failure of a fuel tank, other storage container, or a vehicle used during a traverse. The containers used on the traverse will be structurally compatible with their contents and able to withstand the physical and environmental conditions to be encountered during the traverse. The USAP will utilize tanks and drums that are suitable for use in Antarctic conditions and compliant with industry standards designed to protect hazardous material containers exposed to handling and transportation stresses.

Fuel tanks would be regularly inspected to detect leaks or potential weaknesses in the containers and empty vessels would be available if emergency transfers were necessary. Although, the benefits of double walled tanks are well known, for traverse applications, double walled tanks are not desirable because it is difficult to reliably detect failures of the inner wall in double wall systems and initiate corrective actions.

Containers that may be temporarily stored on the snow surface will be staged in a manner so that they can be effectively located and recovered without damaging the container upon retrieval. Despite the implementation of spill prevention measures, a minimal risk still exists from the failure or loss of a tank, drum, container, or conveyance (hose, pump) or a serious vehicle failure and the subsequent release of hazardous materials to the environment.

If an accidental release occurs, the extent of localized impacts would depend on the type and quantity of material spilled and the surrounding environmental setting. Consistent with established spill response procedures, primary mitigation would involve source control followed by cleanup including the removal of contaminated snow and ice and the use of sorbent materials if the spill occurred on an impermeable surface. Contaminated snow and sorbents would be packed into drums and removed as waste.

If fuel or other liquid Designated Pollutants (lubricant, coolant) are accidentally released to snow covered surfaces, the material would be expected to migrate vertically in the immediate area of the spill, potentially limiting the effectiveness of spill cleanup actions, and resulting in a long-term but localized impact. In locations with a relatively impermeable surface or subsurface layer a more effective cleanup can be achieved, thereby minimizing impacts. Accidental releases involving the catastrophic and irretrievable loss of equipment, fuel, other Designated Pollutants, or wastes in a crevasse would result in a long-term impact unless the condition of the lost materials permit subsequent recovery. Because implementation of the proposed re-supply traverse capability will not involve areas with seasonal sea ice, open water bodies, or local flora and fauna, impacts associated with an accidental release would be expected to remain localized (horizontally, but not vertically in most cases).

6.3.4 Impacts to McMurdo Station Operations

McMurdo Station is the logistical hub for most of the USAP's operations in Antarctica excluding work done on the peninsula supported by Palmer Station and work performed on research vessels. The proposed capability including the expertise and equipment to operate and support re-supply traverse activities would be based at McMurdo Station. McMurdo Station is likely to provide the following types of support:

- Temporary services for traverse personnel (berthing, food service)
- Maintenance and repair of traverse equipment
- Field support (food, emergency equipment and caches, consumable supplies, waste containers)
- Bulk fuels and fuel transfer facilities
- Waste management
- Weather services
- Communications support
- Airlift support (LC-130, Twin Otter, helicopter)
- Medical support

The logistical and personnel resources needed to support the level of re-supply traverse activities described in this environmental review are currently within the capabilities of McMurdo Station operations. The most significant resources available at McMurdo Station that would be needed to support re-supply traverse activities would involve equipment storage and maintenance functions. Advanced resource planning and careful scheduling would be used to avoid or minimize potential conflicts. Field services (e.g., communications, food, fuel caches) that may be needed to support traverse activities are within levels of support currently provided for numerous field activities each year. Environmentally sound fuel transfer infrastructure would need to be further developed as part of preparations for fuel-delivery surface traverses. The support provided by the annual re-supply vessel, annual fuel tanker, and associated cargo and fuel handling resources, airlift capability, and waste management services coordinated by McMurdo Station have sufficient capacity to accommodate the needs of re-supply traverses.

The use of traverse routes by nongovernmental organizations (NGOs) may potentially impact McMurdo Station operations if the Station has to provide search and rescue (SAR) to these parties in emergency situations. Except in emergencies, the U.S. Government does not support private Antarctic expeditions, and the NSF requires full cost recovery when it gives emergency assistance. Antarctic Treaty and Environmental Protocol requirements enforced by an expedition's country of origin are expected to ensure that any such NGO activities will be planned responsibly.

6.3.5 Impacts to Other USAP Operations

In addition to McMurdo Station, the development and implementation of surface traverse capabilities by the USAP could potentially impact other operations in the USAP. Even though McMurdo Station would serve as a central supply hub for proposed traverse operations, it is expected that the traverse equipment and cargo would be staged at Williams Field, a separate facility and aircraft skiway located on the McMurdo Ice Shelf 10 km from McMurdo Station. Facilities located at Williams Field and currently used to support airlift operations would also be expected to be available for staging proposed traverse operations.

Williams Field runway facilities do not typically operate during the first part of the austral summer season. If Williams Field is used to support traverse activities, additional resources may be needed to install and operate the fuel supply hoseline to McMurdo Station and operate the fuel storage and distribution facilities approximately 12 weeks earlier than the current schedule. Since the seasonal sea ice runway would be operational at the same time, these fuel-handling resources would essentially be duplicated. The primary impacts resulting from the concurrent operation of these facilities would be a slight increased risk of fuel spills and the additional fuel management resources needed to simultaneously operate and inspect two systems for spills and leaks.

Operations at the USAP facilities receiving materials transported by surface re-supply traverse may be impacted differently than if the materials were transported by aircraft. For example, at the Amundsen-Scott Station, the quantity of cargo that may arrive via a single traverse would greatly exceed the quantity of cargo that could be delivered by several aircraft in a day. This impact would be offset by the fact that the cargo would be handled by the traverse crew instead of Station personnel and the cargo itself would be much easier to handle since it would not have to be unloaded from aircraft whose engines must remaining running while at the South Pole.

6.3.6 Impacts to Scientific Research in the USAP

The use of surface traverse capabilities in Antarctica will have localized physical impacts such as terrain alteration and air emissions affecting the snow and ice along the traverse route itself. The route of any traverse will be carefully selected to avoid areas of ongoing scientific research and Antarctic Specially Protected Areas (ASPAs), or other sensitive areas controlled by management plans. Major traverse routes in use will be thoroughly documented so that future scientific research may be designed to avoid these areas if potential conflicts are anticipated. If a new traverse route is planned which comes in proximity to a sensitive area, a supplemental review will be performed of the proposed action to identify potential receptors and mitigating measures including redirection of the traverse route.

Physical disturbances and environmental releases such as air emissions and accidental spills resulting from traverse operations have the potential to affect various types of research such as air monitoring, seismic studies, or investigations requiring undisturbed snow and ice. Traverse activities and surface-based surveys will be planned to avoid areas known to be used for these purposes, but trace levels of residues from traverse operations may be permanently deposited in the snow and ice along the route. Past and active traverse routes used by the USAP would be delineated and mapped so that future scientific research efforts that require undisturbed snow or ice can be designed to avoid potential conflicts in areas of known disturbance.

The availability of surface traverse capabilities in the USAP will yield a positive impact to scientific research by providing an alternative cargo transport mechanism to supplement airlift resources particularly for the transport of large or heavy cargo items. For example, the use of traverse capabilities to re-supply the Amundsen-Scott Station would allow the transport of large instruments, such as telescopes or towers that cannot be performed using current airlift resources. In addition, the balanced use of airlift and traverse transport mechanisms will free-up limited airlift resources thereby allowing aircraft to become more available to support new research opportunities.

6.3.7 Impacts to Social Conditions

As described in Section 2, there is a long and diverse history of the use of surface traverses by numerous nations in Antarctica for re-supply and science-related purposes. The development and use of a traverse capability by the USAP would add to this history and potentially impact some of the social conditions in Antarctica.

The use of a surface traverse route and the associated presence of human activity will result in physical disturbances to the terrain which may be considered a temporary and localized visual impact to the aesthetic and wilderness values of the Antarctic landscape. This type of visual impact may be most noticeable following the performance of re-supply traverses which may use groomed, marked routes on a reoccurring and periodic basis. In general, these physical disturbances would tend to disappear gradually depending on the frequency the route is used and as snow accumulates.

Several decades ago, the United States largely abandoned the use of surface traverses favoring aircraft transport. The U.S. has realized that there is not a single mode of personnel and cargo transport which is effective for every type of cargo. The USAP intends to develop an effective traverse capability to supplement the existing airlift resources and rejoin the Antarctic Treaty nations who continue to use this effective mode of transport.

If the USAP establishes one or more traverse routes, there is the potential that they may be used by other nations or NGOs. The extended use of these routes could increase the environmental impacts. As with all other locations within Antarctica, there is no ownership of the land and all entities are free to operate ships, aircraft, and surface vehicles for peaceful purposes. While the presence of an established traverse route could be used to support operations, research, exploration, or tourism by non-USAP entities, there are many risks which must be managed in order for the venture to be successful. Surface field operations in Antarctica must plan for the physical obstacles, environmental conditions, and logistical support needs that must be considered if a traverse route is to be used. Preparations to meet these challenges will require significant time and resources to ensure success. In addition to the required resources, the length of travel time needed to traverse long distances, combined with the relatively short austral summer season may serve to discourage entities from using established traverse routes except as needed to support ongoing operations or scientific research.

All actions proposed by Antarctica Treaty signatory nations are subject to the environmental impact assessment requirements of the Protocol on Environmental Protection to the Antarctic Treaty (Protocol). Specifically, the assessment procedures set out in Annex I, Environmental Impact Assessment, must be applied to decisions about any activities undertaken in Antarctica pursuant to scientific research programs, tourism and all other governmental and non-governmental activities for which advance notice is required under Article VII (5) of the Antarctic Treaty. Annex I describes the different impact categories as well as the requirements for document circulation and review.

In 1994 the Treaty countries made further recommendations on tourism and non-government activities. This "Guidance for Visitors to the Antarctic" is intended to help visitors become aware of their responsibilities under the treaty and protocol. The document concerns the protection of Antarctic wildlife and protected areas, the respecting of scientific research, personal safety and impact on the environment. Regulations have also been written for the organizers of tourist and private ventures that are subject to U.S. legislation and require prior notification of the trip to the organizer's national authorities, assessment of potential environmental impacts, the ability to cope with environmental emergencies such as oil spills, self-sufficiency, the proper disposal of wastes and respect for the Antarctic environment and research activities. The guidelines outline detailed procedures to be followed during the planning of the trip, when in the Antarctic Treaty area and on completion of the trip.

6.3.8 Indirect or Second Order Impacts

The primary indirect or second order impact that may be realized as a result of the development and implementation of surface traverse capabilities is related to a reduction in the level of airlift resources currently allocated to support re-supply missions. As shown in the example to use traverse capabilities to supplement current airlift resources for the re-supply of the Amundsen-Scott Station, approximately 70 LC-130 flights representing 400 flight hours may become available through the use of surface traverse capabilities (Alternatives A and E). The USAP could use these airlift resources to enhance support to existing or spawn new research opportunities in Antarctica while providing a more efficient mode of transport for certain types of cargo.

As previously described, the existing logistical and personnel support systems of the USAP at McMurdo Station have sufficient capacity to support the efforts associated with the development and use of surface traverse capabilities without significant conflicts.

6.3.9 Cumulative Impacts

A cumulative impact is the combined impact of past and present activities as well as those which may occur in the foreseeable future. The primary cumulative impacts that will result from the use of traverse capabilities by the USAP would be associated with repeated use of traverses for re-supply purposes. Potential cumulative impacts would result from the repeated deposition of particulate exhaust emissions on snow and ice surfaces and the release of wastewater and other substances in the environment. Although these impacts would be highly localized to the traverse route and therefore minor, the effects would be persistent and more than transitory. The cumulative impacts would remain relatively isolated and would not be expected to adversely impact human health or the Antarctic environment. Similarly, the use of surface traverse capabilities would not be significant when combined with the impacts from other activities typically performed at various field locations in Antarctica.

6.3.10 Unavoidable Impacts

Unavoidable impacts are those which are inherent to the proposed action and cannot be fully mitigated or eliminated if the action is completed. Unavoidable impacts resulting from the use of surface traverse capabilities include the physical disturbance of the surface along the traverse route, the release of fuel combustion byproducts from the operation of traverse and personnel support equipment, and the temporary occupation of wilderness areas.

6.4 Environmental Impacts Associated with Science Traverses

To identify and evaluate potential impacts associated with scientific traverses and surface-based surveys, the International Trans Antarctic Scientific Expedition (ITASE) traverse recently conducted by the USAP between Byrd Surface Camp and the South Pole was selected as a representative example of a typical scientific traverse. The analysis of environmental impacts focuses on physical disturbance, air quality, releases to the environment and impacts to McMurdo Station operations, other USAP facilities, scientific research, and social conditions in the Antarctic. Additional impacts that are addressed include indirect or second order impacts, cumulative impacts, and unavoidable impacts.

6.4.1 Physical Disturbance to Snow/Ice Environment

The nature and extent of science traverse and surface-based survey activities will be defined by the intended research and will generally involve the physical disturbance of snow and ice areas. Areas characterized in this CEE and potentially impacted by science-related traverse activities include the Ross Ice Shelf, Transantarctic Mountains, and Polar Plateau. Research activities conducted in other environmental settings (e.g., coastal areas, dry land) will require supplemental environmental review.

It is expected that science-related traverses would typically proceed on undeveloped routes in the areas intended for the research but could also use routes established by other entities (i.e., nations) for other purposes. Because science-related traverses are not expected to be used repeatedly, a science traverse would probably try to circumnavigate and avoid crevasses as opposed to filling them for mitigation. Should crevasse mitigation be necessary for safe passage, explosives may be used to expose the crevasse and native snow and ice would be used to fill the void. The effects associated with filling crevasses (i.e., terrain alteration) are expected to be negligible and localized to the traverse route.

Other types of environmental disturbances that would be expected to occur as a result of the proposed action include the generation of noise and vibrations from the traverse vehicles, generators, and ancillary equipment. Individually or combined, these disturbances are not expected to result in a significant impact because they would occur in extremely remote inland areas, with no receptors, and no ecologically sensitive wildlife habitats.

6.4.2 Air Emissions

During the use of USAP traverse capabilities for science-related applications, emissions from the combustion of petroleum hydrocarbon fuels will be released to the atmosphere. These emissions will originate from the internal combustion engines on tractors used to haul trailers, generators and heaters operated for personnel support, and ancillary equipment such as snowmobiles. Table 6-5 presents the estimated operating time and fuel consumption amounts for equipment used to perform a typical scientific traverse.

Table 6-5. Projected Operating Time and Fuel Consumption for a Typical Science-related Traverse

Equipment	Annual Operating Time (hours) [1]	Fuel Combustion Rate (L/hr)[2]	Annual Fuel Consumption (liters)	
			Diesel	Gasoline
2 - Tractors (Challenger 55)	1,000	30	30,000	0
2 - Snowmobiles	500	1	0	575
1 - Generator (30 kW combined capacity)	500	12	6,000	0
4 – Heaters	2,000	1.5	3,000	0

Notes:

[1] Days of operation includes time weather delays and equipment maintenance.

[2] Fuel consumption rate for tractors based on data presented in the *US ITASE 2002-2003 Field Report* (Appendix B). Fuel consumption rates for other equipment based on manufacturer specifications and average operating conditions.

Table 6-6 summarizes the annual emissions for characteristic air pollutant emissions (i.e., sulfur oxides, nitrogen oxides, carbon monoxide, exhaust hydrocarbons, and particulate matter) for each science-related traverse performed. Additional air emissions data for other fuel combustion byproducts are provided in Appendix C.

Table 6-6. Air Emissions From a Typical Science-related Traverse

Fuel Use (liters)	Fuel Combustion Byproducts (kg)				
	Sulfur Oxides	Nitrogen Oxides	Carbon Monoxide	Exhaust Hydrocarbons	Particulates
40,000	21	7.8	3.1	0.4	0.8

Exhaust emissions resulting from the combustion of fuel during relatively short-term scientific traverse activities are expected to be transitory and dissipate as the traverse proceeds along the route. The exhaust emissions are not expected to adversely impact human health or the environment. For comparison, fuel combustion emissions at McMurdo Station, the USAP's largest station and logistical support hub, were measured and determined to have no significant impact on air quality (reference 10). Carbonaceous aerosols (black carbon) have also been measured downwind of exhaust emissions sources in Antarctica (references 11, 12, 13) and, while detected at low concentrations, were found to have no significant impact on the surface albedo or snow and ice chemistry. These observations suggest that because science-related traverse activities use far less fuel than stations operations, gaseous and particulate emissions although potentially detectable are not expected to accumulate to levels which would alter the physical and chemical properties of the terrain or create adverse impacts.

Emissions (SO_2, NO_x, CO, and H_2S) from explosives used to mitigate crevasse hazards during scientific traverses or surface-based surveys may also be released to the environment. It is highly unlikely that explosives will be needed since explosives were not use during four recent years of ITASE traverse activities. If explosives are needed, it is not expected that the quantity of explosives used would be significant.

6.4.3 Releases to Snow/Ice Environment

In addition to air emissions, it is expected that other substances may be released to the snow-covered ice sheet as a result of re-supply traverse activities. These releases may include the discharge of wastewater (greywater) in areas where such discharges are permitted and the release of minor materials such as marker flags that cannot be practically retrieved. Accidental releases such as spills to the environment potentially could also occur during traverse activities.

6.4.3.1 Wastewater Discharge

Based on available resources and if practical, wastewater from personnel support operations would be containerized and transported to a supporting USAP facility for disposition. Wastewater would consist of blackwater (i.e., urine and human solid waste) and greywater containing freshwater made from melted snow and trace residues of soap, food particles, cleaning materials, and personal care products. If needed, wastewater could be discharged to ice pits in snow accumulation areas along the traverse route as allowed by the Antarctic Treaty and the NSF Waste Regulation (45 CFR §671). Optimum wastewater management techniques would be implemented based on available resources (e.g., storage containers, cargo space) and could include a combination of discharge for greywater and containerization for urine and human solid waste. Wastewater would not be discharged to ice-free areas.

Using a model developed for the *USAP Master Permit*, it is estimated that each person at a remote location in Antarctica generates on average 6.88 liters of wastewater (blackwater and greywater) per day. If it is necessary to discharge wastewater in the field, a hole would be dug in the snow at least one meter deep to ensure the waste is isolated from the surrounding environment. The discharged wastewater would become frozen in the ice sheet and immobile. Table 6-7 provides estimates of the volume of wastewater that may be generated and discharged and associated pollutant loadings.

Table 6-7. Projected Wastewater Generated During a Typical Science-related Traverse

Population (person-days) [1]	Wastewater Generation Volume (liters)	Possible Number of Discharge Locations per year
520	3,600	40
Pollutant Loadings [2]		
Total Suspended Solids (kg)	**Biological Oxygen Demand (kg)**	**Ammonia Nitrogen (kg)**
25	50	3

Notes:
[1] A person-day represents one overnight stay
[2] Pollutant Loading Factors:
Total Suspended Solids (0.047 kg/person-day)
Biological Oxygen Demand (0.100 kg/person-day)
Ammonia Nitrogen (0.006 kg/person-day)

6.4.3.2 Other Materials

Minor releases of materials to the environment are expected to occur occasionally during the implementation of a re-supply traverse. Flags marking the trail, hazards, and other landmarks will remain in the field and will eventually disintegrate or become lost when covered with snow and ice. Other types of traverse-related materials that may be released on a random basis include cables or anchoring devices. The type and quantity of these releases will be dependent on the type of field research activities performed. Supplemental environmental reviews will be performed for science-related activities which involve the deployment of specialized pieces of equipment which will not or can not be retrieved. Materials released to the environment will be acknowledged each year in the *Annual Report for the USAP Master Permit*.

6.4.3.3 Accidental Releases

Within the Antarctic Treaty, there are a series of operating agreements under which all Antarctic facilities operate including the Protocol on Environmental Protection, which provides guidelines for spill contingency planning. U.S. activities in Antarctica are not only governed by these treaty provisions, but also by direct U.S. regulations as set forth in the Antarctic Conservation Act. These regulations, which require permitting for all activities conducted in Antarctica, also require specific environmental protection practices including spill response and cleanup. Additionally, the USAP voluntarily has adopted pertinent sections of several other U.S.-based regulatory standards as both a practical and "best management practice" approach. These include the National Environmental Policy Act (NEPA), the Resource Conservation and Recovery Act (RCRA), Occupational Safety and Health Agency (OSHA) regulations, and others. Pertinent U.S. environmental legislation specific to oil spills include both U.S. Environmental Protection Agency and U.S. Coast Guard requirements promulgated in response to the Oil Pollution Act of 1990.

Accidental releases may include spills or leaks primarily involving liquids, the unrecoverable loss of equipment, or the dispersal and loss of materials and wastes due to high winds. Since accidental releases are not planned, their frequency, magnitude, and composition cannot be projected in advance. Existing USAP measures will continue to be implemented to prevent accidental releases to the Antarctic environment. In the event of an accidental release, specific procedures and resources will be available to facilitate cleanup and removal of contaminated media (snow, ice) to the maximum extent practical (see Chapter 7, Mitigating Measures). In addition, traverse operations would utilize procedures contained in the *Field Camp Oil Spill Response Guidebook* (reference 16) for spill response actions. All accidental releases would be documented and reported consistent with the requirements of 45 CFR §671 and the *USAP Master Permit*.

During science-related traverse missions, it is anticipated that fuel and other hazardous materials identified as Designated Pollutants in 45 CFR §671 would be handled or transferred on a daily basis thereby creating a potential for accidental releases. In general, accidental releases occur most often during equipment refueling activities caused by mechanical failures or operator error. During recent ITASE traverses performed by the USAP, comprehensive mitigating measures were applied to refueling procedures successfully preventing spills or other accidental releases.

The risk of an accidental release to the Antarctic environment may also be realized from the catastrophic failure of a fuel tank, other storage container, or a vehicle used during a traverse. Results from the analysis of previous spills and container failures in the USAP will be used to design and specify equipment and procedures which minimizes the risk of releases during surface traverse activities. The containers used for traverse activities will be structurally compatible with their contents and able to withstand the physical and environmental (e.g., temperature) conditions to be encountered during the traverse. Bulk storage tanks would be regularly inspected to detect leaks or potential weaknesses in the containers and empty vessels would be available if emergency transfers were necessary.

It is expected that either full or empty mobile storage tanks or drums used to transport fuel and other bulk liquids needed for the operation of the traverse equipment may be stored on a traverse route. Containers temporarily stored on the snow surface will be staged in a manner so that they can be effectively located and recovered without damaging the container upon retrieval.

Since the equipment used to conduct a science-related traverse may not be configured to transport all of the fuel and other consumable supplies needed for an extended traverse mission, airlift support may be used to periodically re-supply the traverse. Re-supply may occur directly from LC-130 aircraft which land near the traverse equipment or through the retrieval of supplies airdropped or placed in field caches along the traverse route. To minimize the risk of accidental releases resulting from the use of temporary field caches of fuel or other materials, the materials will be placed on the snow surface in a manner to protect the contents and facilitate effective retrieval without damage to the container.

Airdropped materials may be accidentally released to the environment if the containers are damaged or land in conditions where the materials are lost and cannot be recovered. During the 2002-2003 ITASE traverse activities, a total of 96 drums of fuel on 24 pallets were airdropped at four sites along the traverse route. Although the airdrop parachutes failed on five of the 24 deployments causing the pallets to be buried in the snow, all drums were recovered intact with no discernible loss of fuel.

Despite the implementation of spill prevention measures, a minimal risk still exists from the failure or loss of a tank, drum, container, or conveyance (hose, pump) or a serious vehicle or airdrop failure and the subsequent release of hazardous materials to the environment. If an accidental release occurs, the extent of localized impacts would depend on the type and quantity of material spilled and the surrounding environmental setting. Consistent with established spill response procedures, primary mitigation would involve source control followed by cleanup including the removal of contaminated snow and ice and the use of sorbent materials if the spill occurred on an impermeable surface. Contaminated snow and sorbents would be packed into drums and removed as waste.

If fuel or other liquid Designated Pollutants (lubricant, coolant) are accidentally released to snow covered surfaces, the material would be expected to migrate vertically in the immediate area of the spill, potentially limiting the effectiveness of spill cleanup actions, and resulting in a long-term but localized impact. In locations with a relatively impermeable surface or subsurface layer a more effective cleanup can be achieved, thereby minimizing impacts. Accidental releases involving the catastrophic and irretrievable loss of equipment, fuel, other Designated Pollutants, or wastes in a crevasse would result in a long-term impact unless the condition of the lost materials permit subsequent recovery. Because implementation of science-related traverses addressed by this environmental review will not involve areas with seasonal sea ice, open water bodies, or local flora and fauna, impacts associated with an accidental release would be expected to remain localized (horizontally, but not vertically in most cases).

6.4.4 Impacts to McMurdo Station Operations

McMurdo Station is the logistical hub for most of the USAP's operations in Antarctica excluding work done on the peninsula supported by Palmer Station and work performed on research vessels. The proposed capability including the expertise and equipment is an enhancement of the resources that McMurdo Station has provided in the past to support science-related traverse activities. McMurdo Station is likely to provide the following types of support:

- Temporary services for traverse personnel (berthing, food service)
- Maintenance and repair of traverse equipment
- Field support (food, emergency equipment and caches, consumable supplies, waste containers)
- Bulk fuels
- Waste management
- Weather services

- Communications support
- Airlift support (LC-130, Twin Otter, helicopter)
- Medical support

The logistical and personnel resources needed to support the level of science-related traverse activities described in this environmental review are currently within the capabilities of McMurdo Station operations. The most significant resources available at McMurdo Station that would be needed to support any type of traverse activities would involve equipment storage and maintenance functions. Advanced resource planning and careful scheduling would be used to avoid or minimize potential conflicts. Field services (e.g., communications, food, fuel caches) that may be needed to support traverse activities are within levels of support currently provided for numerous field activities each year.

6.4.5 Impacts to Other USAP Operations

It is anticipated that McMurdo Station will serve as the central supply hub for most USAP science-related traverse activities. Depending on the nature of the intended research, other facilities (e.g., Amundsen-Scott Station, Byrd Surface Camp) may be used as supply depots or locations where equipment may be temporarily stored. The stops at these facilities would be integral to the research and planned accordingly, therefore no adverse impacts to facility operations would be expected.

6.4.6 Impacts to Scientific Research in the USAP

The use of surface traverse capabilities in Antarctica will have localized physical impacts (i.e., terrain alteration, air emissions) on the snow and ice along the traverse route itself. The route of any traverse will be carefully selected to avoid areas of ongoing scientific research and Antarctic Specially Protected Areas (ASPAs), or other sensitive areas controlled by management plans. Traverse routes in use will be thoroughly documented so that future scientific research may be designed to avoid these areas if potential conflicts are anticipated. If a new traverse route is planned which comes in proximity to a sensitive area (e.g., ASPA), a supplemental review will be performed of the proposed action to identify potential receptors and mitigating measures including redirection of the traverse route.

Physical disturbances and environmental releases (e.g., air emissions, accidental spills) resulting from traverse operations have the potential to affect various types of research such as air monitoring, seismic studies, or investigations requiring undisturbed snow and ice. Traverse activities and surface-based surveys will be planned to avoid areas known to be used for these purposes, but trace levels of residues from traverse operations may be permanently deposited in the snow and ice along the route. Past and active traverse routes used by the USAP would be delineated and mapped so that future scientific research efforts that require undisturbed snow or ice can be designed to avoid potential conflicts in areas of known disturbance.

The availability of surface traverse capabilities in the USAP will yield a positive impact to scientific research by providing an alternative cargo transport mechanism to supplement airlift resources particularly for the transport of large or heavy cargo items. For example, the use of traverse capabilities to re-supply the Amundsen-Scott Station would allow the transport of large instruments, such as telescopes or towers that cannot be performed using current airlift resources. In addition, the balanced use of airlift and traverse transport mechanisms will decrease the reliance on aircraft thereby allowing the USAP airlift resources to become available for other purposes.

Surface traverse capabilities will also provide a platform to potentially supplement a greater variety of scientific research projects or advanced surface-based survey activities in Antarctica. As documented in the recent ITASE experience, the availability of surface traverse capabilities can provide researchers with a mobile, interactive venue for research along geographical corridors similar to that afforded by large field camps but without the limitations of fixed camp-based data collection efforts. For example, conducting traverse-based research on a routine basis will allow the high-resolution sampling of glaciological parameters (in particular, accurate snow accumulation and temperature measurements), subglacial geology (through high resolution seismics), meteorology, climate sciences, and aeronomy. It is expected that the availability of surface traverse resources may result in a paradigm shift in the scientific community, and that scientists will propose innovative investigations that cannot yet be predicted.

6.4.7 Impacts to Social Conditions

As described in Chapter 2, there is a long and diverse history of the use of surface traverses by numerous nations in Antarctica for science-related purposes. The development and use of a traverse capability by the USAP would add to this history and potentially impact some of the social conditions in Antarctica.

The use of surface traverses to conduct surface-based scientific research and the associated presence of human activity will result in physical disturbances to the terrain which may be considered a temporary and localized visual impact to the aesthetic and wilderness values of the Antarctic landscape. Visual impacts resulting from science-related traverses or surface-based surveys would be expected to be barely noticeable, since the route may be traveled only once or much less frequently than re-supply traverse missions. The physical disturbances would be expected to disappear gradually after the traverse is completed as snow continues to accumulate along the traverse route.

For the past several decades, the United States preferred the use of aircraft resources to support scientific activities at field sites and largely abandoned the use of surface traverses. The U.S. has realized that for some types of research there is a developing need to collect data on smaller distance scales which may not be effectively supported solely by airlift resources. The USAP intends to develop traverse capabilities to effectively provide a support mechanism for surface-based research and rejoin the Antarctic Treaty nations who continue to use these resources as an integral component of scientific studies.

6.4.8 Indirect or Second Order Impacts

The use of surface traverse capabilities by the USAP for science-related research purposes is not anticipated to result in any significant indirect or second order impacts. The scope of this CEE focuses on the use of traverse equipment to provide a mobile platform for the performance of research investigations. Potential impacts associated with the research methods proposed for use on science-related traverse missions will undergo separate environmental reviews.

6.4.9 Cumulative Impacts

A cumulative impact is the combined impact of past and present activities as well as those which may occur in the foreseeable future. Similar to other scientific research activities performed by the USAP each year, science-related traverse activities or surface-based surveys will, by design, generally take place in undisturbed areas on a short-term basis. Therefore, no significant cumulative impacts are expected from these activities.

6.4.10 Unavoidable Impacts

Unavoidable impacts are those which are inherent to the proposed action and cannot be fully mitigated or eliminated if the action is completed. Unavoidable impacts resulting from the use of surface traverse capabilities include the physical disturbance of the surface along the traverse route, the release of fuel combustion byproducts from the operation of traverse and personnel support equipment, and the temporary occupation of wilderness areas.

6.5 Summary of Impacts

The potential impacts from the use of surface traverse capabilities for either re-supply or scientific purposes have been identified and evaluated consistent with the Guidelines for Environmental Impact Assessment in Antarctica (reference 17). Table 6-8 summarizes the criteria used to evaluate the significance of the potential impacts relative to the extent, duration, intensity, and reversibility of each activity as well as the probability of its occurrence. Table 6-9 summarizes all potential environmental and operational impacts that may be caused by re-supply traverse activities, and Table 6-10 summarizes the impacts that may be caused by scientific traverses and surface-based surveys.

Table 6-8. Criteria for Assessment of Potential Impacts on the Environment

		Criteria of Assessment			
Impact	**Environment**	**Low (L)**	**Medium (M)**	**High (H)**	**Very High (VH)**
EXTENT	*Air* *Snow/ice* *Terrestrial* *Aesthetic & Wilderness*	*Local extent* Action results in an isolated impact and confined to the site where the action occurred	*Partial extent* Action is isolated but possibly may migrate and affect surrounding area	*Major extent* Initially the action is isolated but likely to migrate and affect surrounding environment	*Entire extent* Large-scale impact along the entire traverse; migration will cause further impact
DURATION	*Air* *Snow/ice* *Terrestrial* *Aesthetic & Wilderness*	*Short term* Several weeks to one season; short compared to natural processes	*Medium term* Several seasons to several years	*Long term* Decades	*Permanent* Environment will suffer permanent impact
INTENSITY	*Air* *Snow/ice* *Terrestrial* *Aesthetic & Wilderness*	*Minimal Affect* Natural functions and processes of the environment are not affected	*Affected* Natural functions or processes of the environment are affected, but on a moderate or short-term basis	*High* Natural functions or processes of the environment are affected and changed	*Extensive* Natural functions or processes of the environment are fully disrupted and adversely impacted
REVERS-IBILITY	*Air* *Snow/ice* *Terrestrial* *Aesthetic & Wilderness*	*Reversible* Impacts are reversible; the affected environment will return to its initial state	*Affected* Impacts are essentially irreversible but are isolated and do not significantly interact with the surrounding environment	*High* Impacts are irreversible and may alter the surrounding environment over the long term	*Irreversible* Impacts will result in permanent changes and adversely affect the environment
PROB-ABILITY		Impact should not occur under normal traverse operations and conditions	Impact possible but unlikely	Impact likely or probable to occur during traverse operations	Impact inherent to the proposed action and unavoidable

Table 6-9. Summary of Environmental and Operational Impacts from Re-supply Traverses

Activity	Duration of Activity	Output	Environmental and Operational Impacts (legend Table 6-8)						Mitigating Measures (Table 7-1) [1]
			Affected Environment	Extent	Duration	Intensity	Reversibility	Probability	
Crevasse Mitigation	As Needed (mitigation only required during initial route development)	Emissions from the use of explosives	Air	L	L	L	L	H	2.2
			Snow/Ice	L	L	L	M	H	2.2
		Physical Disturbance– terrain alteration	Snow/Ice	L	L	L	M	H	2.2
		Physical Disturbance - noise, vibration, EM radiation	Snow/Ice	L	L	L	L	M	2.2
			Other Research Projects	L	L	M	L	L	2.2 7.1 - 7.2
Operation of Tractors	Daily, 120 days per austral summer	Exhaust Emissions	Air	L	L	L	L	VH	3.1 - 3.2
			Snow/Ice	L	H	L	M	VH	3.1 - 3.2
		Physical Disturbance – terrain alteration	Snow/Ice	L	L	L	M	VH	2.1
		Physical Disturbance - noise, vibration, EM radiation	Snow/Ice	L	L	L	L	VH	2.1
			Other Research Projects	L	L	L	L	VH	7.1 - 7.2
			Wildlife	L	L	L	L	L	7.3
		Visual Indicators – markers, groomed surfaces	Aesthetic & Wilderness Values	L	L	L	M	H	8.1 - 8.3
Power Generation	Daily, 120 days per austral summer	Exhaust Emissions	Air	L	L	L	L	VH	3.1 – 3.2
			Snow/Ice	L	M	L	M	VH	3.1 – 3.2

Table 6-9. Summary of Environmental and Operational Impacts from Re-supply Traverses

Activity	Duration of Activity	Output	Environmental and Operational Impacts (legend Table 6-8)						Mitigating Measures (Table 7-1) [1]
			Affected Environment	Extent	Duration	Intensity	Reversibility	Probability	
Personnel Support	As Needed (up to 120 days per austral summer)	Wastewater discharge (no discharge unless waste cannot be containerized)	Snow/Ice	L	L	L	M	M	4.1 – 4.2
Fuel Storage and Handling	Daily, 120 days per austral summer	Accidental Releases/Spills	Snow/Ice	M	M	M	M	M	4.4 – 4.6
Hazardous Materials Management	Daily, 120 days per austral summer	Accidental Releases/Spills	Snow/Ice	L	M	M	M	L	10.1 – 10.4
Waste Management	Daily, 120 days per austral summer	Accidental Releases/Spills	Snow/Ice	L	M	L	M	L	11.1 – 11.3
Field Logistics (field caches, airdrops)	Austral summer (120 days)	Physical Disturbance	Snow/Ice	L	M	L	L	M	4.3
		Release of Irretrievable Materials	Snow/Ice	L	M	L	M	L	4.3, 4.7
		Accidental Releases/Spills	Snow/Ice	L	M	M	M	L	4.3, 4.7
Logistics Support - McMurdo Station	Year-round	Increased equipment maintenance, storage, field ops support	McMurdo Station Operations	L	L	L	M	VH	5.1 – 5.2

Table 6-9. Summary of Environmental and Operational Impacts from Re-supply Traverses

Activity	Duration of Activity	Output	Environmental and Operational Impacts (legend Table 6-8)						Mitigating Measures (Table 7-1) [1]
			Affected Environment	Extent	Duration	Intensity	Reversibility	Probability	
Logistics Support – Other USAP Facilities	Austral summer (120 days)	Equipment and cargo staging, fuel distribution	Facility Operations	L	M	M	L	H	6.1

Note:
[1] Mitigating measures involving traverse design and planning (1.1-1.3) and impact monitoring (9.1-9.5) will be applied to each activity as appropriate.

Table 6-10. Summary of Environmental and Operational Impacts from Typical Science-Related Traverses

			Environmental and Operational Impacts (legend Table 6-8)						
Activity	**Duration of Activity**	**Output**	**Affected Environment**	**Extent**	**Duration**	**Intensity**	**Reversibility**	**Probability**	**Mitigating Measures (Table 7-1) [1]**
Operation of Tractors	As Needed Based on Research (one austral summer or less)	Exhaust Emissions	Air	L	L	L	L	VH	3.1 – 3.2
			Snow/Ice	L	M	L	M	VH	3.1 – 3.2
		Physical Disturbance – terrain alteration	Snow/Ice	L	L	L	M	VH	2.1
		Physical Disturbance - noise, vibration, EM radiation	Snow/Ice	L	L	L	L	VH	2.1
			Other Research Projects	L	L	L	L	VH	7.1 – 7.2
			Wildlife	L	L	L	L	L	7.3
Crevasse Mitigation	As Needed (mitigation will only be used if crevasses cannot be avoided)	Emissions - Explosives	Air	L	L	L	L	L	2.2
			Snow/Ice	L	L	L	M	L	2.2
		Physical Disturbance– terrain alteration	Snow/Ice	L	L	L	M	L	2.2
		Physical Disturbance - noise, vibration, EM radiation	Snow/Ice	L	L	L	L	L	2.2
			Other Research Projects	L	L	L	L	L	2.2 7.1 – 7.2
Power Generation	As Needed Based on Research (one austral summer or less)	Exhaust Emissions	Air	L	L	L	L	H	3.1 – 3.2
			Snow/Ice	L	L	L	M	H	3.1 – 3.2

Table 6-10. Summary of Environmental and Operational Impacts from Typical Science-Related Traverses

Activity	Duration of Activity	Output	Environmental and Operational Impacts (legend Table 6-8)						Mitigating Measures (Table 7-1) [1]
			Affected Environment	Extent	Duration	Intensity	Reversibility	Probability	
Personnel Support	As Needed Based on Research (one austral summer or less)	Wastewater discharge (no discharge unless waste cannot be containerized)	Snow/Ice	L	L	L	M	M	4.1 – 4.2
Fuel Storage and Handling	As Needed Based on Research (one austral summer or less)	Accidental Releases/Spills	Snow/Ice	L	L	M	M	M	4.4 – 4.6
Hazardous Materials Management	Daily, 120 days per austral summer	Accidental Releases/Spills	Snow/Ice	L	L	M	M	L	10.1 – 10.4
Waste Management	As Needed Based on Research (one austral summer or less)	Accidental Releases/Spills	Snow/Ice	L	L	L	M	L	11.1 – 11.3

Table 6-10. Summary of Environmental and Operational Impacts from Typical Science-Related Traverses

Activity	Duration of Activity	Output	Environmental and Operational Impacts (legend Table 6-8)						Mitigating Measures (Table 7-1) [1]
			Affected Environment	Extent	Duration	Intensity	Reversibility	Probability	
Field Logistics (field caches, airdrops)	As Needed Based on Research (one austral summer or less)	Physical Disturbance	Snow/Ice	L	L	L	L	H	4.3
		Release of Irretrievable Materials	Snow/Ice	L	L	L	M	L	4.3, 4.7
		Accidental Releases/Spills	Snow/Ice	L	L	M	M	M	4.3, 4.7
Logistics Support - McMurdo Station	As Needed Based on Research	Increased Equipment maintenance, storage, field ops support	McMurdo Station Operations	L	L	L	M	H	5.1 – 5.2
Logistics Support – Other USAP Facilities	As Needed Based on Research (one austral summer or less)	Equipment and cargo staging, fuel distribution	Facility Operations	L	L	L	L	L	6.1

Note:
[1] Mitigating measures involving traverse design and planning (1.1-1.3) and impact monitoring (9.1-9.5) will be applied to each activity as appropriate.

7.0 MITIGATION OF ENVIRONMENTAL IMPACTS AND MONITORING

7.1 Introduction

Mitigating measures represent specific actions that may be taken to reduce or avoid potentially adverse impacts to the environment or related impacts to the USAP. This chapter of the Comprehensive Environmental Evaluation (CEE) describes measures that will be taken or are under consideration to mitigate (i.e., reduce or avoid) impacts to the environment and USAP operations resulting from the development and use of surface traverse capabilities. This section also describes the activities that will be conducted to monitor and document impacts of traverses that may be performed as a result of the proposed action and, if appropriate, trigger corrective action.

7.2 Mitigating Measures

A list of mitigating measures applicable to re-supply and science-related traverses and surface-based surveys is presented in Table 7-1. The mitigating measures relate to the potential impacts discussed in Chapter 6, and include a series of measures that would be implemented during the planning and design phases of traverse activities.

The mitigating measures have been designed to be flexible and address a variety of conditions that may be encountered. Some of the proposed mitigating measures have already been incorporated into various field procedures used by the USAP. In addition, Table 7-1 includes mitigating measures which are applicable to the environmental requirements of the *USAP Master Permit* such as the management of Designated Pollutants (i.e., hazardous materials), the management and disposition of all hazardous and nonhazardous wastes, the control of substances released to the environment, and the monitoring of environmental conditions and impacts.

The most significant series of mitigating measures are initiated during the planning and preparation stages of a traverse or surface-based survey activity and well before the actual field work is underway. Frequently more than a year in advance, the specific goals of a traverse are compiled, resource specifications and procedures needed to accomplish the mission are developed, equipment is procured and staged, and personnel are trained. During the planning and preparation stages, features are built into the design of the proposed traverse activity to ensure that the resources needed to conduct the traverse and mitigate potential impacts are appropriately available. Organizational impacts related to USAP facilities that may be involved in the proposed action may be effectively mitigated through advanced planning, scheduling, and allocation of resources and facilities.

Prior to the initiation of traverse activities, the USAP will develop an impact monitoring strategy to detect, if any, temporal and spatial changes caused by traverse operations. Environmental impact assessment would be conducted during all phases of operations, particularly during the planning phases to ensure that resources are adequately available to support mitigating measures and minimize environmental impacts. Through a regular process the USAP performs a preliminary review of proposed actions, including operations and research activities, to identify potential environmental impacts and to identify those impacts which have not been previously evaluated in environmental documents such as Records of Environmental Review (ROERs), Initial Environmental Evaluations (IEEs), and Comprehensive Environmental Evaluations (CEEs). Where warranted, further environmental evaluation, development of specific mitigating measures and subsequent documentation is performed. Proposed activities involving surface traverses will also undergo this review, and activities in a different environmental setting or having the potential to yield impacts that have not been identified in this CEE will be subject to a supplemental environmental evaluation.

Table 7-1. Summary of Mitigating Measures

Aspect	Mitigating Measure
Traverse Design and Planning (1.0)	1.1 Traverse route: • The surface route selected for traverse operations should be designed to meet the goals of the mission (re-supply, scientific research) and minimize disturbances to the environment • The route should be located in areas where traverse operations and unplanned events such as accidental releases will not adversely impact the sensitive regions of the surrounding environment. Maintain a minimum distance of 250 meters from Antarctic Specially Protected Areas (ASPAs) • If a traverse route is located near a marine environment, ASPA, or other sensitive area, perform a supplemental environmental review to determine the impact of proposed activities
	1.2 Equipment, personnel support resources, and staffing: • The size and number of tractors and trailers/sleds should be appropriate to support the goals of the mission (e.g., re-supply, scientific research) and the environmental conditions (e.g., slope, snow cover) expected during the traverse • The number of personnel assigned to the traverse should be appropriate to meet the goals of the mission and provide an adequate margin of safety • Utilize tractors of proven design and operability characteristics (e.g., maintenance) for surface applications. Tractors should be designed to minimize energy use and production of exhaust emissions • Trailers should be optimally configured for the conditions (e.g., high axles, skis or tracks aligned to those of the lead tractor) • Facilities needed for personnel support and research (e.g., power generation, water production equipment) should be designed to minimize energy use and the production of exhaust emissions. Consider using solar energy or alternative fuels to diesel or gasoline (e.g., propane) • Traverse support equipment (e.g., trailers, personnel modules) should be designed to adequately accommodate the storage of all Designated Pollutants (i.e., hazardous materials) used during the traverse • Traverse support equipment and resources (e.g., containers) should be provided to adequately contain and store all wastes generated during the traverse • Traverse equipment and resources for material transfers (e.g., refueling) should be designed for that purpose and incorporate spill prevention features • Traverse operating procedures will be designed to include regular inspections (e.g., at least daily) to prompt rapid response if a release or pending container failure is detected. • Traverse support equipment and resources should be provided to enable spill response (e.g., shovels, absorbents, waste drums) and the adequate transfer and containment of material from any damaged or leaking vessel • Utilize procedures contained in the *Field Camp Oil Spill Response Guidebook* for spill response actions and develop supplements as needed to address traverse activities • Provide spill response training to traverse personnel
	1.3 Traverse planning should address the following activities and incorporate additional mitigating measures as appropriate to minimize or avoid impacts to the environment:

Table 7-1. Summary of Mitigating Measures

Aspect	Mitigating Measure
	• Operation of personnel support facilities • Wastewater management • Deployment, use, and decommissioning of field caches • Use of airdrops • Establishment of temporary support camps or stopover location
Physical Disturbance to Snow/Ice Environment (2.0)	2.1 Minimize the amount of terrain alteration or disturbance during operation of personnel support modules by confining activities to areas on or immediately adjacent to the designated traverse route
	2.2 Mitigate crevasse hazards through avoidance, if possible. If physical crevasse hazard mitigation (i.e., filling) is necessary, minimize impacts by: • Limiting the extent of crevasse exposure (i.e., removal of snow bridges) to the length required for safe operations and filling crevasses only to the extent needed to allow safe passage by the traverse equipment • Filling crevasses with surrounding native materials
Air Emissions (3.0) **Releases to the Snow/Ice Environment (4.0)**	3.1 Perform regular preventive maintenance on traverse equipment, based on operating hours or other maintenance criteria, to sustain optimal performance and reduce emissions.
	3.2 Shutdown equipment when not in use to minimize exhaust emissions and utilize engine heaters or equivalent devices to minimize idling of diesel-powered equipment, if practical
	4.1 Prohibit wastewater discharges in areas where the ice-flow may terminate in ice-free or blue ice areas of high ablation
	4.2 Limit wastewater discharges to the maximum extent practical and containerize and transport the wastewater to a supporting USAP facility for disposition. In areas where wastewater is discharged: • Limit wastewater discharges to one disposal pit per support module location • Limit wastewater discharges to urine and greywater • If wastewater is to be discharged to an ice sheet, the disposal pit should be at least one m deep to effectively isolate the waste from the surrounding environment • Prohibit the discharge of wastewater on the surface of the terrain • Prohibit discharge of materials containing Designated Pollutants (e.g., chemicals, fuel wastes, lubricants, glycol) • Record the approximate volume of wastewater discharged at each location during support module operations
	4.3 Use of caches or temporary storage areas: • If equipment, materials, or supplies are cached along the traverse route, store the materials in a manner to prevent them from becoming encrusted in snow and ice (e.g. store on pallets) and possibly damaged upon retrieval • Mark and document storage locations to prevent the materials from becoming lost or irretrievable • If airdrops of fuel, materials, or supplies are conducted to support traverse operations, recover all packaging materials (e.g., pallets, parachutes) • Inspect airdropped containers for signs of damage and remediate any spills or leaks immediately
	4.4 Material transfers: • Develop and implement a consistent approach for material transfers (e.g., refueling) and equipment maintenance operations that incorporates spill prevention

Table 7-1. Summary of Mitigating Measures

Aspect	Mitigating Measure
	techniques including the use of containment devices • Drain portable pumps, hoses, and nozzles after use and store in appropriate containment structures • Following all fuel transfers and equipment maintenance operations, inspect adjacent areas for signs of spills or leaks and remediate immediately
	4.5 Inspect the following daily to detect leaks or damage: • Bulk fuel storage tanks, pipelines, valves, distribution pumps, and hoses • Equipment (generator, heater) tanks, fuel lines • Vehicles (e.g., fuel tanks, oil pans, hydraulic lines, coolant systems) • Storage containers (e.g., drums containing fuel, oil, glycol)
	4.6 Cleanup leaks or spills immediately following their detection to the maximum extent practical, manage resulting contaminated materials as Antarctic Hazardous waste, and report all spills and remedial actions as required by 45 CFR §671
	4.7 Report all lost equipment or instruments as required by 45 CFR §671
Impacts to McMurdo Station Operations (5.0)	5.1 Plan traverse operations and support activities sufficiently in advance to minimize impacts to McMurdo Station operations
	5.2 Conduct traverse staging operations at a location which will not conflict with normal station operations
Impacts to Other USAP Operations (6.0)	6.1 Incorporate scheduled traverse operations into the planning process to ensure affected USAP facility operations and potential conflicts can be adequately identified
Impacts to Scientific Research in the USAP (7.0)	7.1 Prohibit traverse operations in ASPAs unless specifically required for scientific research and conducted in accordance with applicable restrictions
	7.2 Avoid traverse operations near known sensitive scientific areas (e.g., air, seismic monitoring) unless required for scientific research
	7.3 Avoid disturbing wildlife and maintain at a minimum the following separation from animals or receptors: 250 meters (tractors), 150 meters (snowmobiles), 15 meters (on foot)
Impacts to Social Conditions (8.0)	8.1 Avoid traverse operations near historic sites and monuments and maintain minimum vehicle separation of 50 meters when moving
	8.2 Minimize the amount of disturbed snow surface by having vehicles follow the path of the lead vehicle as much as possible
	8.3 Preserve the aesthetic value of the areas surrounding traverse routes by limiting the placement of markers and flags to those quantities needed to maintain safe operations
	8.4 Avoid the discharge of wastewater to the maximum extent practical
	8.5 Deny use of USAP resources by NGOs
Impact Monitoring (9.0)	9.1 Perform an environmental review of all planned traverse field operations and research efforts to identify those activities which may have the potential to yield impacts to the environment. Develop appropriate mitigating measures with traverse planners accordingly
	9.2 Develop a comprehensive monitoring plan for traverse activities which identifies the temporal and spatial parameters to be measured to assess impacts
	9.3 Incorporate traverse activities into the *Permit Reporting Program* to document

Table 7-1. Summary of Mitigating Measures

Aspect	Mitigating Measure
	activities conducted each year that can be used to evaluate environmental impacts (e.g., fuel combustion, waste generation, environmental releases)
	9.4 Audit USAP traverse activities as a whole annually to (1) verify that activities are being performed as planned, (2) collect data to provide a comparison of the measured or observed impacts to the predicted impacts, and (3) suggest or develop corrective actions as necessary to mitigate increased or unexpected impacts
	9.5 Record the locations of traverse activities, including description and quantity of: • materials remaining in the field (e.g., caches) • releases to the environment from operations • releases to the environment from scientific research • accidental releases (e.g., spills)
Hazardous Material Management (10.0)	10.1 Store all materials containing hazardous materials (i.e., Designated Pollutants) in containers which are compatible with the contents and are structurally adequate to accommodate the handling and stresses associated with transport on the traverse
	10.2 Utilize bulk fuel storage tanks specifically designed for transportation applications which include protection against structural damage if filled tanks are transported over rough terrain
	10.3 Limit materials containing Designated Pollutants (e.g., fuel, oil, glycol) used for traverse activities and personnel support operations to the types and amounts needed, including adequate safety margins
	10.4 Minimize the storage of materials containing Designated Pollutants in the field during the austral winter. If Designated Pollutants, equipment, supplies, or wastes are temporarily stored along the traverse route during the operating season or during the austral winter: • Mark and document storage locations to prevent the materials from becoming lost • Store containers (e.g., tanks, drums) in a manner to prevent them from becoming encrusted in snow and ice and possibly damaged upon retrieval • Store containers in a manner to prevent accidental releases to the environment • Regularly inspect bulk storage tanks to detect leaks and potential weaknesses in the containers • Provide empty vessels so that primary storage tanks can be emptied if a leak or potential weakness in the container is detected • Recover and return all items to a supporting USAP facility for disposition by the end of the following austral summer season
Waste Management (11.0)	11.1 Provide resources (e.g., containers) to manage all wastes generated during the traverse consistent with the requirements of the *Waste Management Plan and Users Guidance* and: • Contain all wastes to avoid releases to the environment (e.g., light objects being scattered by the wind) • Segregate and label Antarctic Hazardous waste and nonhazardous waste streams • Secure wastes during transport
	11.2 Inspect Antarctic Hazardous waste containers for leakage or deterioration on a weekly basis and document the inspections per the *NSF Waste regulation* (45 CFR §671.11(b))
	11.3 If practical, containerize all sanitary wastewater and greywater for transport to a supporting facility. If transport of sanitary wastewater is not practical, only discharge urine and greywater (per 45 CFR 671) and containerize human solid waste

Table 7-1. Summary of Mitigating Measures

Aspect	Mitigating Measure
	(see mitigating measure 4.2)
	11.4 Minimize the storage of nonhazardous wastes and Antarctic Hazardous wastes in the field during the austral winter. If wastes are temporarily stored along the traverse route during the operating season or during the austral winter: • Mark and record storage locations to prevent the materials from becoming lost • Store containers (e.g., tanks, drums) in a manner to prevent them from becoming encrusted in snow and ice and possibly damaged upon retrieval • Store containers in a manner to prevent accidental releases to the environment • Return all wastes cached during the austral winter to a supporting USAP facility for disposition by the end of the following austral summer season

7.3 Environmental Reporting and Review

All activities associated with the use of surface traverses that relate to potential environmental impacts and compliance with U.S. environmental regulations will be documented and systematically evaluated. For example, the U.S. Waste Regulation (45 CFR §671) is applicable to all U. S. activities in Antarctica. The Waste Regulation establishes requirements for the issuance of Permits and associated reporting with respect to the management of Designated Pollutants (i.e., hazardous materials), the management and disposition of wastes generated in Antarctica, and release of any substances into the environment. Pursuant to the Waste Regulation, NSF has issued the *USAP Master Permit* (reference 3) to the civilian support contractor, Raytheon Polar Services Company (RPSC) for the period 1 October 1999 through 30 September 2004. The current Permit is expected to be renewed on 1 October 2004. Traverse activities conducted in Antarctica will be subject to the terms and conditions of the applicable *USAP Master Permit.*

By 30 June of each year, RPSC (the Permit holder) prepares the *Annual Report for the USAP Master Permit* documenting activities conducted for the previous 12-month period at permanent stations and individual outlying facilities and field sites, regarding waste management and releases to the environment. All traverse activities related to wastes and releases will be included in the Annual Report. In addition, the Permit holder will conduct an annual review to verify that the activities described in the Master Permit including those associated with any traverses are accurate and representative. Any revised conditions and significant changes will be identified and documented accordingly in subsequent *Amendments to the USAP Master Permit.*

The Permit holder has established a formal process to gather data needed for Permit reporting purposes known as the *Permit Reporting Program*. The program was designed to collect Permit-related information in an efficient and consistent manner addressing all activities conducted under the Permit at each permanent station and each individual outlying facility operated in the USAP. Relevant information pertaining to traverse activities will be included in the *Permit Reporting Program* for subsequent use in the *Annual Report for the USAP Master Permit* and the *Amendments to the USAP Master Permit*.

Data obtained through the *Permit Reporting Program* will also be used to characterize activities and conditions that are used both to assess and monitor environmental impacts. For example, Permit-related parameters that are reported and evaluated each year include fuel consumption and associated air emissions, waste generation and disposition, and planned and accidental releases to the environment. These parameters will be reviewed to identify conditions which are significantly different than those described in the *USAP Master Permit*. Data pertaining to traverses and regularly obtained through the *Permit Reporting Program* will be evaluated based on the conditions and potential impacts assessed in this Comprehensive Environmental Evaluation.

8.0 GAPS IN KNOWLEDGE AND UNCERTAINTIES

8.1 Introduction

The scope of this environmental review was designed to primarily focus on the operational aspects of conducting traverse activities in Antarctica. Specialized activities specific to a single project (e.g., instrument deployment, sample collection, construction of a new facility) and not in common with general traverse activities will require subsequent characterization and supplemental environmental review. This chapter describes several basic assumptions associated with the USAP's intention to develop and implement a traverse capability and identifies data gaps or uncertainties that may affect this evaluation of impacts.

8.2 Basic Assumptions

The development and use of surface traverse capabilities is certain to provide measurable benefits to the USAP. The traverse capabilities that are being considered represent a known and viable transport mechanism that would be used to optimally complement, not replace, existing airlift resources. The availability of both surface traverse and airlift transport capabilities would allow the USAP to select an efficient and environmentally sensitive method which is best suited for the intended mission.

For many years, other nations have successfully performed traverses to re-supply inland facilities in Antarctica using equipment and procedures similar to the proposed action. It has also been proven that traverses are a useful tool for the performance of scientific research, as indicated by the history of Antarctic traverses by many nations, including those performed recently as part of the extensive International Trans Antarctic Scientific Expedition (ITASE).

The extent that the USAP may utilize the proposed traverse capabilities in a given year is dependent on the variable logistical and research needs of the program. Similarly, the extent of field support resources that will be provided will be dependent upon the specific needs of the traverse mission. It is expected that McMurdo Station resources would provide most of the support to future USAP traverse operations, and some traverse missions may also utilize USAP field support resources such as airlift transported supplies, field caches, or airdrops. The levels of external support evaluated in this environmental review are representative of the available USAP resources expected to be used to support traverse activities for the foreseeable future. Because these support activities must be planned and scheduled well in advance, activities involving impacts which are substantially different that those identified in this environmental review would be assessed separately.

This environmental review focuses on the mechanical aspects of performing traverse or surface-based survey activities for re-supply or science-related purposes. These activities are comparable to the vast Antarctic traverse experience of the international community. There is no indication that the basic parameters used to characterize these traverse activities or associated support activities will change significantly from the conditions identified and evaluated in this review. Future traverse activities which would be performed under operating conditions or environmental settings that are significantly different than those described in this CEE would undergo supplemental environmental review. Therefore, there are no major data gaps or uncertainties related to the development and implementation of traverse capabilities that could materially affect the conclusions of this environmental review.

8.3 Uncertainties

The technical information related to the proposed action and evaluated in this environmental review was derived from two examples, a McMurdo to South Pole re-supply proof of concept traverse currently under evaluation, and the operational performance data from the recent ITASE traverse performed by the USAP. Based on data from these examples, potential environmental impacts for traverse operations were identified and evaluated relevant to the environmental conditions defined in this CEE. Uncertainties may exist with respect to the performance of traverse activities that occur under conditions different than those as characterized by the examples.

Traverse operating conditions which have the potential to influence the evaluation of environmental impacts include the route, equipment, and logistical approach. Impacts associated within a range of operating conditions have been characterized in this review; therefore, any variations are not expected to significantly affect the output of the activities or alter the conclusions. The following identifies possible data gaps or uncertainties in these areas.

The specific route that may be utilized in the future for either re-supply or scientific research missions is dependent on the specific needs of the USAP at the time the traverse is planned. This environmental review focused on potential impacts in three broad snow or ice-covered areas including the Ross Ice Shelf, the Transantarctic Mountains, and the Polar Plateau. Proposed traverse activities in areas significantly different than these such as Antarctic Specially Protected Areas or ice-free areas would require supplemental environmental review. Along a specific route, the extent of terrain alteration activities that may be needed for a traverse is dependent on the local environmental conditions including crevasses, sastrugi, and snow drifts. The number and size of crevasses that may require mitigation by filling for safe passage cannot be predicted nor can the extent of surface grooming needed for safe and efficient passage of the traverse equipment.

The number, type, size, and configuration of traverse equipment that would comprise a particular traverse activity are dependent on the needs of the mission. The configuration of equipment evaluated in this environmental review is representative of typical USAP traverse activities in the foreseeable future. It is expected that the configuration of future traverse missions would incorporate factors currently under proof of concept evaluation and would utilize operating experience gained from previous traverse missions performed by the U.S. and others.

Each surface traverse conducted by the USAP will require development of a customized operating strategy designed to meet the specific objectives of the mission. Operating parameters that may affect the nature and intensity of proposed traverse activities and influence related impacts include:

- Number of traverse trips (single, roundtrip, multiple)
- Operating schedule (total duration, number of travel hours per day)
- Number of people (operators, scientists)
- Number of traverse stops (temporary camps, rest stops, research locations)
- Substances released to the environment (exhaust emissions, wastewater discharge)
- Field maintenance and repair activities
- Use of temporary field storage areas for traverse equipment, fuel, or supplies

There is a large range and combination of operating parameters that may be considered for any particular traverse mission. The operating parameters evaluated in this environmental review are representative of typical USAP traverse activities for the foreseeable future.

8.4 Estimation Methods

Uncertainty is inherent in the methods that were used in this environmental review to estimate releases to the environment. Generic models were used to estimate fuel combustion exhaust emissions from traverse equipment and the potential discharge of wastewater in snow and ice-covered areas.

Generic emissions models were used to estimate exhaust gas emissions since actual testing data for traverse equipment operating under Antarctic conditions are not available. Emission factors were selected to best represent the type and size of equipment being characterized. In general, these models are used by regulatory authorities and risk assessors to provide estimates of exhaust emissions. Because these models do not account for fuel combustion efficiencies or emission standards that may be met by currently available equipment, the emission factors generally represent a conservative estimate, therefore actual emissions are expected to be less.

The projected quantity of wastewater that could potentially be discharged and the resulting pollutant loadings were quantified using per capita wastewater production rates developed for field operations and described in the *USAP Master Permit*. These models are applied to USAP operations throughout Antarctica for Permit reporting purposes and are reviewed each year. Inaccuracies in the estimates derived from these models are not expected to affect the conclusions derived from this environmental review. To the maximum extent practical, wastewater discharges will be avoided.

9.0 CONCLUSIONS

9.1 Introduction

This Comprehensive Environmental Evaluation (CEE) identified the potential impacts associated with the development and implementation of surface traverse capabilities by the USAP. The scope of the proposed action is unique because it encompasses all traverse operations that may be performed by the USAP not just those exclusively for a specific purpose (re-supply, science-related research), only for a designated period of time, or along a single route.

The USAP proposes to use surface traverse capabilities in conjunction with existing airlift resources to efficiently transport cargo and conduct field-related scientific research in a safe and environmentally responsive manner. Currently the USAP does not possess a robust and fully mature traverse capability. The traverse activities that the USAP has accomplished to date have been done on a very limited scale using available equipment that may not be the best suited for the intended application.

Potential environmental impacts associated with typical surface traverse activities were identified and evaluated using two scenarios. The first example involved the re-supply of the Amundsen-Scott Station from McMurdo Station using traverse methods currently undergoing engineering evaluation in a proof of concept study. To evaluate potential impacts associated with scientific traverses and surface-based surveys, the International Trans Antarctic Scientific Expedition (ITASE) of which the USAP is a participant was selected as a second representative example for the use of the traverse capability.

The methods used to identify and evaluate the impacts of the proposed activities are consistent with the *Guidelines for Environmental Impact Assessment in Antarctica* (reference 17) and are similar to those used in recent CEEs prepared for similar types of proposed activities in Antarctica, including the Draft *Comprehensive Environmental Evaluation for ANDRILL* (reference 18) and the *Comprehensive Environmental Impact Evaluation for Recovering a Deep Ice Core in Dronning Maud Land, Antarctica* (reference 19). In addition, the methods are consistent with those used for two preliminary assessments of the environmental impacts for traverse activities performed by the Australian National Antarctic Research Expedition, *Preliminary Assessment Of Environmental Impacts of Autumn Traverse From Mawson Station To LGB6, 250 Km To The South, To Depot Fuel For The PCMEGA Expedition In The 2002/03 Summer* (reference 20) and *Preliminary Assessment of Environmental Impacts PCMGA Expedition In The 2002/03 Summer* (reference 21).

9.2 Benefits of the Proposed Action

The proposed action is intended to supplement the USAP's current airlift capability to transport cargo and support in-field scientific research. Benefits realized by the implementation of a traverse capability include:

- The availability of a transport option that may be better suited than aircraft for certain types of cargo (e.g., size, weight), logistical needs, environmental conditions (e.g., severe weather), or in-field research requirements.
- Reduced fuel consumption for re-supply missions, since each tractor can haul approximately twice the cargo as a fully laden LC-130 for the same fuel investment. Less fuel consumed directly relates to fewer exhaust gas air emissions.
- Reduced reliance on airlift resources that may facilitate a reduction in the number of missions or allow the aircraft to become available for other purposes.

- Ability to operate under a broader range of Antarctic conditions than aircraft. If needed, traverse equipment may be able to operate earlier and later during an austral summer season than aircraft.
- Reduced station-based cargo handling support because re-supply traverse personnel may be used to load and unload cargo.
- Established traverse routes may provide proven corridors to facilitate and enhance in-field scientific research.
- Robust traverse capabilities may provide the resources needed to conduct more comprehensive in-field research.

9.3 Physical Disturbances to the Snow/Ice Environment

The traverse activities being considered in this environmental review would only occur on snow and ice covered areas. By the nature of the proposed action, traverse activities would unavoidably disturb the surface of the terrain. Although the disturbance would be primarily confined to the width of the traverse route, the impact may be more than minor since the route could extend hundreds of kilometers. The number of reoccurring traverses on a particular route remains unknown as it depends on the intended goals of the mission. Depending on the route, crevasses which cannot be avoided would be filled with native snow and ice to facilitate safe passage of the traverse equipment. The natural processes of wind action and snow accumulation will obliterate visual evidence of vehicle traffic over a short period of time resulting in only a temporary impact. Physical disturbance impacts caused by proposed USAP traverse activities on areas containing ice sheets, glaciers, and the Polar Plateau are therefore considered to be low.

Undoubtedly, the performance of surface traverses will cause physical disturbances to the Antarctic environment and alter the wilderness value. These disturbances will be transitory and consistent with present and historical uses of traverse resources to foster the progress of Antarctic exploration. It is expected that the physical benefits derived from the use of traverse resources by the USAP for scientific research and operational support will far exceed any diminishment of the pristine character of the environment.

9.4 Air Emissions

The combustion of fuel and the resulting release of exhaust byproducts to the atmosphere will be an unavoidable consequence of the proposed action to conduct surface traverse operations using mechanized equipment. Although the volume of fuel consumed and the resulting air emissions may be significant for a particular traverse mission, the exhaust gases and particulates are expected to rapidly dissipate in the atmosphere downwind along the extent of the traverse route. These emissions may be visually noticeable or detectable near their sources, but the emissions are not expected to pose a long-term or adverse impact to the air quality or surface albedo.

Exhaust emissions resulting from the combustion of fuel during traverse activities are expected to be transitory and dissipate as the traverse proceeds along the route. For comparison, the air quality at McMurdo Station, which uses considerably more fuel in one year than a typical traverse, was monitored continuously for a year and was found to be well below the Ambient Air Quality Standards in the United States. This suggests that if the stationary sources at McMurdo Station do not adversely impact the environment, likewise the mobile sources on the traverse which use far less fuel would not have an adverse impact. In addition, to transport the same quantity of cargo, traverse operations use less fuel and emit far fewer exhaust emissions than the LC-130 aircraft currently used by the USAP in Antarctica.

9.5 Releases to Snow/Ice Environment

Various types of materials or substances may be released to the snow and ice environment either intentionally or accidentally during the performance of traverse activities. Objects deployed in the field to support traverse operations such as route marker flags may become encrusted in snow, lost, or deteriorate over time. It is anticipated that wastewater produced by traverse personnel will be containerized and transported to the maximum extent practical to a supporting USAP station for disposition. If wastewater must be discharged, it will only be released in areas allowed by the Antarctic Treaty. Wastewater, if discharged, will become permanently frozen in the snow, isolated below the surface, and will not pose a threat to human health or the environment. It is anticipated that abandoned objects will not contain hazardous materials and will not pose an adverse impact to the environment.

Throughout the progress of traverse operations, substantial quantities of fuel may be handled and used to operate traverse equipment as well as being transported as cargo. An accidental release such as spills or leaks of fuel or other hazardous materials (lubricants, coolants) cannot be predicted but represents a potential impact to the environment. However, spill prevention measures have been incorporated into the design of the equipment and traverse operating procedures. If a spill is detected, control measures can be rapidly implemented to respond to the incident. Fuel or other hazardous materials, which may be accidentally released on snow-covered terrain, would be expected to migrate vertically through the snow firn until reaching an impermeable surface where the material would spread laterally. In general, the USAP manages and transports large quantities of hazardous materials such as fuel on a daily basis and significant releases to the environment are relatively rare. If a spill occurs during a traverse operation, it has potential to affect the environment on a long-term but localized basis and it is expected that the released material would be isolated, limiting further migration.

9.6 Other Impacts

Implementation of the proposed traverse capabilities is expected to moderately affect operations at certain USAP stations and field camps involved with the traverse activities. Major operational conflicts or impacts will be avoided through advanced planning and resource scheduling.

Scientific research performed in the USAP will also be affected through the implementation of traverse capabilities. The impacts to science will be largely positive resulting from the use of the traverse capability to supplement existing airlift resources and provide new opportunities for research. Traverse activities will disturb the terrain but these impacts will be documented so that future research may be designed to avoid potential interferences.

USAP traverse activities will affect the social condition of the Antarctic environment represented by its wilderness value. The use of the traverse capability by the USAP will be isolated to specific routes and will be analogous to the traverse activities performed by other nations that operate in Antarctica. It is expected that the benefits realized by the USAP's use of traverse capabilities will far outweigh the localized and largely transient diminishment of the wilderness quality of the Antarctic environment.

9.7 Summary

The development and use of traverse capabilities by the USAP is a significant operational and scientific undertaking representing a major commitment of resources and potentially resulting in observable or measurable environmental impacts. The expected scientific and operational benefits related to the USAP's use of traverse capabilities have been thoroughly evaluated and are deemed to be substantial. The outputs (environmental impacts) resulting from the performance of traverse activities are well known, understood by numerous organizations that operate in Antarctica, and have been addressed in this CEE.

The USAP intends to use this CEE to address the potential impacts associated with the mechanical aspects of performing science-related or cargo transport traverses in Antarctica. Impacts associated with unique operations, specialized research techniques, or traverse routes which occur in areas (i.e., environmental settings) that are significantly different than those characterized in this CEE would be evaluated in supplemental environmental reviews.

The environmental impacts resulting from the performance of traverse activities may be more than minor or transitory but are localized along the traverse route. As realized by numerous other operators in Antarctica, the impacts associated with the use of surface traverse capabilities are relatively benign compared to the substantial benefits this transport mechanism offers. Overall, the projected impacts associated with the USAP's use of traverse capabilities were determined to be more than minor or transitory but the impacts would not result in a widespread adverse impact to the Antarctic environment.

10.0 NONTECHNICAL SUMMARY

This Comprehensive Environmental Evaluation was prepared by the National Science Foundation to evaluate potential impacts resulting from the proposed development and implementation of surface traverse capabilities by the USAP. The purpose of developing a surface traverse capability will be to enhance the USAP's current logistical support mechanism for the re-supply of facilities in Antarctica, specifically to provide a more capable alternate transportation method to complement the existing airlift resources. A second, yet equally important purpose for the implementation of surface traverse capabilities, will be the use of the traverse as a platform to perform advanced surface-based scientific studies in Antarctica. Overall, the implementation of a traverse capability would yield numerous benefits to the USAP, including decreased reliance on aircraft resources, increased opportunities to expand science in Antarctica, including the South Pole, and reduction in the quantity of fuel consumed to transport cargo and reduced air emissions resulting from the combustion of fossil fuels.

The methodology and equipment to conduct surface traverses in Antarctica is currently available. Various Antarctic Treaty nations, including the United States, have successfully performed traverses to meet numerous logistical and scientific goals. Currently the USAP does not possess a robust and fully mature traverse capability and can only perform surface traverses on a limited basis using existing resources. The intended use of the traverse capability to be developed by the USAP will be analogous to the traverse activities currently being performed by other nations that operate in Antarctica and are expected to continue in the future.

Description of Proposed Activities

The scope of the proposed action analyzed in this CEE is unique because it encompasses all traverse operations that may be performed by the USAP. Traverses may be designed for either re-supply or science-related research purposes and may utilize more than one traverse route. Surface traverses used for re-supply missions would typically be conducted between two primary facilities, following improved and marked routes, and would be used more than once. Traverses used for scientific purposes would follow routes that were selected to support the intended research and may be used only once.

Both types of surface traverses will typically involve the use of several motorized tracked vehicles towing sleds or trailers which contain fuel for the traverse equipment, living and working modules for the traverse crew, cargo, and other materials. Both re-supply and scientific traverses may stop each day of travel for rest, equipment inspection or repair, and scientific research. Each traverse would have the resources and equipment to refuel tractors, perform routine maintenance, and collect wastes for subsequent disposition at supporting stations. In some cases, sanitary wastewater may be discharged in snow-covered areas as allowed by the Antarctic Treaty.

The scale of re-supply and science traverses may be significantly different. Re-supply missions would involve the transport of deliverable payloads as well as the fuel and consumable supplies needed during the trip. For example, in an optimally configured re-supply mission from McMurdo Station to the South Pole, six tractors would be used, each capable of delivering approximately 20,000 to 27,000 kg of cargo while consuming approximately 20,000 liters of fuel on a 30-day roundtrip journey. To transport an equivalent amount of cargo to the South Pole from McMurdo Station, LC-130 aircraft would consume slightly less than twice as much fuel.

Unlike a re-supply traverse mission, a research traverse may require fewer and smaller tractors to transport the equipment and supplies needed to support the traverse crew and perform the intended research. Scientific traverses may depend on airdrops or strategically placed caches for periodic replenishment of consumable supplies. A typical scientific traverse may be conducted over a period of 40 days, using two tractors each consuming approximately 14,000 liters of fuel over the duration of the mission.

In this environmental review, the USAP has considered several alternatives for the proposed action. For re-supply purposes, Alternative A is an optimally configured system of traverse vehicles whose frequency of operation would complement existing airlift support mechanisms. Other alternatives considered included the development of the traverse capability and use of it on a minimal frequency basis only (Alternative B), under reduced intensity operating conditions (Alternative C), using minimal field support resources such as caches, depots, or airdrops (Alternative D), or only on established routes (Alternative E). The No Action Alternative, that is, not developing a surface traverse capability, was also considered and was designated as Alternative F. Several other alternatives were identified but were eliminated from detailed analysis because they failed to meet the required level of performance.

For science-related traverse activities or surface-based surveys, it is expected that the field activities will be specifically designed to support the proposed research; therefore, there are no relevant alternatives other than performing the research as proposed or not doing it at all.

Environmental Impacts

In this CEE, the USAP has addressed the potential impacts associated with the mechanical aspects of performing science-related or cargo transport traverses in Antarctica. The environmental setting for proposed traverse activities that was defined in this CEE included snow- and ice-covered areas of the Ross Ice Shelf, Transantarctic Mountains, and the Polar Plateau. Impacts associated with unique operations, specialized research techniques, or traverse routes which occur in sensitive areas or areas that are significantly different than those characterized in this CEE would be evaluated in supplemental environmental reviews.

Potential environmental impacts associated with typical surface traverse activities were identified and evaluated using two scenarios. The first example involved the re-supply of the Amundsen-Scott Station from McMurdo Station using traverse methods currently undergoing engineering evaluation in a proof of concept study. To evaluate potential impacts associated with scientific traverses and surface-based surveys, the International Trans Antarctic Scientific Expedition (ITASE) of which the USAP is a participant was selected as a second representative example for the use of the traverse capability.

By the nature of the proposed action, traverse activities will undoubtedly disturb the surface of the snow and ice-covered terrain. This disturbance would be primarily confined to the width of the traverse route and would be influenced by the number of reoccurring traverses on a particular route. Crevasses which cannot be avoided would be filled with native snow and ice to facilitate safe passage of the traverse equipment. The natural processes of wind action and snow accumulation will quickly remove any visual evidence of vehicle traffic resulting in only temporary impacts.

The use of mechanized equipment and the associated combustion of fuel will result in the unavoidable release of exhaust byproducts to the atmosphere. Traverse equipment will use less fuel and produce significantly fewer air emissions than aircraft transporting an equivalent amount of cargo. The exhaust gases and particulates are expected to dissipate in the atmosphere downwind of the traverse route. These emissions may be visually noticeable or detectable near traverse vehicles, but the emissions are not expected to pose a long-term or adverse impact to the air quality, surface albedo, or snow and ice chemistry.

Few releases to the snow and ice environment are expected as a result of traverse activities. Measures will be taken to prevent accidental spills of fuel, oil, glycol, or other hazardous substances used to support traverse activities, including materials stored in the field or transported by airdrop. Materials released during the course of traverse operations may include inert materials such as marker flags that will become encrusted in snow and ice. Wastewater may be discharged at various stopping points along the traverse route in areas allowed by the Antarctic Treaty and if it is not practical to containerize the material for further disposition. If wastewater is released, it would be sanitary wastewater and generally less than 7 liters per person per day. Wastewater discharged in the field would be isolated below the surface, become permanently frozen in the snow, and would not pose a threat to human health or the environment.

Surface traverse activities may result in other impacts. Operations at certain USAP stations and field camps involved with the traverse activities may be affected, but major operational conflicts will be avoided through advanced planning and resource scheduling. It is expected that mostly positive impacts to scientific research performed in the USAP will result from the new research opportunities provided by the traverse capabilities. Impacts resulting from traverse activities will be documented so that future research performed in Antarctica may be designed to avoid potential interferences from physical disturbances or releases. USAP traverse activities will also affect the social condition of the Antarctic environment represented by its wilderness value although these impacts will be localized, and the benefits realized by the USAP's use of traverse capabilities will far outweigh the resulting temporary impacts. The use of surface traverses by the USAP will continue the long-standing tradition of Antarctic exploration, in-field scientific research, and support of various facilities on the continent that are routinely performed by other nations.

Mitigating Measures and Monitoring

This CEE describes a number of measures that will be taken to mitigate (reduce or avoid) impacts to the environment and USAP operations resulting from the development and use of surface traverse capabilities. These mitigating measures have been designed to be effective and practical by addressing various aspects of traverse operations including:

- Traverse Routes
- Traverse Resources (equipment, personnel support resources, staffing)
- Physical disturbances to the snow and ice environment
- Air emissions
- Releases to the snow and ice environment
- Impacts to USAP Facilities and operations
- Impacts to scientific research in the USAP
- Impacts to social conditions of Antarctica

Provisions for most of the mitigating measures are developed during the planning and preparation stages of a traverse or surface-based survey activity and well before the actual field work is underway. During the planning and preparation stages, features are built into the design of the proposed traverse activity to ensure that the resources needed to conduct the traverse and mitigate potential impacts are available. Organizational impacts related to USAP facilities that may be involved in the proposed action will be effectively mitigated through advanced planning, scheduling, and allocation of resources and facilities.

Prior to the initiation of traverse activities, the USAP will develop an impact monitoring strategy to detect, if any, temporal and spatial changes caused by the proposed action. Environmental impact assessment and monitoring would be conducted during all phases of traverse operations, particularly during the planning stages to ensure that resources are adequately available to support mitigating measures and minimize environmental impacts.

Conclusions

The development and use of surface traverse capabilities by the USAP is a significant operational and scientific undertaking in the USAP representing a major commitment of resources. The benefits as well as the environmental impacts resulting from the performance of traverse activities are well known, understood by numerous organizations that operate in Antarctica, and have been addressed in this CEE.

The operational and scientific benefits expected from the USAP's use of traverse capabilities are deemed to be substantial and include:

- Availability of a transport option that may be more suitable under certain conditions than the exclusive use of aircraft
- Reduced fuel consumption and combustion exhaust air emissions
- Reduced reliance on airlift resources
- Ability to operate under a broader range of Antarctic conditions
- Availability of resources to expand the scope of in-field scientific research

The environmental impacts resulting from the use of surface traverse capabilities include:

- Physical disturbance to the snow and ice environment
- Release of fuel combustion byproducts (air emissions) to the atmosphere
- Minor releases of abandoned materials such as trail marker flags
- Possible releases of wastewater to snow and ice areas
- Potential accidental releases of fuel or other hazardous materials, or catastrophic losses of equipment and materials
- Impacts to operations at McMurdo Station and other USAP facilities
- Impacts to the wilderness value of Antarctica

The environmental impacts resulting from the use of surface traverse capabilities may be more than minor or transitory but will be localized along a designated traverse route. As realized by numerous other operators in Antarctica, the impacts associated with surface traverses are relatively benign compared to the substantial benefits this transport mechanism offers. Overall, the projected impacts associated with the USAP's use of traverse capabilities were determined to be more than minor or transitory but the impacts would not result in a widespread adverse impact to the Antarctic environment.

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12.0 LIST OF RECEPIENTS

Via a website link, the draft Development and Implementation of Surface Traverse Capabilities in Antarctica Comprehensive Environmental Evaluation (CEE) was made available for review to all interested parities including Antarctic Treaty nations, international and U.S. Federal agencies, research institutions, private organizations, and individuals. Printed hard copies were provided to the following:

Federal Agencies

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13.0 GLOSSARY

The following definitions are provided for unusual words or unusual uses of words in this document. These are not necessarily general definitions of these words.

Ablation - Erosion of a glacier or ice sheet by processes such as sublimation (i.e., vaporation of ice to atmospheric water vapor) and wind erosion. Areas of ice ablation are areas where the rate of ice removal by sublimation and wind erosion is high enough that a net loss of ice occurs. Ice ablation results in blue ice formations, which are exposed blue glacial ice without the usual cover of snow.

Accretion - Build-up of snow and ice. Areas of snow accretion are areas where there is a net positive accumulation of snow from precipitation, after the effects of sublimation and wind erosion and deposition have been considered.

AN-8 - A type of turbine fuel with ice inhibitors. AN-8 can be used by diesel engines as well as helicopters and jet or turboprop aircraft. JP-8 is a similar grade of diesel fuel but is not certified for use in aircraft.

Antarctic Treaty - The Antarctic Treaty was signed in Washington, D.C. in 1959 and entered into force in 1961. It establishes a legal framework for the area south of 60 degrees South, which includes all of Antarctica, and reserves Antarctica for peaceful purposes and provides for freedom of scientific investigation. The Treaty does not recognize, dispute, or establish territorial claims and prohibits the assertion of new claims.

Arches - Corrugated metal arches which serve to shelter storage and operations areas at the Amundsen-Scott South Pole Station.

Austral - Of or pertaining to southern latitudes. The austral summer is the period, approximately November–February, when Antarctic temperatures are highest and when most USAP activities occur.

Baseline Conditions - The facilities and resources required to operate and maintain the Amundsen-Scott South Pole Station including improvements realized as a result of the SPSE and SPSM projects.

Biological Oxygen Demand – A measure of how much decay of dissolved organic compounds in wastewater can deplete the dissolved oxygen concentration.

Bladder (fuel) - A portable, flexible synthetic-material fuel tank that is designed for use at temporary or remote sites. Bladders are shaped like pillows and are laid on the ground, snow or ice, sometimes over an impermeable liner, and then filled with fuel.

Bulk Storage Tank – A large fuel storage tank used to resupply smaller day tanks or to supply large fuel users such as power plants and aircraft.

Cumulative Impacts - As defined by the President's Council on Environmental Quality (40 CFR 1508.7), a cumulative impact is "the impact on the environment which results from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions regardless of what agency or person undertakes such other actions. Cumulative impacts can result from individually minor but collectively significant actions taking place over a period of time."

Day Tank - A small tank that provides fuel for heating or other needs at an individual building. Day tanks are usually filled several times a week.

Decommissioning - The removal of a structure, vehicle, or piece of equipment from service or use. For the purposes of this environmental impact assessment, decommissioning of a structure refers to its dismantling (i.e., demolition) and removal from the South Pole.

Designated Pollutants - Substances which exhibit hazardous characteristics as defined in 45 CFR Part 671.

Graywater - Slightly contaminated wastewater from dishwashing, bathing and similar activities. Graywater does not contain human waste.

Ice Sheet - Continental masses of glacial ice sometimes covered with surface snow. Almost the entire Antarctic continent is covered by ice sheets moving slowly from areas of snow accumulation to the sea or to areas of ice ablation.

Initial Environmental Evaluation (IEE) - An environmental document defined in Annex 1 to the Protocol on Environmental Protection to the Antarctic Treaty. The IEE is prepared to determine whether a proposed activity might reasonably be expected to have more than a minor or transitory effect on the environment. If the IEE indicates that the proposed activity is likely to have no more than a minor or transitory effect on the environment, the activity may proceed with the provision that appropriate monitoring of the actual impact should take place; otherwise, a Comprehensive Environmental Evaluation should be prepared.

International Geophysical Year (IGY) - July 1, 1957 to December 31, 1958, a cooperative endeavor by the world's scientists to improve understanding of the Earth and its environment. Much of the field activity took place in Antarctica where 12 nations established some 60 research stations.

LC-130 – Four engine turboprop aircraft equipped with skis and used by the USAP to transport personnel and cargo.

Loading (wastewater) – The rate (mass per time) at which a wastewater constituent is discharged. The loading of a constituent is determined by multiplying its concentration in the wastewater (mass per volume) times the wastewater discharge flow rate (volume per time).

National Environmental Policy Act (NEPA) of 1969 - NEPA makes it the policy of the federal government to use all practicable means to administer federal programs in an environmentally sound manner. All federal agencies are required to take environmental factors into consideration when making significant decisions (Findley and Farber, 1991).

Project IceCube - This project involves a one-cubic-kilometer high-energy neutrino observatory being built and installed in the clear deep ice below the South Pole Station.

Protocol on Environmental Protection to the Antarctic Treaty - The Protocol was adopted by the Antarctic Treaty parties in 1991 to enhance protection of the Antarctic environment. The Protocol designated Antarctica as a natural reserve and set forth environmental protection principals to be applied to all human activities in Antarctica, including science, tourism, and fishing.

Retrograde – As used by the USAP, the transport of any items (e.g., wastes, used equipment, research samples) to the United States or other countries for processing or disposition (e.g., disposal, recycling, analysis).

Sanitary Wastewater - For the purposes of this environmental impact assessment, wastewater includes all liquid wastes entering the sewage collection pipe systems, including those from living quarters, galleys, laboratories, and shops. It does not include hazardous waste streams or industrial chemicals which are collected separately and either recycled or disposed of in permitted facilities in the United States

Secondary Containment - Facilities (e.g., dikes or double walls) to contain the contents of a fuel tank or pipeline in case of rupture.

Shear Zone – An area affected by converging ice masses and often containing crevasses or areas of surface instability.

South Pole Station Modernization Project (SPSM) - The reconstruction of the Amundsen-Scott South Pole Station, consisting of a new elevated complex of modular buildings and a series of subsurface steel arches. SPSM follows the South Pole Safety and Environment Project (SPSE) which was a series of three construction projects involving the replacement of the most critical components of the station's infrastructure to ensure continued safe operations. The SPSE project was completed in FY 2001 and included the replacement of the Garage/Shops complex, the Power Plant, and Fuel Storage.

Traverse – As used in the context of this environmental impact assessment, the process of transporting cargo or equipment over the snow covered surface of the terrain using tracked vehicles and sleds.

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15.0 APPENDICES

Appendix A - Analysis of McMurdo to South Pole Traverse as a Means to Increase LC-130 Availability in the USAP
Appendix B - US ITASE 2002-2003 Field Report
Appendix C - Air Emissions from Fuel Combustion Sources
Appendix D - Response to Comments

APPENDIX A

ANALYSIS OF MCMURDO TO SOUTH POLE TRAVERSE AS A MEANS TO INCREASE LC-130 AVAILABILITY IN THE USAP

Analysis of McMurdo to South Pole Traverse as a Means to Increase LC-130 Availability in the USAP

George L. Blaisdell[1]
David Bresnahan[2]

Introduction

The objective of this exercise is to outline and quantify one of the options considered by the NSF Office of Polar Programs in their effort to increase the availability of LC-130 aircraft missions. This NSF goal is directed at shifting to a more favorable balance, the ratio of LC-130 missions spent on infrastructure and general logistics support compared to direct science support. The specific option considered here is that of establishing an oversnow trail and transportation system connecting McMurdo to South Pole. With such a trail, the USAP could shift the bulk of commodities transport from LC-130s to surface vehicles, freeing up the specialized and rare LC-130s for tasks in the “open field” or at minimally prepared skiways, and thereby contributing to the NSF goal.

This study will build on the prior traverse feasibility work (e.g., Evans, 1996), which determined that an oversnow route exists that avoids all but a few crevassed regions and all but one short steep grade (Blaisdell, 1999). Those studies, while encouraging, still leave some critical feasibility issues in question. Additionally, they focused strictly on the technical feasibility of establishing and operating a surface transportation network between McMurdo and South Pole, placing little or no attention on other important aspects of such a scheme. For example, development timelines, cost estimates, risk considerations, and suitable operating procedures (as they integrate into the current USAP field season) were not addressed. The following discussion will document a first attempt to attach these factors to the traverse scheme.

Prior Studies

The concept of an oversnow trail to South Pole has been considered on and off for many years. Recently (starting in 1993) several preliminary and ad hoc studies were conducted by glaciologists and air photo specialists familiar with portions of the Transantarctic Mountains that flank the Ross Ice Shelf. Their goal was to determine, by remote means, which glaciers in the range might be suitable for heavy tractor train travel. Aerial reconnaissance flights as part of other studies within the Transantarctic Mountains were also used to analyze the glaciers.

These initial studies utilized both existing air photos from the USGS map library (some dating back to the 1950’s) and recent high-resolution satellite imagery to categorize the many glaciers that could provide access from the Ross Ice Shelf to the polar plateau. The principal concerns were to find routes with even, modest grades and firm, dry snow conditions. More importantly, however, minimal crevassing was desired for the route. A brief history of recent work follows.

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Transantarctic Mountains

The minutes of a 9 June 1993 meeting about South Pole traversing show that a review of Jim Matthews' (Holmes and Narver) independent study of traverse routes was discussed. In Matthew's analysis he identified three glaciers for consideration, the Skelton, the Barnes, and the Scott glaciers. It is not certain why he focused on these three glaciers. His opinion of these routes is as follows.

a. Skelton- First choice by far because of its history of traverses beginning in 1957. Steep grade (7-8% for stretches of 0.25 miles) will require two tractors for a load of 75,000 lbs.

b. Barnes and Scott Glaciers- Distant second and remote third choices, respectively. (This reference to the Barnes Glacier is presumably an error; the Barnes Glacier is on the west side of the Antarctic Peninsula.)

A systematic study of the Transantarctic Range by glaciologists was begun shortly after this meeting. In a 20 July 1993 report "Initial Review of Over-Ice Routes from McMurdo to South Pole," Robert Bindschadler (NASA) assesses the route potential of 20 glaciers from the Skelton to, but not including, the Reedy. Evaluations were based on an analysis of aerial and satellite photographs at the SCAR Library as well as 1:250,000 topographic maps.

This report includes Bindschadler's note stating that the Byrd Glacier was omitted by oversight, but that, "my recollection is that there are sections crevassed across the entire width and it can be discarded as a possible route." Ian Whillans (Byrd Polar Research Center, Ohio State University) subsequently confirmed that the Byrd Glacier is heavily crevassed and out of the question as a tractor route.

Bindschaldler rated the 20 most likely glaciers that the traverse could take; only the Leverett Glacier received an encouraging score of 'Good.' The only adverse comment about the Leverett pertained to the distance from McMurdo. (It wasn't clear why this fact was considered negatively.) Glaciers rated 'Fair' (Table 1) suffered some combination of gradient and crevasse problems that made them seem less than ideal. To warrant a 'Poor' rating substantial gradient and crevasse problems were apparent. A 'Not Practicable' rating signified that crevassing was too severe to allow any reasonable consideration for tractor train movement.

On 26 July 1993, a memorandum by Bob Bindschandler, Jim Matthews, and Ian Whillans based on work they had done together with Bob Allen and D'Ann Lear (both from the USGS) was issued under Ohio State University letterhead (Byrd Polar Research Center). This memo discussed an inspection of aerial photographs of potential tractor train routes through the Transantarctic Mountains. The document refines the categorizations of the above 20 July report as follows.

From the list of glaciers with 'Good' and 'Fair' ratings, three were designated 'Promising'; The Leverett ("long trip on the Ross Ice Shelf required"), the Hatherton ("Trickiest part seems to be at head..."), and the Skelton ("Seems more tricky than other routes"). Two glaciers were noted as 'May be Possible'; the Beardmore and the Shackleton. In spite of this designation strong warnings against both of these glaciers were noted. For example, regarding the Beardmore; "These crevasses probably eliminate this route from possibility for tractors," and for the Shackleton; "There is no hope."

On 22 November 1993 C.R. Bentley (University of Wisconsin) issued a memo to the Senior NSF Representative at McMurdo regarding a reconnaissance of polar plateau access. This memo described a Twin Otter over flight of the Hatherton and Skelton Glaciers made the previous day by him together with Will Harrison (University of Alasks, Geopysical Institute) and Barclay Kamb (University of California). Both glaciers were essentially eliminated in Bentley's view, the Hatherton because of bare ice and an impassable headwall, and the Skelton because of severe crevasse problems in the 15-mile stretch from Clinker Bluff to Neve Nunatak.

A memo from Keith Echelmeyer to Bob Bindschadler, Ian Whillans and the Senior NSF Representative at McMurdo (dated 23 November 1993) described a Twin Otter reconnaissance of the Leverett Glacier made the previous day. It presented a favorable impression of the route potential including the statement, “I don't think that the route would require filling in any major crevasses, nor would one have to cross any large ones.”

During a 13 December 1993 LC-130 flight from South Pole along Leverett Glacier Ian Whillans made observations of the route. In a memo to Bob Bindschadler and Dave Bresnahan (NSF/OPP) he describes, for the section between the head of the Leverett and South Pole, blue ice, long sastrugi, and large crevasses, but generally good conditions. Further, he states that “within the Leverett valley there is a nearly uniform gradient with crevassed places requiring care and short, wide sastrugi indicating small wind speed, raising the concern that snow may be soft due to small initial density.”

In the memo “Report on Field Visit to Leverett Glacier, January 1994,” Gordon Hamilton (Byrd Polar Research Center, Ohio State University) documents observations made on a 10 January 1994 Twin Otter field reconnaissance to investigate snow structure, measure slope angles and reconnoiter crevasses. Four Twin Otter landings were made on various parts of the Leverett Glacier, surface snow structure was evaluated and pits dug for snow stratigraphy (snow density profiles included in the report show densities to be near 400 kg/m^3 from the surface down to nearly a meter). Two 7m (approximately) cores were taken for analysis at McMurdo.

The report states “Leverett Glacier...seems to be a good choice for a tractor route..., and the viability of the route along the transantarctic escarpment must also be investigated but assuming that meets specifications (especially snow conditions) then Leverett Glacier is recommended as the route through the mountains to the plateau.”

Two geographic hurdles are identified in “Search for a Safe Tractor Route from McMurdo Station to the South Pole” by Ian Whillans, Gordon Hamilton and Carolyn Merry in an enclosure to a 4 May 1994 letter to Erick Chiang (NSF/OPP). These areas were identified in the course of their work done to identify a suitable surface tractor route between McMurdo and South Pole and presented at the Antarctic Traverse Workshop held in late May 1994. This document specifies as obstacles a) the area of large crevasses east of Minna Bluff and White Island (now known as the McMurdo Shear Zone), and b) the route through the Transantarctic Mountains. Their work to that date had concentrated on the search for a route through the mountains, and this document briefly traces the process of elimination leading to the Leverett Glacier. It concludes with the statement, “Selection has been narrowed to a single good route. We are now considering refinements.”

In July 1994, Gordon Hamilton reviewed USGS aerial photography of the Skelton and Hatherton Glaciers, taken in November 1993. He concludes that the glaciers photographed are no longer considered possible routes for the South Pole tractor traverse.

The motivation for examining these photographs was to see what can be learned and applied to an aerial photography mission of Leverett Glacier, scheduled for late 1994.

Continued studies of the tractor route across McMurdo Ice Shelf (memo dated 24 September 1994) by Ian Whillans, Carolyn Merry, and Gordon Hamilton utilized Landsat Thematic Mapper images. They describe the analysis of images to find a route across the McMurdo Ice Shelf and across the shear zone between the slowly moving McMurdo Ice Shelf and the fast moving Ross Ice Shelf. Reflecting their growing confidence with the Leverett Glacier as the avenue to the polar plateau (based on satellite image and air photo study), they state the shear zone is likely to be the greatest single obstacle along the route from McMurdo Station to South Pole. They also note beyond the shear zone is a street of nearly featureless ice on the Ross Ice Shelf.

Although there are somewhat conflicting viewpoints in the earliest studies mentioned above regarding the suitability of possible routes to the polar plateau (especially the Skelton Glacier), the results of these studies seemed to conclude that only the Leverett Glacier appeared to come reasonably close to satisfing all of the criteria desired for heavy tractor trains.

McMurdo Shear Zone

Satellite images of the zone between the Ross and McMurdo Ice Shelves clearly show a somewhat wrinkled, or turbulent appearance. Extensive crevassing in this zone is quite apparent between the south end of White Island and Minna Bluff. Here, huge open rifts occur and the Ross Ice Shelf is scrapped past the tip of Minna Bluff. Not obvious but strongly suspected were many hidden crevasses along the northern continuation of this boundary between the two ice shelves. Historical travelers across this shear zone have had mixed success, with some falling into crevasses completely unexpectedly and others blithely passing unhindered.

Whillans and Merry (1996) have done comparative studies of “time-lapse” satellite images in the McMurdo Shear Zone to estimate the direction and rates of ice movement. On the basis of the derived ice shelf motions, they were able to make predictions of the areas where hidden crevassing might occur. The orientations and size of crevasses were also predicted. Subsequently, Arcone et al (1996) have performed Ground Penetrating Radar (GPR) surveys (Delaney et al, 1996) of the Shear Zone to precisely identify the zone and nature of crevassing in this area.

Feasibility

All of the parties involved in data collection and route assessment agree that the Leverett glacier represents the most favorable avenue from the Ross Ice Shelf to the polar plateau. Being located about as far as you can travel from McMurdo before beginning to climb is also very beneficial for the tractors. Further, none of the personnel involved in the field assessment identified outright “show stoppers” leaving all of us encouraged that an oversnow tractor train trail is a viable alternative to flying to South Pole.

Immediately following the field studies of the potential traverse routes, Blaisdell was assigned by NSF Office of Polar Programs to use available data to make a first estimate of the economic feasibility of a McMurdo-South Pole surface delivery route. Together with several colleagues, Blaisdell combined tractor performance data with what is know about the terrain along the candidate routes to determine potential delivered loads, fuel consumption, and travel time (Blaisdell, 1999; Blaisdell et al, 1997). The results of these analyses can be stated quite simply; for a modern tractor train traveling along the Leverett traverse route

- Each tractor-trailer unit can deliver to South Pole about 60,000 lb, or 2 times the payload of a single LC-130
- Each tractor-trailer unit, carrying with it round-trip fuel, will consume nearly the same amount of fuel used by a single LC-130 for the round trip
- Each tractor-trailer unit will require approximately 330 hours of driving time to complete the round trip, while the LC-130 makes the round trip in roughly 6 hours (including South Pole on-ground time)

Based on these results, it certainly appears that the margin of benefit is large enough that, even if Blaisdell's analyses are too optimistic, a tractor can compete head-to-head with an LC-130 in terms of quantity of goods delivered per unit of consumed fuel. Obviously the big difference is in terms of speed of delivery and the, as yet undetermined, difference in cost to operate a tractor-trailer unit for some 335 hours compared to an LC-130 for 6 hours.

Indeed, there is precedence for such optimism. The joint French-Italian initiative to build a station at Dome Concordia is being supplied almost entirely by surface transport from Dumont D'Urville using Caterpillar Challenger tractors with sleds and trailers (Fig. 1). This 1120 km (one-way) traverse has been completed 13 times to date and has met with good success. It stands as a good analog to the proposed McMurdo-South Pole traverse. The most recent reports of the Dome C logistic traverse (Godon and Cucinotta, 1997; Godon, 2000) presents values confirming several estimates used in the Blaisdell studies (e.g., average speed, fuel consumption). Additionally, there are many "lessons learned" that will be directly applicable to the USAP traverse, such as the most beneficial mix of personnel, how to select personnel, trail grooming, and how to divide up critical supplies to minimize risk, to name a few.

Figure 1. Traverse operations for the French-Italian Dome C project.

There is less written about the Russian traverse from Mirny to Vostok (1420 km, one way) but it too can be used as an example confirming that it is reasonable to perform surface transportation as a main supply mechanism between two distant stations in Antarctica (Klokov and Shirshov, 1994). This traverse began operation in 1956 and has been performed for many years as the principal supply means for Vostok. It is our understanding that the majority of the difficulties experienced by the traverse in recent years centers around the use of unsuitable (unreliable) vehicles and the lack of appropriate personnel support (both on and off the continent).

Both the Dome C and Vostok traverses experience over 80% of their elevation gain during the first 25% of the journey (when the tractor loads are at their maximum). Additionally, in the first 25% of these routes, called the coastal zone, deep soft snow, large sastrugi, strong winds with blowing snow, and crevasses are added to the steep slopes to challenge the tractors. Despite this, both programs report average outbound (loaded) speeds of 8.5 to 9.5 km/h and average return (unladen) speeds of 10.5 to 13.5 km/h. The current analyses for the 1600 km McMurdo to South Pole traverse (Leverett route), which gains only 5% of its elevation in the first 65% of the journey, estimates an average speed of 7.2 km/h for the outbound trip and 14 km/h for the return segment. This comparison suggests that the envisioned McMurdo to South Pole traverse is basing its analysis on realistic values.

Description of Traverse Option

In its simplest form, the McMurdo to South Pole traverse scheme involves a family of tractor-trailer units traveling along a marked and semi-maintained corridor on a given schedule with the purpose of delivering needed goods. In this, it is no different that any other surface transport operation. For much of the world the routes and the tractors are highly developed and specialized, but there exist surface transport operations in remote and harsh areas (e.g., Sahara Desert, Northwest Territories) that bear similarities to what is envisioned here.

Prior Results

Based on the prior studies noted above, we assume the following to be the most likely parameters for the McMurdo to South Pole traverse.

- The trail will roughly follow the path shown in Figure 2, using the Leverett Glacier to transition from the Ross Ice Shelf to the polar plateau.
- Caterpillar Challenger tractors, probably model C65, will be the prime mover. (The original analysis was performed for the C65 model. Since that time, up-powered models – the C75, C85 and C95 – have become available. However, the biggest advantage of the greater horsepower models is their greater drawbar pull in low gears, where, for this application, the tractors are traction limited rather than power limited. These bigger tractors also provide a bit greater drawbar pull in higher gears as well, but, without a complete analysis, this does not appear to have a big enough impact on the delivered payload to justify their greater cost to purchase and maintain.)
- Tracked 42-ft trailers, matched to the Challenger tractors and using the same rubber-belted tracks, will be the standard cargo carrier for loads. To reduce unnecessary “tare” weight, the trailers will be skeletal and will allow securing a variety of modular loads or loose loads. Other trailers or sledges may be considered for

specialized purposes (e.g., recovery trailer for malfunctioning equipment that can't be fixed on the trail), but these are likely to be few in number.

- Recognizing that fuel is the single largest commodity delivered to South Pole, and that it represents a concentrated and easily configured payload, it is assumed that traverse equipment will be optimized for fuel delivery. To wit, the tracked trailers will be have ample fuel storage capacity to fully load the trailer. The fuel tank(s) will be segmented, have secondary containment, and will be placed to minimize the height of the trailer's CG and to allow modular or loose loads to be placed on the trailer as well.

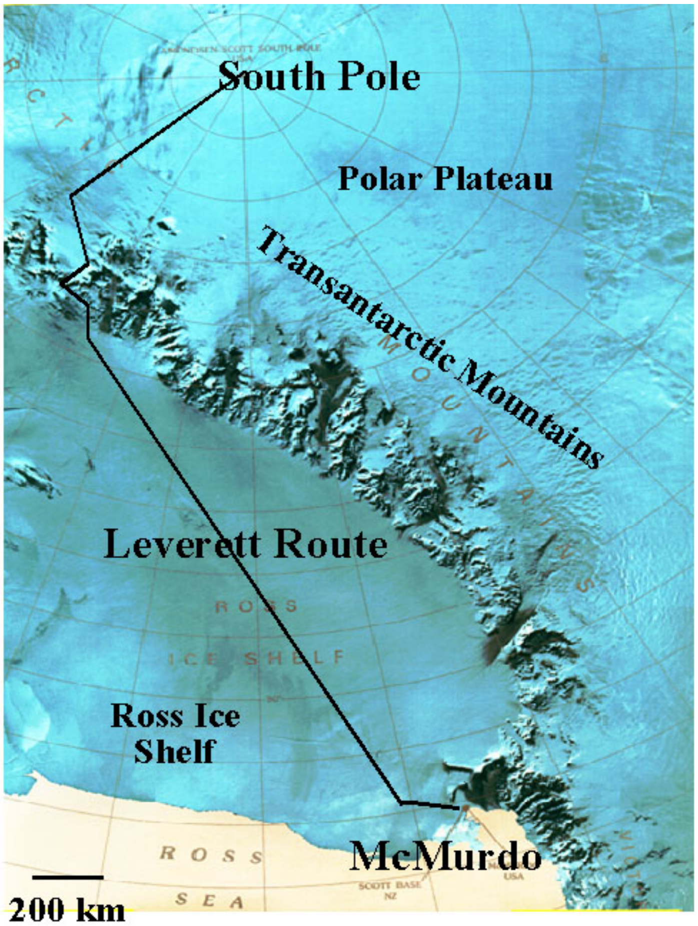

Figure 2. Traverse route using the Leverett Glacier for access from the Ross Ice Shelf to the Polar Plateau.

- Each tractor will be linked to more than one trailer for the traverse. The standard configuration will be one tractor pulling two 42-ft trailers. In some cases a tractor may pull a specialized trailer or sled plus one or more 42-ft tracked trailers.
- A round-trip traverse will require 222 hours of driving to reach the South Pole (66% of total driving time) and 113 hours to return to McMurdo (33%). The tractors consume 15.3 gal/hr, meaning the outbound leg will use 3400 gallons of fuel, with 1727 gallons burned to return. Each tractor will leave McMurdo towing a total payload (gross load minus tare weights) of 95,000 lb. It will arrive at South Pole with 63,800 lb, of which 60,125 lb can be left as delivered payload (the remaining 3675 lb is fuel needed for a portion of the return trip).

New Details

To complete the analysis planned here, further details of the traverse need to be specified. In particular, the envisioned execution of a traverse must be spelled out in order to perform an economic analysis. Several operational schemes can be considered (Table 1); we have discussed these at length, reaching an agreement that what follows is a sustainable and realistic scenario. To be certain, other schemes could be considered and are perhaps practiced by traversing parties, but we believe that the following fits most comfortably into the current USAP operating arrangement. Additionally, it closely matches the pattern used successfully by the Dome C traverse group.

Table 1. Potential daily traverse operating patterns.

	Pros	**Cons**
A. **24-hour operations**	Shortest time on trail Most efficient use of tractors	Need stop time for PM Need 2 or 3 operators per tractor (rotating) Requires sleep (recovery), food prep, eating, etc. while moving Potential psychological impact and physical drain on operators
B. **12 hrs on, 12 hrs off**	Gives adequate time for daily maintenance Gives adequate time for sleeping, eating, socializing while stopped Need only 1 operator per tractor	12-hours driving is long for one operator each day Twice as much time on trail compared to A. Engines at idle for 12 hours or cold starts each morning
C. **Two 8-hr shifts on, 8 hrs off**	Gives brief rest period for sleeping, eating, and socializing (but perhaps too short) Gives adequate time for daily maintenance Requires 30% less time on trail compared to B.	“Off” time is probably too short for complete rest cycle Need two operators per tractor During work day one set of operators will always have 8 hours of “being along for the ride” with nothing to do Engines at idle for 8 hours or cold starts each morning
D. **Two 7-hr shifts on, 10 hrs off**	Gives adequate rest period for sleeping, eating, and socializing Gives adequate time for daily maintenance Requires 15% less time on trail compared to B.	Need two operators per tractor During work day one set of operators will always have 7 hours of “being along for the ride” with nothing to do Engines at idle for 10 hours or cold starts each morning

We have selected a 12-hours on/12-hrs off schedule for operating on the traverse trail (scheme B, Table 1). This strikes us as the most efficient use of the combination of tractors and operators. Schemes A, C, and D (Table 1) all require more than one operator per tractor. (One could argue for having a single operator drive 14-hrs per day, covering both of the shifts indicated in scheme D. However, we think that might exceed the long-term endurance of operators, who will ultimately be expected to perform several round-trip traverses to South Pole each season.) Favoring scheme B, we feel that the extra “cost” of having the tractors not working for 12-hrs per day is more than offset by having a minimum of personnel on each traverse team. Minimizing personnel means increased payload and reduced complexity, since each additional person on-board equates to more food and energy consumption, more waste produced and more personal gear. This scheme also maximizes productive operator hours by not having second (and perhaps third) shift workers riding along with nothing to do during their off-duty hours. And finally, this scheme ensures that there is adequate time for eating, sleeping and maintenance while the train is not moving. By itself, this last attribute may contribute the most to the sustainability of the traverse, by reducing physical stress on operators (proper rest, nutrition, social interaction, and time for communication with the "outside" world) and by ensuring that tractor maintenance is not short-changed for a few extra hours of sleep or a good meal.

We suspect that once a few traverses have run, an "ideal" on-trail schedule will soon become apparent. Also, it is not possible yet to know how many days should be planned for weather delays. In this analysis we will principally work from the basis of required driving hours to make the trip, with a buffer available for a few weather days.

It is traditional, and clearly prudent, for tractors to form convoys when traveling the traverse trail. In polar tradition a group of vehicles making an extended trip is called a "swing." A number of factors can be taken into account when determining the size of a swing. From a safety viewpoint, it should probably not be less than three tractors. The Dome C traverse group have determined that, given the amount of tractor fuel and personnel and tractor sustenance materiel needed (living module, food, generator, medical supplies, spare parts, etc) pay-load is not delivered until 3.6 tractors have been included in a swing. They typically operate eight tractors per swing.

We chose to start with a plan for 5 tractors per swing. We assume that there will be a minimum of 5 and a maximum of 7 staff on each swing. (Personnel skill mix is not addressed here, but some mention of recommended specialties is given later when calculating costs.) Current technology is at a point where it is possible to have as few as one of the swing tractors driven by a person, the remaining tractors being "slaved" electronically to the first. Both military and civil applications have shown the viability of this approach, which would be ideal for the relatively slow-moving traverse. In time, we see the traverse moving toward this means of minimizing staff, once the route and operations are well known. Such a semi-autonomous operation would also make routine use of remote diagnostics tools, which are also available now on the commercial market.

We envision that each tractor will tow two 42-ft trailers, meaning that each swing contains 20 module positions, if we define a position as a 20-ft long by 8-ft wide area of trailer deck. For safety reasons, two separate life support modules will accompany each swing. One should be a primary and complete living module with berthing, food preparation and dining areas. A second, back-up survival module (not necessarily as plush as the primary module) should be included and be physically separated from the primary unit to prevent both being lost in a single mishap (fire, roll-over, etc.). Each module should be capable of berthing and feeding the whole swing team. However, for routine operations, we envision that the primary module will be used to berth up to four and will be the primary kitchen/dining facility. The back-up module will supply additional beds and a lounge area during routine operations. Food stores should be divided and included in both habitat modules. The back-up module should have its own sustenance power production capacity and a snow melter for potable water. Both modules should have a complete set of communications equipment and critical medical supplies. A third module will include spare parts, contain primary energy production and potable water generation facilities, as well as a bathroom (head). It is anticipated that all wastes will be collected in a holding tank and be processed in the McMurdo waste treatment plant at the conclusion of each swing.

One option for these three modules is that they have their own running gear (tracks or skis) and be towed in conjunction with the 42-ft trailers. However, since this adds tare weight and an extra source of motion resistance, we plan that the modules be paced on the standard 42-ft trailers. Assuming that each of these three modules can be fit into a 20-ft module position, this leaves 17 open positions on the standard trailers. While this might seem like a loss of payload capacity for the trailers, recall that the standard 42-ft trailers have below-deck fuel storage capacity equivalent to the maximum trailer payload. Since the sustenance modules are not expected to be very heavy, the trailer should still be able to carry a maximum load.

Prior results give 222 hours driving time from McMurdo to South Pole and 113 hours for the return (Blaisdell et al, 1997). Using travel scheme B (Table 1), this results in the outbound trip occupying 18.5 calendar days, with 9.5 needed to return. Allotting one full day for unloading, backloading (if required) and "socializing" at South Pole, this yields a 29-day round trip. Giving credit to Mother Nature and Murphy, we assume that there may be a few down days, and call this a month's journey. An annual traverse plan based on these assumptions is presented in Table 2. Each team performs three round trips each season, with a 10-day break in McMurdo between each swing. This time in McMurdo is set aside for the operators to "recover," and for them to perform major maintenance on their equipment. Additionally, they will make preparations for their next swing (e.g., putting together loads, checking weather forecasts). This schedule fits exactly with the current USAP summer season for both McMurdo and South Pole. Thus, the personnel contract period is no different than for other seasonal workers. Additionally, air support is available throughout the traverse period.

Table 2. Proposed annual traverse schedule.

	leave MCM	arrive NPX	leave NPX	arrive MCM
TEAM 1				
Swing A	20 Oct	8 Nov	10 Nov	20 Nov
Swing C	30 Nov	19 Dec	21 Dec	31 Dec
Swing E	10 Jan	29 Jan	31 Jan	10 Feb
TEAM 2				
Swing B	25 Oct	13 Nov	15 Nov	25 Nov
Swing D	6 Dec	24 Dec	26 Dec	5 Jan
Swing F	15 Jan	3 Feb	5 Feb	14 Feb

The scenario presented (scheme B, Table 1), with the Table 2 schedule, achieves 30 tractor trips to South Pole each season. Prior results calculate that each tractor delivers just over 60,000 lbs to South Pole on each trip (Blaisdell et al, 1997). However, this did not include the impact of carrying along the support modules. We assume that the three modules will total about 4000 lbs. This means that each of the six swings deposits a payload of 280,000 lbs (5 x 56,000). A season's traverse activity delivers 1.68 million lb, or 243,500 gallons of fuel. Estimated annual South Pole fuel requirements (once the reconstruction effort is completed in 2005) are 3.23 million lb, meaning that this traverse scenario delivers 52% of the station's needs.

We plan that the traverse operation be staged from the Williams Field complex. While the equipment will be serviced in McMurdo, we think it will be wise to keep the traverse-related loading and unloading activities, and parking of equipment (during the summer season) out of the way of "town" operations.

Contingency Considerations


Figure 3. USAP Challenger 65 utility tractor.

It is inevitable that there will be equipment breakdowns along the trail. However, we anticipate using modern, proven equipment, thus minimizing break-down risk. For example, the proposed tractor type, the Caterpillar Challenger (Fig. 3), has worked in the McMurdo area for some years, and more recently at South Pole, with good success and providing knowledge of its strengths and weaknesses (e.g., a mean major overhaul interval of 12,000 hours in the USAP, compared to 7,000 hours for the typical agricultural user). The trailers are also a known commodity for the USAP (Fig. 4). Most, if not nearly all of the swing team members will be experienced mechanics, with specialized training on the traverse equipment. It may also be possible that the traverse equipment will be leased from the manufacturer. This could be attractive for the USAP because of the potential for the manufacturer to provide major maintenance and to routinely refresh the fleet of tractors. (An added benefit of leasing is a smoothed capital investment load.)

We expect that, occasionally, a tractor or trailer will go down "hard," meaning that it is not a simple matter for the traverse crew to achieve a fix in the field without additional support or a major delay. For such instances, we envision two potential solutions. In the first, a ski aircraft (or helicopter, if within its range) is dispatched to the site of the break-down with specialized parts, mechanics, and perhaps a temporary shelter to achieve the fix. If this is not practical, it is expected that there will be a "low-boy" trailer for recovering and returning to McMurdo the down equipment. We suggest that, upon such a breakdown, the swing proceed on, leaving the malfunctioning equipment along the trail. The low-boy, towed by a Challenger tractor, would leave with the next departing swing (which would configure itself to pick up the delayed load), carrying on the low-boy a replacement for the damaged equipment. At the break-down site, the recovery vehicle would drop off the replacement and pick up the broken down equipment. Before having departed McMurdo, the travel schedules of the swings will need to be coordinated so that, we hope, the low-boy can return in the company of a swing homebound from the South Pole.

A medical emergency could also be encountered on the traverse. We plan that at least one of the team has a high level of emergency first response training, that at least two have advanced life-saving training, and that all have some level of wilderness first aid proficiency. A medical evacuation by air will be the recourse for any treatment required that is beyond the capacity of the swing team to tackle. Of course, all traverse members will have previously been screened physically and psychologically to a level similar to USAP winter-over candidates.


Figure 4. Tandem tracked trailers on traverse from Marble Point to McMurdo.

The schedule shown in Table 2 leaves little margin for weather or mechanical delays. We anticipate that the ten days between swings for each traverse team will be more than adequate for the tasks that must be accomplished in McMurdo, and expect this to be the buffer for unexpected occurrences.

Timeline for Development

We anticipate that the development of the traverse operation will pick up from where it left off at the end of the 1995-96 season (Evans, 1996). We expect that there will be a small research phase, followed by a pioneer phase leading to a ramp-up to the desired full operational status. Procurements will need to be made along the way and constitute a major item of the development process because of the long time period between the decision to purchase and the actual delivery of the equipment at McMurdo (under ideal conditions this is about 18 months for customized heavy equipment). Table 6 shows three potential development periods. To stand a chance of achieving the aggressive schedule (which doesn't establish a "production" traverse until the 2002-2003 season), the USAP would have to take action immediately. Given the cost and commitment associated with the traverse, and the fact that the USAP has not yet decided that the traverse is its most desirable option for increasing available LC-130 hours, this schedule is probably not realistic. The conservative and moderate timeframes shown could reasonably be achieved with a USAP "go" decision during FY00. However, neither of these schedules establish routine operations until at least the 2003-2004 season.

Impact of Traverse Operation on Current USAP

As presented here, the traverse is principally a self-contained addition to the current USAP. Thus, we feel that its influence on current operations is minimal, in terms of perturbations or disturbances to the USAP standard operating procedures. Areas of significant impact and interaction with the current system are shown in Table 7. A timeline is given in Figure 5 showing how the traverse fits into the current USAP summer season.

Table 7. Items of major impact by the traverse on current USAP operations.

Location	**Impacts**
CONUS	Traverse will likely require an EIA/EIS The volume of equipment needed will require considerable specifier/purchaser time during brief period Load planners will need to learn during first few years how best to divide and schedule tractor and LC-130 loads Weight and cube of traverse equipment in vessel
CHC	No significant impact
MCM	Heavy Shop space and traverse equipment parts warehousing Addition of swing operators to population count Dedicated dorm space for swing operators, who will be in town only about 50 days over course of summer season Coordinator and coordinator's assistant staffing and office space Weather support Trail food ordering, stocking, and preparation Earlier deployment of fuel hose to Williams Field Reduced overall fuel usage from MCM tank farm Trail waste added to MCM waste stream Traverse does not assist in current-season delivery of vessel cargo
NPX	First tractor train arrives about one week following traditional flight opening Relief of "fuelie" teams Transient lodging, shower, meal for swing operators at routine intervals Reduced frequency/volume of flight missions Traverse does not assist in current-season delivery of vessel cargo

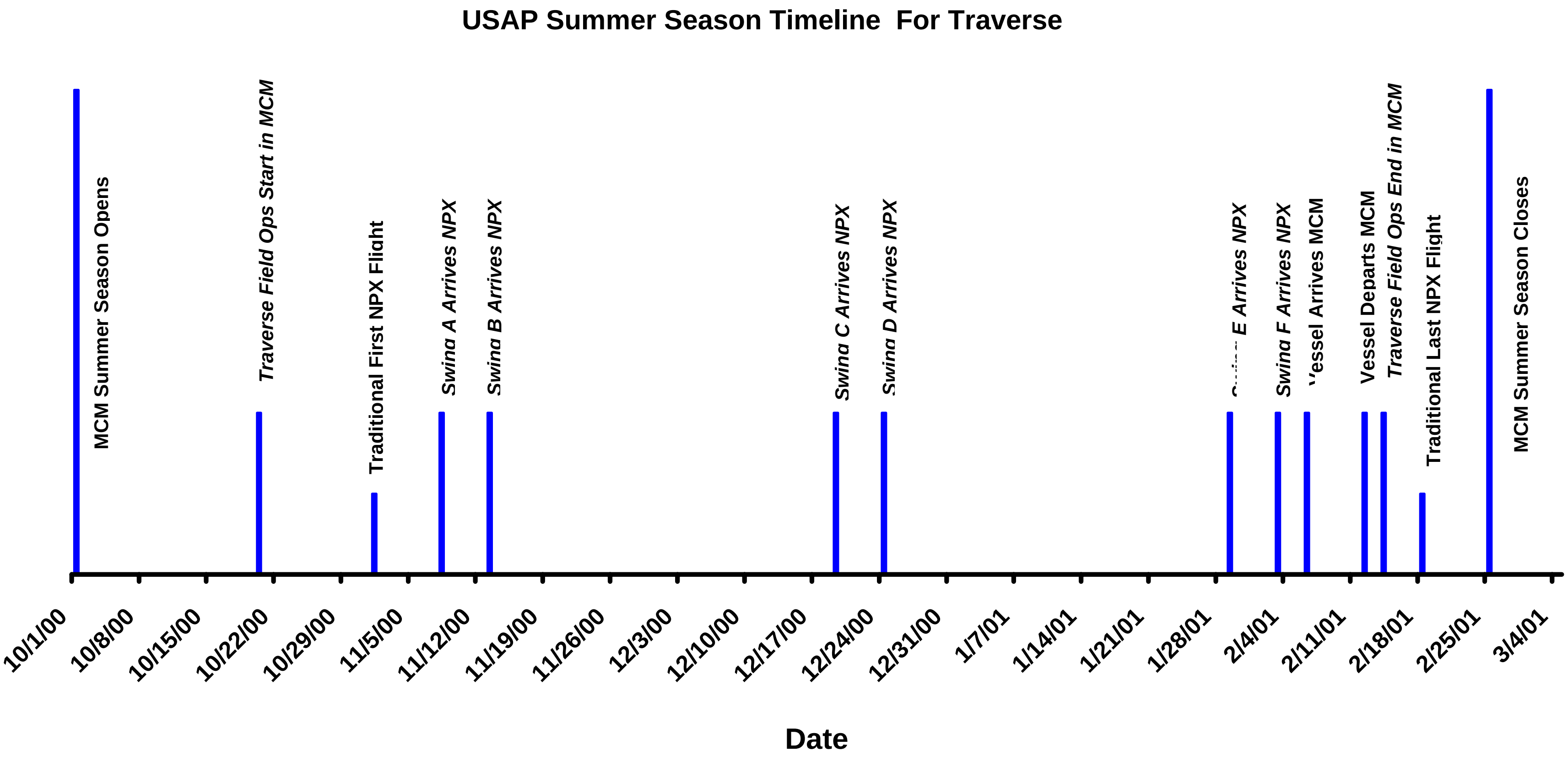

Figure 5. Traditional USAP summer season showing timing of traverse operations as given in Table 2.

Evaluation of Risk

We have identified nine real or potentially significant risks (Table 8). For each, we made an estimate of the likelihood of it occurring, the impact to the USAP if it should occur, the cost (not in dollars, but in increased pressure on the current USAP system), and the factors that can assist in mitigating or eliminating the occurrence of such a risk factor. It is encouraging that the USAP has considerable prior experience with the most likely to occur of these risk factors. Also, it is fortunate that the possibility exists to exhibit a reasonable amount of control over most of the new and unique risks.

Overall, the risks shown do not appear to represent a major cost concern to the USAP, nor do they put equipment and personnel at any more significant peril than is routine in the current program.

Direct and Indirect Benefits Associated with the Traverse

There are a number of attractive features of the traverse as a means of reducing LC-130 airlift to South Pole. Prior analyses (Fig. 6) show that the only advantage of the LC-130 aircraft over a tractor train for deliveries to South Pole is the very short time en-route. For the other factors, the tractor is able to deliver slightly more than twice the payload with the same amount of consumed fuel. Since fuel is the major commodity delivered to South Pole, the need for it to arrive from McMurdo in 3 hours, versus in 20 days, is not important (as long as it does arrive!).

The relationship between LC-130 and tractor train (5-tractor swings) deliveries to South Pole is shown in Figure 7. We assumed an LC-130 payload of 26,000 lbs, since this represents the recent average delivered payload. This means that the tractor train to LC-130 ratio is close to 1 swing to 10 flights (the actual ratio is 1:10.77). We show in Figure 7 the recommended initial production traverse operation of six swings per season, thus relieving the need for about 64 LC-130 flights. This represents delivery of close to 1.7 million pounds of goods, slightly over half the required annual fuel delivery to South Pole. This scenario yields to the USAP more than 380 flight hours that could be reprogrammed for science or other missions.

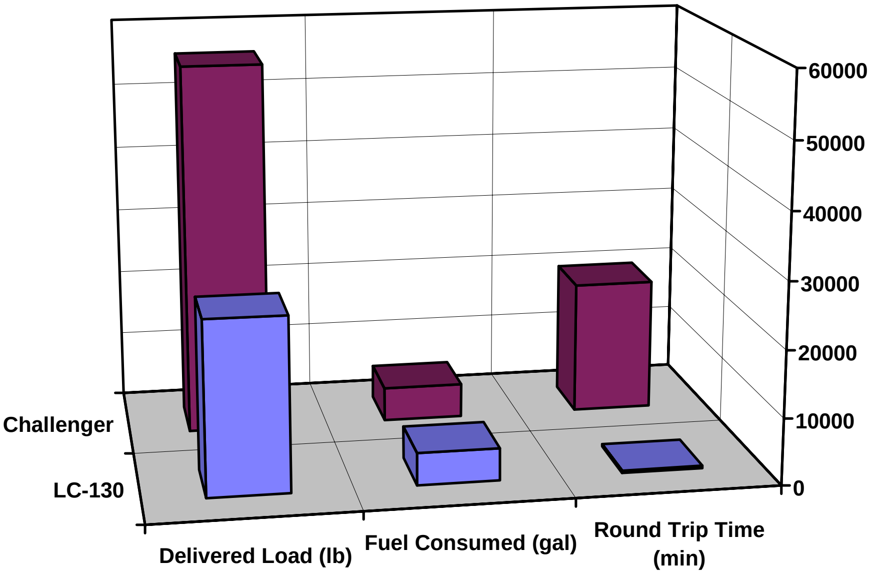

Figure 6. Comparison of delivery statistics for LC-130 and single tractor.

The current (FY99) number of completed South Pole flight missions is 264. A significant fraction of these flights are associated with the Station Modernization effort, which will be completed in 2005. A realistic "steady state" flight season is 180 missions. It is impractical to plan for traversing to completely compensate for LC-130 missions,

Table 8. Analysis of risk.

Risk Factor	Estimated Probability of Occurrence	Estimated Impact	"Cost"	Mitigation Factors
Severe Weather	Very likely	Minimal delays over course of season	Eats into 10-day interval between team's swings	Well established route; good forecasting; Reliable navigation systems
Equipment Breakdown	Likely	Minimal delays over the course of a season; occasional "tow truck" mission	Delay of 1 or more trailer arrival at NPX; Cost of "tow truck" mission and repair, or cost of on-site fix	Rigorous and aggressive PM in McMurdo and on trail; Use of proven equipment; Appropriately trained swing staff (mechanical and psychological)
Trail Deterioration (sastrugi, soft snow, opening of known crevasses)	Probable	Slows speeds; Increased operator discomfort; Increased trail maintenance efforts	Eats into 10-day interval between team's swings; Potential for need for extra personnel for trail maintenance	Understand trail and identify all en-route crevasses; Understand most effective trail maintenance techniques (including crevasse mitigation)
Undetected crevasses	Very low	Potentially devastating	Major delay for determining detour or mitigation effort; In bad case, loss of equipment, payload and need for major recovery effort; In worst case, personnel injury	Complete understanding of glaciology of route; Complete GPR survey prior to operations and frequently thereafter (at least for first several years)
Fuel Spill	Extremely low	Loss of payload; PR nightmare	$1.24 per gallon; Cost of clean-up; Delay for tank repair	Secondary containment on tanks; Regular prescribed daily tank inspections; Trained quick-response clean-up team on call

Table 8. Analysis of risk (continued).

Risk Factor	Estimated Probability of Occurrence	Estimated Impact	“Cost”	Mitigation Factors
Personnel in Remote Field	Certain	Extra 10-14 (or more) persons in deep field	Potential for needed rescue/relief mission	Is an extension of current deep field parties; Have experience with ITASE moving deep field party; After first couple years this becomes a familiar operation
Psychological “Load” on Swing Team	Moderate to low	Unexpected staff turn-over; Morale problems for swing team	Delays due to less-than-efficient operation; Cost of mid season reassignments or hiring actions	Careful selection and proper screening of swing personnel; Proper allowance for R&R between swings; Proper allowance for rest, nutrition, social contact while on trail
Medical Emergency	Low	Delay of swing; Loss time	Eats into 10-day interval between team’s swings; Medivac or rescue mission	Careful selection and proper screening of swing personnel; Routine check-ups after each swing; Proper allowance for R&R between swings; Proper allowance for rest, nutrition, social contact while on trail
NGA Use of Trail	Low	Occasional delay of swing; Trail damage; NGA need for assistance; More NPX visitors	Eats into 10-day interval between team’s swings; Increased trail maintenance; Humanitarian rescue	Don’t advertise trail OR Vigorous advertisement of no-assistance policy
Development Doesn’t Progress or Yield as Planned	Low	Economics do not develop as favorably as they were assumed; Future plans based on traverse need to be modified	Traverse deliveries cost as much or more than air delivery; Traverse operation adversely impacts normal USAP summer operations; Underutilized equipment	Monitor development during pioneering phase; Continue to compare estimates/results with international examples (e.g., Dome C traverse)

since personnel and critical cargo (e.g., science equipment, mail, food) will always need speedy delivery. Additionally, there is a practical limit to the number of swings (i.e., swing operators and equipment) that could be performed in a season. It has been suggested (E. Chiang, personal communication) that at least 60 annual flights is a minimum desirable over the course of the South Pole 100-day summer season.

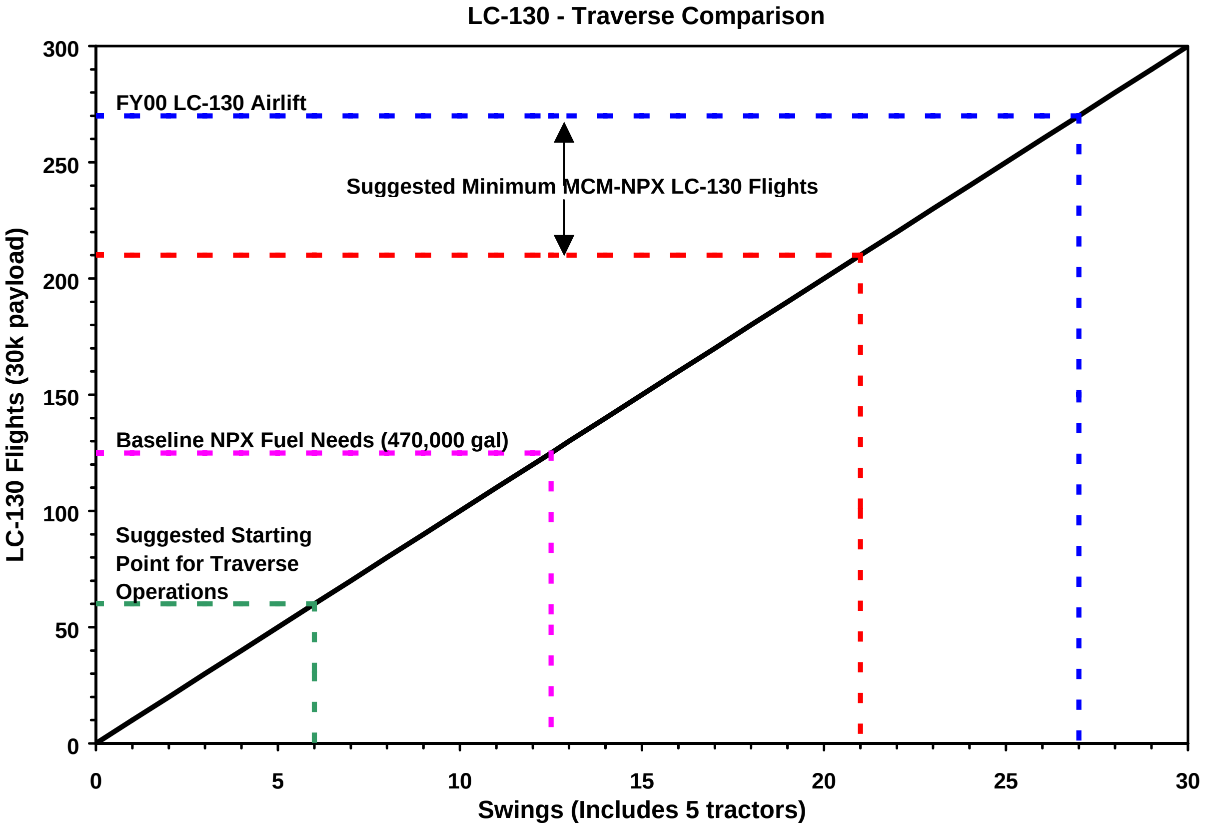

Figure 7. Potential for Traverse Contribution to Reduced LC-130 Airlift.

Given a baseline of 180 LC-130 payloads to be delivered to South Pole, with 60 flight missions desired, leaves 120 full aircraft payloads or 12 tractor train swings required to make up the difference. This is twice the scenario presented here and is probably doable. However, the most cost effective way to increase the number of swings to South Pole is to increase the number of trips each tractor makes each season (vice the costly purchase of more tractors and trailers and their associated maintenance tails). We think that, given the length of the delivery season and the length of the tractor train journey, it is probably not feasible to squeeze more than four swings per season out of a given tractor. This would require, in our estimation, swing operators to "tag" at the end of each swing, so that the tractor sits idle only for the length of time necessary for its Heavy Shop check-up. An alternating set of swing teams would work the traverse operation, and perform other duties in McMurdo in between stints on the trail. (The total number of swing operators in this scheme is greater than our original arrangement, but they would be multi-tasked personnel, so the extra cost may be minimal.) Working with the two 5-tractor groups we have specified in this exercise, this enhanced scenario would produce eight swings per season. Eight swings equates to 40 tractor loads, or 86 full-payload flight missions, representing 2.24 million pounds delivered. Under this scheme, 86 missions, or 515 hours of LC-130 flight time is given back to the USAP for alternate use.

An advantage of the traverse option is its ability to provide a flexible and distributed relief of LC-130 hours. Provided the traverse principally delivers fuel the 380 (or 515) hours that the traverse frees can be used at any time in the season. (For the first few seasons, we suggest that very few time-critical items travel by tractor train.)

The traverse further provides greater flexibility to the USAP in that payloads are not constrained to the 9-ft x 9-ft cross-section imposed by the LC-130 cargo bay. Long loads may also be carried with greater ease with the traverse system.

We anticipate that the swing operators will be trained in loading and unloading their cargo, as well as driving. Thus, the cargo and fuel teams at South Pole would be relieved of the need to unload 1.8 million pounds (under the 6 swings per season schedule) or 2.4 million pounds (with 8 swings per season). We don't know what fraction of their seasonal hours this represents, but it is labor hours that can be put to other use by the small logistic staff at South Pole.

A less direct advantage of the traverse is the development of a new corridor of access. The recent ITASE project has resurrected science traverses in the USAP; the number of projects involved in this traverse indicates there is considerable interest in the type of research that can be done by a moving, ground-based field party. The traverse trail, and its "frequent" traffic will offer scientist the potential to perform projects along the direct transects of the Ross Ice Shelf, the Leverett Glacier through the Transantarctic Mountains, and a portion of the polar plateau. Additionally, spurs could be developed off the traverse trail to suit specific science needs, with drop-off and pick-up or re-supply at the trail-head by passing swings. During the 1995-1996 traverse route feasibility study, and since then, a number of scientists have approached one of us asking about when the traverse would be operational, with the intent of using it as a portion of the USAP infrastructure capable of supporting their research interests.

Lastly, the traverse has some benefit in its ability to act as the development platform for future and more complex science traverses. The lessons learned and the equipment developed for the South Pole logistics traverse will have direct application to any such USAP activities.

Analysis and Conclusions

The evidence gathered to date, from the field and from "paper analyses" such as this, suggest that the traverse is truly technically and economically feasible. We would feel like classic optimists in making such a statement were it not for the availability of figures for the Dome C traverse, which bears a number of similarities to the proposed McMurdo to South Pole traverse. In every case, we have estimated values, rates, durations, etc based on experience, intuition, and available USAP data, only to find that the number arrived at is very close to what the Dome C operation have reported for their operation.

In economic terms, our analysis is completed as shown in Table 9. We have chosen a 10-year linear amortization period for the capital cost of equipment and for completing the development of the traverse trail and Standard Operating Procedure (SOP). This is based on the expected minimum life of the tractors.

The "bottom line" is represented in Table 9 in relation to two different frames of reference, cost per "saved" LC-130 South Pole mission and cost per pound of payload delivered. We don't know how the values of $21,930 and $16,320 per saved LC-130 mission (for the 6- and 8-swing options) compare to the actual cost of the USAP contracted LC-130 service. However, this appears to be close to the costs we have heard referenced, and is certainly less than the approximately $5000 per hour charged for the purchase of Military Airlift Command (MAC) Special Aircraft Airlift Mission (SAAM) C-130 time.

Table 9. Economic analysis of Traverse Option

		VALUE ($)
Up-Front Costs		
	Development	510,000
	Capital Investment *	7,455,000
Operational Costs		
	Annual Cost *	667,000
	10-Year Cost *	6,670,000
10-yr Linear Amortization of Up-Front Costs		
	Development	51,000
	Capital Investment	745,500
Total Cost		
	Annually	1,463,500
	Over 10 Years Operation	14,635,000
Comparative Value		
In Cost per LC-130 Mission Relieved		
	6-Swings/Season Scheme (64 missions releived)	21,930
	8-Swings/Season Scheme (86 missions relieved)	16,320
In Cost per Pound Delivered		
	6-Swings/Season Scheme (1.68 M lb delivered)	0.84
	8-Swings/Season Scheme (2.24 M lb delivered)	0.63

*****Leasing tractors would reduce capital investment and increase annual operating costs. Lease cost is not known at this time, so comparison is not possible.

In terms of delivery costs, the traverse options show a rate of $0.84 and $0.63 per pound. (The Dome C traverse operation reports an overall transport cost of $1.36 per pound, includes all development cost for their traverse). Again, we don't know what is the cost for LC-130 delivery.

We conclude from this and prior analyses, that the traverse has significant technical and economic merit, especially when viewed as a means to relieve a portion of the LC-130 airlift missions currently providing logistics support to South Pole. There may even be an environmental argument for the traverse, given that aircraft consume more fuel (4800 gal) than they deliver (3800 gal) with each dedicated South Pole fuel mission. (Each tractor consumes 5100 gal while delivering 8100 gal.)

Certainly, there will need to be refinements to the numbers and scenarios presented here and in prior studies. However, there seems to be convergence and good agreement among the various studies, suggesting that, even when viewed from different perspectives, these calculations are reasonable. Even better, the well-documented Dome C traverse experience is proving that not only are these estimates supportable, but that a sustained logistics traverse can be operated with acceptable and manageable levels of risk.

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APPENDIX B

US ITASE 2002-2003 FIELD REPORT

US ITASE 2002-2003 Field Report

Prepared in the field and submitted by:
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On behalf of the 2001-2002 US ITASE traverse team.

Summary

During the fourth US ITASE season (2002-2003) the field team traversed 1250 km from Byrd to South Pole. The traverse was comprised of 13 members, two Challenger 55s, and various heavy and light sleds. The bulk of the AN8 fuel used by the Challengers was air dropped to four sites along the route. Route selection was based upon the science objectives of the US ITASE researchers and safe route selection was aided by examination of RADARSAT images and an onboard crevasse detection system

Eleven, integrated science programs were supported by US ITASE in 2002-2003. Science was conducted both during travel and at eight sites. Continuous shallow (~120 m) and deep (>3000m) radar, high precision kinematic GPS, and surface snow sampling comprised the travel component of the science. Near real-time shallow radar information was used to finely tune the location of study sites and to tie these sites together via identification of long distance subsurface marker horizons. At each site 3” and 2” diameter ice cores were collected that will provide samples for stable isotopes, major soluble ions, water soluble trace gases, trace elements, organic acids, activity, stratigraphy, porosity, permeability, and density. A total of 920 m of ice core was collected. Atmospheric sampling of surface air and air to a height of 23 km was conducted as well as high precision GPS surveys to determine mass balance, ice flow direction and speeds, and ice surface topography.

Introduction

US ITASE offers the ground-based opportunities of traditional style traverse travel coupled with the modern technology of satellite image route selection, GPS navigation, crevasse detecting radar, satellite communications and multi-disciplinary research. By operating as an oversnow traverse US ITASE offers scientists the opportunity to experience the dynamic range of the Antarctic environment. US ITASE also offers an important interactive venue for research (currently eleven integrated science projects) similar to that afforded by oceanographic research vessels and large polar field camps, without the cost of the former or the lack of mobility of the latter. More importantly, the combination of disciplines represented by US ITASE provides a unique, multi-dimensional (x, y, z and time) view of the ice sheet and its history. Over the past four field seasons (1999-2003) US ITASE sampled the environment of West Antarctica into East Antarctica over spatial scales of >5000 km, depths of >3000 m, heights in the atmosphere of >20 km, and time periods of several hundred years (sub-annual scale) to hundreds of thousands of years (millennial scale).

Members of the 2002-2003 US ITASE Field Team

*Steve Arcone (CRREL) – PI surface radar
Daniel Dixon (U Maine) Graduate student glaciochemistry, snowpit physical studies
Markus Frey (U Arizona) – Graduate student air/snow chemistry
Gordon Hamilton (U Maine) – PI surface glaciology
Carl Hess (Raytheon) – Mechanic
Andrea Isgro (Raytheon) – Cook, medical officer
Susan Kaspari (U Maine) – Graduate student glaciochemistry
Jim Laatsch (USA CRREL/Dartmouth) – Undergraduate student shallow radar
Paul Mayewski (U Maine) – Field Leader, PI glaciochemistry
Lynn Peters (Raytheon) – Camp Manager
Blue Spikes (U Maine) – Graduate student surface glaciology
*Eric Steig (U Washuington) – PI stable isotopes
Brian Welch (St. Olaf College) – Post-doc deep radar
Mark Wumkes (Glacier Data and Ice Core Drilling Services) – Ice core driller
Betsy Youngman (U Arizona) – Atmospheric chemistry technician

* partial field season – departed 6 December due to delays in field schedule

Brief Description of US ITASE 2002-2003 LogisticActivities

During the 2002-2003 season the US ITASE traverse included:

(1) 13 members (two others were unable to participate due to early season delays)
(2) the Challenger 55 used on the 2000-2001 season initially equipped with narrow tracks – now fitted with wide tracks
(3) the Challenger 55 used on the 2001-2002 traverse – fitted with wide tracks and a wide axle
(4) one Aalaner sled borrowed from Scott Base for carrying fuel (provided to the traverse after an initial failed attempt at using a Berco as a fuel sled)
(5) one Berco sled with a permanent shelter configured with 9 berths and space for science activities
(6) one Berco sled with a permanent shelter configured as a kitchen and berthing for up to 4 people
(7) one Berco sled to carry ice cores and food
(8) one Berco for science equipment
(9) one Polar Haven mounted on a Berco sled for use as a mechanic workspace and berthing for 4 people
(10) an assortment of smaller sleds (e.g., 2 Maudheims, one Polar Associate, 3 Nansens and 2 Komatiks)
(11) two LC-130 fuel drops were made early in the season to provide AN8 fuel for the traverse.

The traverse route planned for 2002-2003 extended 1250 km from Byrd Surface Camp to South Pole. The traverse team arrived at Byrd on 20 November – five days behind schedule due to weather in McMurdo and Byrd. The Byrd put-in crew (Lynn Peters, Carl Hess, Andrea Isgro plus other Raytheon staff) arrived at Byrd 28 October. Fuel was air dropped along the traverse route several days prior to 31 October.

On 23 November the traverse team departed for Site 1 (270 km from Byrd). After nearly 48 hours of continuous attempts the traverse team had covered only 46 km. There was little doubt that forward progress was not practical when the Berco fuel sled continually had snow above its axles and the wide Komatik (Zebowski) sleds became snow anchors due to low clearance. Our extremely slow progress was a consequence of:

(1) Deeper snow than anything encountered during previous ITASE and ITASE related traverses (1994-95, 1999-00, 2000-01, 2001-02). We assume the increased snowfall was related to the impact of the 2002-03 El Nino on West Antarctica.

(2) Loss of the Alaaner sled used as a fuel sled in 2000-01 and 2001-02. We attempted to use a Berco sled in lieu of the Alaaner shipped back to Scott Base at the end of the 2001-02 season.

(3) Lack of wide tracks on the older Challenger 55. The narrow tracks that functioned adequately during 2000-01 and 2001-02 were insufficient for the deeper snow encountered in 2002-03.

After discussion with McMurdo we returned to Byrd. Several alternatives were suggested: completing only part of the planned traverse, shuttling lighter loads, limiting science objectives, and waiting at Byrd for the Alaaner fuel sled and a set of Challenger 55 wide tracks. We were advised that every attempt would be made to provide us with both the Alaaner and the wide tracks. The Alaaner and wide tracks arrived at Byrd 5 December.

By 6 December the wide tracks were mounted (in just several hours) and the Alaaner loaded with fuel. The traverse departed that day for Site 1. Travel to this site averaged ~5km/hour as a consequence of soft snow. From Site 1 to Site 3 travel remained relatively slow due to soft patches, sometimes necessitating pulling a single train by two Challengers in tandem. Adjustments to sled loads and configurations gradually improved travel. Unfortunately the only sled available for carrying empty fuel barrels was needed to carry scientific equipment and the atmospheric sampling set-up was off-loaded from Zebrowski sleds that acted like snow anchors. After traversing the transition from West to East Antarctica through the Bottleneck travel on the East Antarctic Plateau improved until ~100km from South Pole where deep (12”+) snow forced us to ferry loads to South Pole.

Major Scientific and Logistical Accomplishments of the 2002-2003 Field Season

Between 23 November 2002 when the US ITASE team arrived at Byrd and 7 January 2003 when the team departed South Pole the following major scientific and logistic goals were accomplished:

(1) Two Challenger 55s traversed a total of 1250 km on the main traverse and ~500 km on day trips.

(2) Continuous radar observations (crevasse detection (400 MHz) and shallow depth (400 MHz) were made over the 1250 km of the main traverse route. Deep (2.5 MHz) radar was conducted over all but 166 km of the full 1250 km and over ~200 km of day trips. High precision kinematic GPS data were collected in tandem with the radar profiling along the entire traverse route.

(3) Five original science sites were occupied for periods of 2-3 days, plus work at Byrd conducted during the wait for the Alaaner and wide tracks, plus one reconnaissance site in preparation for phase two of US ITASE.

Site	Latitude	Longitude	Elevation	Ice Core Total (m)
Byrd	80 S	120 W	1520 m	71
1	82 01’ S	110 03’ W	1745 m	118
2	83 30’ S	104 59’ W	1964 m	119
3	85 00’ S	104 59’W	2401 m	75
4	86 30’ S	107 59’ W	2595 m	123
5	88 00’ S	108 00’ W	2600 m	78
SPRESO	89 55’ S	147 34’ E	2810 m	319*
X9	89 S	59 58 W	2790 m	17

*300 m collected by ICDS SPRESO team for US ITASE

A total of 920 m of ice cores were recovered utilizing both the 3” diameter Eclipse drill purchased by NSF for use by US ITASE and a 2.2” diameter lightweight drill built by Glacier Data for the University of Maine. Analyses to be conducted on these cores include: stable isotopes, major ion chemistry, trace and reversible species chemistry, beta activity, stratigraphy, porosity, and permeability.

(4) Atmospheric and shallow chemistry observations were conducted at eight sites for periods of 24-48 hours. This sampling included real-time, continuous observations of peroxides (H2O2 and organic peroxides), formaldehyde and ozone near surface and ozone profiles up to an altitude of ~20 km. 2”-cores (total length 38 m) from 7 sites were analyzed for H2O2 and HCHO on site using a continuous flow analysis melter system. The seasonal signal of H2O2 provided an on site estimate of the mean annual accumulation over the past 10-15 yr and was used along with stratigraphic determination of annual accumulation as an orientation for the minimum drilling depth.

(5) Basic meteorological observations were collected at all sites and 10 m depth temperatures for comparison with infrared satellite estimates of mean annual temperature.

(6) Five high precision GPS ‘coffee can’ experiments were deployed (Sites 1-5) to calculate mass balance and the distribution of basal sliding motion.

(7) High precision GPS mapping was conducted at Byrd and Site 3 as validation for NASA’s ICESat experiment.

Details of the 2002-2003 Traverse and Recommendations for Future Improvements

The information presented below does not guarantee perfect US ITASE seasons in the future, however, it is intended to be an important step in the evolution of research style oversnow traverse capability. Several discussion items follow. They represent the combined thoughts of the members of the US ITASE 2002-03 traverse. They are offered as a starting point for discussions with OPP/NSF and Raytheon concerning future US ITASE activities.

Heavy Oversnow Vehicles

US ITASE operated with two Challenger 55s during 2002-2003. Each vehicle pulled between 30,000 and 45,000 lbs. The vehicles performed very well once both were equipped with wide tracks. Only routine maintenance was required.

Heavy oversnow vehicle recommendations for future traverses:

(1) One mechanic's position should be maintained for each heavy vehicle.

(2) The older Challenger should be fitted with a rear winch and cable, heavy-duty hitch, and counter weights similar to the newer Challenger as requested in our 2001-02 field report.

(3) As requested in our 2001-02 report blockage problems for engine screens in freezing fog and diamond dust conditions should be investigated to prevent overheating and 1-3 km frequency stops to clear screens in fog conditions. This may be resolved through the addition of pusher fans or reversible fans.

(4) The older Challenger has a 60" wide axle (including spacers) and the newer Challenger has an 80" wide axle. The newer Challenger negotiated turns far more easily (by 100s of m) when pulling sleds than the older Challenger. The reduced turning capacity of the older Challenger resulted in the train bogging down several times. Further the wider axle Challenger cut a path outside that of following Berco sleds allowing the latter to cut through untouched snow, reducing ground clearance problems.

Heavy Oversnow Sleds and Permanent Shelters

Four Berco sleds (3000 lbs each) and one Alaaner sled (6000 lbs) were used during the 2001-2002 season. The Alaaner was replaced by another Berco for the onset of the 2002-03 season. A replacement Alaaner or equivalent fuel sled was requested in the 2001-02 field report. The Alaaner request was based on the success of using this sled in two previous seasons. However, because the Alaaner was already on extended loan from Scott Base it was returned to Scott Base at the end of the 2001-02 season. We were informed that it would be replaced by a Berco.

A description of the use for each sled follows:

(1) Berco 1 ("Blue Room") served as a science facility (warm space for computers and wet chemistry preparation) plus berthing for up to 9 people. The Blue Room has a solar/wind powered system with a bank of 10 batteries. Shallow radar and kinematic GPS profiling was carried out in this structure during the travel legs.

(2) Berco 2 afforded kitchen space. Seating for 14-15 is possible during special dinners, and up to 10 "comfortably" on a routine basis. The kitchen also

offered berthing for 4 people. The kitchen has a solar/wind powered 24 volt system with a bank of 10 batteries (although the 24 V inverter failed mid season and was replaced with a spare 12 V system).

(3) Berco 3 was fitted at Byrd with a Weather Haven. It provided space for work on mechanical, ice coring, and radar equipment, berthing for 4 people, and overflow space for dining.

(4) Berco 4 provided space for ice core boxes plus food stores.

(5) Berco 5 was originally intended to carry fuel drums. It sank to its axles on the first attempt to Site 1 and was replaced by the Alaaner as a fuel sled. This Berco served as a sled for science cargo and the ATM sled. The ATM sled (Zebowski style) sank in the snow due to low ground clearance.

(6) The Alaaner sled proved once again to be a superb fuel sled.

Heavy oversnow sled and permanent shelter recommendations for future traverses:

(1) The Alaaner sled proved to be an excellent, if not essential sled, carrying 50+ fuel drums in 2001-02 (40+ in 2002-03), 9 100 lb propane cylinders, and various other items. The ski design on this sled is well suited to oversnow transport. Alaaner axles have high ground clearance. Alaaner skiis are shaped like floats (convex underside for flotation, convex upper side to shed snow) and white to minimize heating. Although satisfactory for lighter loads the Berco sleds have half the load capacity (~17,000 lbs Berco, ~40,000 lbs Alaaner), and significantly less flotation. The Alaaner consistently floated on the snow surface. FLOTATION, FLOTATION, FLOTATION.

(2) Check all sleds before deploying to the field. The Berco sent to Byrd for the 2001-02 season was missing both of its front pulling chains (no doubt removed during transport and misplaced). The Alaaner sent to Byrd for the 2002-03 season, although greatly appreciated, was missing: lubrication for axles, one bolt in the hitch mount, and had severely scratched ski surfaces that increased drag, potentially leading to bogging down.

(3) Retain the Polar Haven mounted on Berco 3 as a workshop and berthing space. More ideally replace the Polar Haven with another permanent shelter that provides a warm workspace and berthing for four people. The additional berthing will relieve the crowded berthing for nine in the Blue Room. The Polar Haven was a last minute addition to US ITASE in 2001-02 and proved to be extremely valuable. Unfortunately the Polar Haven used in 2001-02 was installed without a window (fortunately a last minute installation at Byrd offered one small window), and was covered with mylar and bubble wrap preventing radio transmission until fitted with an external antennae.

(4) The Blue Room and kitchen shelters should be replaced with aluminum CONEX containers as originally requested. CONEX containers are: relatively light, fit into C130s deleting the necessity for construction in the field, more robust under rough transport than nailed structures, designed to be accepted by Berco sleds as indicated by mounts at Berco corners, easy to pack due to large end door, ideal structures for storage of over winter equipment, and can be

packed at home institutions or in McMurdo similar to the system used by oceanographic vessels.

(5) Sleds with low ground clearance should be avoided on intermediate (eg., US ITASE) and heavy traverses.

(6) All heavy sleds should come with tie downs for cargo straps. We managed to produce tie downs using webbing taken from airdropped parachutes.

(7) Per requests in earlier seasons a load cell should be provided to determine proper sled configuration in trains, assess sled sliding capabilities, and assist in future planning,

Snowmobiles

Two snowmobiles were requested for 2002-03. Two were supplied. One was shipped back to McMurdo with a broken track system. The other came on the traverse, but was not of sufficient quality to sustain long trips.

Snowmobile Recommendations for 2002-2003:

(1) The Alpine 2s appear to be too worn for remote parties. We had requested either Alpine 2s or Yamaha VK540s.

Fuel and Power

Several types of fuel were utilized during the 2002-2003 season:

(1) Quantity 100, 55gal drums of AN8 for the Challenger 55s to travel ~1300km each. During the 2000-2001 traverse fuel consumption was ~0.75km/gal. (an average of heavy loads and return light loads). The 2001-2002 traverse assumed 0.75 km/gal. plus ten extra drums. Using as a basis for fuel consumption the heavier loads towed in 2001-2002 and the need for small extra fuel supplies to do side trips an estimate of 0.6 km/gal. provided a greater margin of error for future fuel consumption estimates. Because most of the 2002-2003 traverse from Byrd to South Pole was uphill and we encountered significant travel issues on our first attempt to Site 1 we changed our fuel consumption estimate to 0.5 km/gal. The actual consumption was closer to 0 .6 to 0.65 km/gal allowing us to cache fuel for future activities.

(2) Quantity 9, 55 gal drums of Mogas for one snowmobile and five generators. This estimate was based on 2001-02 estimates. Actual consumption was closer to 6 drums.

(3) Quantity 12, 100lb propane cylinders for heating the Blue Room. Kitchen, and Polar Haven and for cooking. We might have used 12 propane cylinders except the temperatures encountered were far more moderate than expected. It was extremely hard to keep propane heaters operating so consumption was reduced.

(4) Quantity 22 gallons of white gas were on board as back up for propane stoves but were not used.

(5) Generators were used during 2002-2003 season for melting water, drilling, 24-hr on-site atmospheric chemistry measurements, and radar experiments. One Herman Nelson was available for thawing motors.

(6) Solar and wind power systems were significantly improved this year. The wind power system operated efficiently for the first time since it was installed in 2000-01. However, the battery bank for the solar systems did not weather well over the winter. The kitchen 3000 watt power inverter failed necessitating transfer of the 1800 watt system from the Polar Haven.
(7) US ITASE requested two small solar systems for the 2002-03 season. Parts were made available, but they had to be constructed in the field. Further the components were not always suitable to handling in the cold because of size, type, or placement.

Fuel and power recommendations for future traverses:

(1) Heating fuels that operate at low temperatures should be introduced for field use.
(2) Battery banks for solar power arrays in the Blue Room and kitchen should not be left to over winter in the deep field.
(3) Considerably more support should be given by Raytheon to the development and construction of solar and wind power systems. We utilized several small and large systems. While improving each year – the systems could be more fully and efficiently utilized.

Air Support including Fuel Drops

It is not clear how many C130 flights were dedicated to US ITASE this season since many of the flights to Byrd contained fuel and supplies for other teams. However, once the heavy vehicles and heavy sleds are in the field US ITASE should require no more than two C130 flights for put in, two for take out, and one to two for fuel emplacement.

One Twin Otter flight came to US ITASE in 2002-2003 to transport essential science cargo that was inadvertently not placed on a C130 flight.

Twin Otter close support was provided for the surface glaciology program. The tasking involved revisits to sites installed during earlier US ITASE seasons. The scheduling was convenient and the aircrew provided excellent support (in the air and helping with science work on site).

Two LC-130 airdrops were dedicated to US ITASE in 2002-03. A total of 24 pallets (4 drums per pallet) were air dropped at four sites along the traverse route. The 109th ANG did a superb job of placing the fuel drops at sites planned for scientific activities. All drops landed on target. Five chutes did not deploy. No fuel loss was observed, although some pallets required extensive excavation with a Challenger 55 for recovery. Airdrops most definitely provide an excellent way to avoid carrying large amounts of fuel and burning fuel to carry fuel.

All fuel drums either taken from Byrd or dropped along the traverse route were filled prior to deployment to within only ~8-10" of the barrel top. At most drop sites it took nearly one pallet of drums to top off four pallets.

An AN8 fuel cache was placed by the traverse during the 2002-2003 season at one site to assist with Twin Otter flights required for resurvey of GPS installations: 6 full

(AN8) barrels bermed on 6 empty barrels at 86 30’ 08.9” S, 107 59’ 26.1” W. 24 empty barrels were left at 83 32’ 09.48” S, 104 59’ 15.32” W to lighten the sled loads and allow forward progress.

Air support recommendations for future traverses:

(1) Fuel drums should be filled to the specified 4” to improve fuel delivery efficiency.
(2) Once US ITASE vehicles and sleds are fully deployed US ITASE can be supported by a maximum of six C130 flights per season or by Twin Otter and C130 airdrops. Continual change and exchange of sleds and vehicles, and construction of shelters that could be replaced by CONEX containers has necessitated considerably more flight allocation than necessary.

Light Sleds

A variety of light weight sleds were employed in 2002-2003 including:

(1) three Nansen sleds for camp activities, snowmobile work, and a 2” ice core platform
(2) one Maudheim for the 3’ ice core drill and ice core sampling equipment
(3) one Polar Associate to carry snowmobiles
(4) one Maudheim for tools, Herman Nelson, Challenger spares and fluids
(5) one Komatik (Zebowski) for deep radar (Pope Mobile)
(6) one Komatik for Polar Pooper
(7) two Komatiks for empty drums and science cargo – both were returned to McMurdo from Byrd after the first attempt to Site 1 because they functioned like snow anchors
(8) one Komatik for the ATM shelter – this sled was eventually mounted on a Berco because it too acted like a snow anchor.
Special Note: Unfortunately Berco #5 was used for science equipment formerly on Komatiks and the ATM Komatik reducing dramatically the potential for retrograding empty fuel barrels. Some barrels were discarded of necessity en route (with the knowledge of the NSF Rep McMurdo).

Light sled recommendations for future traverses:

(1) Light sleds should be carefully selected for traverses in regions with soft or thick snow keeping in mind sufficient ground clearance and track separation relative to heavier sl;eds.

Ice Coring Equipment

The primary drill used for the 2000-2003 seasons was the Icefield Instruments Eclipse 3’’ ice drill first used by US ITASE in 1999-2000. Overall performance was excellent with minor mechanical breakdowns. It offers notable logistic advantages that make it particularly useful for field traverse programs. It is lightweight and can be easily transported on a dedicated Maudheim sled, without complete disassembly. It takes a 3" diameter core and therefore requires fewer core boxes to transport and store the core than the standard 4" PICO drill. Eclipse ice core quality was excellent throughout all drilling depths making processing easier. ICDS supported valuable modifications to the Eclipse drill and provided a highly experienced driller.

A new 2" ice core drill (ITASE) designed by Glacier Data was introduced in 2001-02 and modified for use in 2002-03. The ITASE drill was designed for and purchased by the University of Maine and utilized by several US ITASE projects. It was used in conjunction with the Eclipse to reduce time on site and served extremely well.

Ice coring equipment recommendations for future traverses:

(1) It is essential to have an experienced driller on US ITASE traverses.
(2) The Eclipse drill control box and spare require weatherproofing to avoid wet circuitry problems.
(3) The Eclipse drill requires a modified slip ring assermbly on the sonde to avoid snow packing in this section and resultant slip ring failure induced drill spin that necessitates drill cable retermination.

Crevasse Detection Equipment

A crevasse detector was supplied and maintainned by CRREL during the field season. No crevasses were detected en route. However, crevasses were seen 5-10 km off to the side of the route suggested by RADARSAT examination.

Crevasse detection equipment recommendations for future traverses:

The crevasse detector utilized a small computer screen that was extremely hard to see and continually monitor. Further it required a dedicated operator. The system should be fitted with an audio signal tro warn the driver.

Polar Pooper

The ITASE toilet is mounted on a Komatik, improving its durability and allowing it to second as an equipment sled. The Polar Pooper plowed through sastrugi slowing forward motion in 2002-03, but faired better than the other Komatiks because it was lightly loaded.

Camping Equipment

Several sleeping bags issued to ITASE personnel were not cleaned prior to issue.

Communications

US ITASE had one NSF issued Iridium phone, two Iridium phones provided by the Museum of Science (MOS) Boston, one Iridium provided by the University of Maine, 2 HF PRC 1099 HF radios, four VHF radios and, five VHF base stations. Daily communications were routinely accomplished with the Iridium. The two Iridium phones supplied by MOS were used for transmitting daily logs for the US ITASE outreach program. Because only one NSF Iridium was available for US ITASE we were issued a 2001-02 vintage NSF SIM card for one MOS phone expanding our communication capability. The University of Maine Iridium phone provided a data link for personal and business use.

Communications recommendations for future traverses:

(1) Iridium phones should be considered routine tools for communication and safety. Ideally one phone should be issued per 2 people in each field party.

US ITASE Outreach

During the US ITASE 2002-2003 field season the field team participated in several outreach activities. These included: a Wednesday night lecture in McMurdo, a Sunday night lecture at South Pole, news articles for the Antarctic Sun, biweekly live interviews with the Boston Museum of Science (1 November to mid Jan) and the media.

US ITASE had a TEA assigned for the 2001-02 field season. However, the TEA was injured while in McMurdo and returned home. With the remaining funds US ITASE hired a school teacher (Peggy Lewis) interacted with US ITASE remotely while remaining in Iowa. We were also fortunate in 2002-03 to have a former TEA (Betsy Youngman) join the team as a field tech. She maintainned a TEA like involvement while conducting her regular ITASE science activities.

Ann Zielinski maintainned the link between US ITASE, MOS, and various other outreach activities from her office at the University of Maine.

Acknowledgements

US ITASE was most fortunate this year to have three highly experienced, highly capable Raytheon personnel involved in the project. Lynn Peters returned to US ITASE this year to serve as camp manager and mechanic. Carl Hess joined US ITASE this year as mechanic. Andrea Isgro joined US ITASE this year as the first full time cook and as medical officer.

There is no doubt at all that US ITASE owes an immense debt of gratitude to these three individuals for keeping us moving, comfortable, well fed, happy, and able to conduct our science.

We would also like to thank all of the other Raytheon staff who were involved in US ITASE. Notably our POC Kirk Salveson.

And, of course, thank you to the 109th New York Air National Gaurd for airdrops and flights.

APPENDIX C

AIR EMISSIONS FROM FUEL COMBUSTION SOURCES

Table C-1. Estimated Air Emissions from Fuel Combustion Sources During Resupply Traverses Conducted in Alternative A

	Tractors		**Generators**		**Heaters**		**Snowmobiles**		
	Fuel Usage: 58 L/hr; 700,000 L/yr		Fuel Usage: 12 L/hr; 25,000 L/yr		Fuel Usage: 1.5 L/hr; 6,600 L/yr		Fuel Usage: 1 L/hr; 1,200 L/yr		
Air Pollutant	**Emissions Factor (kg/L) [1][2]**	**Emissions (kg/yr)**	**Emissions Factor (kg/L) [1][3]**	**Emissions (kg/yr)**	**Emissions Factor (kg/L) [4][5]**	**Emissions (kg/yr)**	**Emissions Factor (kg/L) [1][6]**	**Emissions (kg/yr)**	**Total Emissions (kg/yr)**
Sulfur Oxides	5.71E-06	4.00E+00	7.39E-06	1.85E-01	6.91E-03	4.56E+01	6.05E-06	7.26E-03	**4.98E+01**
Nitrogen Oxides	1.52E-05	1.06E+01	2.07E-05	5.17E-01	2.40E-03	1.58E+01	4.16E-06	4.99E-03	**2.70E+01**
Carbon Monoxide	4.70E-06	3.29E+00	2.01E-05	5.03E-01	6.00E-04	3.96E+00	1.75E-03	2.10E+00	**9.85E+00**
Exhaust Hydrocarbons	7.22E-07	5.05E-01	4.31E-06	1.08E-01	NCA		6.42E-04	7.71E-01	**1.38E+00**
Particulate Matter	6.91E-07	4.83E-01	3.04E-06	7.59E-02	2.40E-04	1.58E+00	1.59E-05	1.91E-02	**2.16E+00**
Carbon Dioxide	1.49E-03	1.04E+03	2.24E-03	5.59E+01	2.66E+00	1.75E+04	1.17E-02	1.40E+01	**1.87E+04**
Total Organic Carbon (TOC)	NCA		NCA		6.67E-05	4.40E-01	NCA		**4.40E-01**
Non-methane TOC	NCA		NCA		4.08E-05	2.69E-01	NCA		**2.69E-01**
Methane	NCA		NCA		2.59E-05	1.71E-01	NCA		**1.71E-01**
Nitrous Oxide	NCA		NCA		1.32E-05	8.71E-02	NCA		**8.71E-02**
Polycyclic Organic Matter (POM)	NCA		NCA		3.96E-07	2.61E-03	NCA		**2.61E-03**

Notes:

NCA = No characterization data available.

[1] U.S. EPA Nonroad Emissions Model, U.S. EPA National Vehicle and Fuel Emissions Laboratory, draft version, June 1998.

[2] Emissions factor for tractors, in kg/L = [emissions factor in lbs/hour x 0.4536 kg/lb]/57.8 L/hr fuel consumption

[3] Emissions factor for generators, in kg/L = [emissions factor in lbs/hour x 0.4536 kg/lb]/12.1 L/hr fuel consumption

[4] U.S. EPA Office of Air and Radiation. *Compilation of Air Pollutant Emission Factors. AP-42*, Volume II, Mobile Sources, Fourth Edition. September 1985.

[5] Emissions factor for heaters, in kg/L = [emissions factor in lbs/gallon x 0.4536 kg/lb/3.78 liters/gal]/1.6 L/hr fuel consumption

[6] Emissions factor for snowmobiles, in kg/L = [emissions factor in lbs/hour x 0.4536 kg/lb]/1.2 L/hr fuel consumption

Table C-2. Estimated Air Emissions from Fuel Combustion Sources During Resupply Traverses Conducted in Alternative B

Air Pollutant	**Tractors**		**Generators**		**Heaters**		**Snowmobiles**		**Total Emissions (kg/yr)**
	Fuel Usage: 58 L/hr; 350,000 L/yr		Fuel Usage: 12 L/hr; 13,000 L/yr		Fuel Usage: 1.5 L/hr; 3,400 L/yr		Fuel Usage: 1 L/hr; 600 L/yr		
	Emissions Factor (kg/L) [1][2]	**Emissions (kg/yr)**	**Emissions Factor (kg/L) [1][3]**	**Emissions (kg/yr)**	**Emissions Factor (kg/L) [4][5]**	**Emissions (kg/yr)**	**Emissions Factor (kg/L) [1][6]**	**Emissions (kg/yr)**	
Sulfur Oxides	5.71E-06	2.00E+00	7.39E-06	9.60E-02	6.91E-03	2.35E+01	6.05E-06	3.63E-03	**2.56E+01**
Nitrogen Oxides	1.52E-05	5.30E+00	2.07E-05	2.69E-01	2.40E-03	8.16E+00	4.16E-06	2.49E-03	**1.37E+01**
Carbon Monoxide	4.70E-06	1.65E+00	2.01E-05	2.62E-01	6.00E-04	2.04E+00	1.75E-03	1.05E+00	**5.00E+00**
Exhaust Hydrocarbons	7.22E-07	2.53E-01	4.31E-06	5.60E-02	NCA		6.42E-04	3.85E-01	**6.94E-01**
Particulate Matter	6.91E-07	2.42E-01	3.04E-06	3.95E-02	2.40E-04	8.16E-01	1.59E-05	9.53E-03	**1.11E+00**
Carbon Dioxide	1.49E-03	5.22E+02	2.24E-03	2.91E+01	2.66E+00	9.03E+03	1.17E-02	7.01E+00	**9.59E+03**
Total Organic Carbon (TOC)	NCA		NCA		6.67E-05	2.27E-01	NCA		**2.27E-01**
Non-methane TOC	NCA		NCA		4.08E-05	1.39E-01	NCA		**1.39E-01**
Methane	NCA		NCA		2.59E-05	8.81E-02	NCA		**8.81E-02**
Nitrous Oxide	NCA		NCA		1.32E-05	4.49E-02	NCA		**4.49E-02**
Polycyclic Organic Matter (POM)	NCA		NCA		3.96E-07	1.35E-03	NCA		**1.35E-03**

Notes:
NCA = No characterization data available.
[1] U.S. EPA Nonroad Emissions Model, U.S. EPA National Vehicle and Fuel Emissions Laboratory, draft version, June 1998.
[2] Emissions factor for tractors, in kg/L = [emissions factor in lbs/hour x 0.4536 kg/lb]/57.8 L/hr fuel consumption
[3] Emissions factor for generators, in kg/L = [emissions factor in lbs/hour x 0.4536 kg/lb]/12.1 L/hr fuel consumption
[4] U.S. EPA Office of Air and Radiation. *Compilation of Air Pollutant Emission Factors. AP-42*, Volume II, Mobile Sources, Fourth Edition. September 1985.
[5] Emissions factor for heaters, in kg/L = [emissions factor in lbs/gallon x 0.4536 kg/lb/3.78 liters/gal]/1.6 L/hr fuel consumption
[6] Emissions factor for snowmobiles, in kg/L = [emissions factor in lbs/hour x 0.4536 kg/lb]/1.2 L/hr fuel consumption

Table C-3. Estimated Air Emissions from Fuel Combustion Sources During Resupply Traverses Conducted in Alternative C

	Tractors		**Generators**		**Heaters**		**Snowmobiles**		
	Fuel Usage: 58 L/hr; 350,000 L/yr		Fuel Usage: 12.1 L/hr; 25,000 L/yr		Fuel Usage: 1.5 L/hr; 6,600 L/yr		Fuel Usage: 1 L/hr; 1,200 L/yr		
Air Pollutant	**Emissions Factor (kg/L) [1][2]**	**Emissions (kg/yr)**	**Emissions Factor (kg/L) [1][3]**	**Emissions (kg/yr)**	**Emissions Factor (kg/L) [4][5]**	**Emissions (kg/yr)**	**Emissions Factor (kg/L) [1][6]**	**Emissions (kg/yr)**	**Total Emissions (kg/yr)**
Sulfur Oxides	5.71E-06	2.00E+00	7.39E-06	1.85E-01	6.91E-03	4.56E+01	6.05E-06	7.26E-03	**4.78E+01**
Nitrogen Oxides	1.52E-05	5.30E+00	2.07E-05	5.17E-01	2.40E-03	1.58E+01	4.16E-06	4.99E-03	**2.17E+01**
Carbon Monoxide	4.70E-06	1.65E+00	2.01E-05	5.03E-01	6.00E-04	3.96E+00	1.75E-03	2.10E+00	**8.21E+00**
Exhaust Hydrocarbons	7.22E-07	2.53E-01	4.31E-06	1.08E-01	NCA		6.42E-04	7.71E-01	**1.13E+00**
Particulate Matter	6.91E-07	2.42E-01	3.04E-06	7.59E-02	2.40E-04	1.58E+00	1.59E-05	1.91E-02	**1.92E+00**
Carbon Dioxide	1.49E-03	5.22E+02	2.24E-03	5.59E+01	2.66E+00	1.75E+04	1.17E-02	1.40E+01	**1.81E+04**
Total Organic Carbon (TOC)	NCA		NCA		6.67E-05	4.40E-01	NCA		**4.40E-01**
Non-methane TOC	NCA		NCA		4.08E-05	2.69E-01	NCA		**2.69E-01**
Methane	NCA		NCA		2.59E-05	1.71E-01	NCA		**1.71E-01**
Nitrous Oxide	NCA		NCA		1.32E-05	8.71E-02	NCA		**8.71E-02**
Polycyclic Organic Matter (POM)	NCA		NCA		3.96E-07	2.61E-03	NCA		**2.61E-03**

Notes:

NCA = No characterization data available.

[1] U.S. EPA Nonroad Emissions Model, U.S. EPA National Vehicle and Fuel Emissions Laboratory, draft version, June 1998.

[2] Emissions factor for tractors, in kg/L = [emissions factor in lbs/hour x 0.4536 kg/lb]/57.8 L/hr fuel consumption

[3] Emissions factor for generators, in kg/L = [emissions factor in lbs/hour x 0.4536 kg/lb]/12.1 L/hr fuel consumption

[4] U.S. EPA Office of Air and Radiation. *Compilation of Air Pollutant Emission Factors. AP-42*, Volume II, Mobile Sources, Fourth Edition. September 1985.

[5] Emissions factor for heaters, in kg/L = [emissions factor in lbs/gallon x 0.4536 kg/lb/3.78 liters/gal]/1.6 L/hr fuel consumption

[6] Emissions factor for snowmobiles, in kg/L = [emissions factor in lbs/hour x 0.4536 kg/lb]/1.2 L/hr fuel consumption

Table C-4. Estimated Air Emissions from Fuel Combustion Sources During Resupply Traverses Conducted in Alternative D

	Tractors		**Generators**		**Heaters**		**Snowmobiles**		
	Fuel Usage: 58 L/hr; 700,000 L/yr		Fuel Usage: 12 L/hr; 25,000 L/yr		Fuel Usage: 1.5 L/hr; 6,600 L/yr		Fuel Usage: 1 L/hr; 1,200 L/yr		
Air Pollutant	**Emissions Factor (kg/L) [1][2]**	**Emissions (kg/yr)**	**Emissions Factor (kg/L) [1][3]**	**Emissions (kg/yr)**	**Emissions Factor (kg/L) [4][5]**	**Emissions (kg/yr)**	**Emissions Factor (kg/L) [1][6]**	**Emissions (kg/yr)**	**Total Emissions (kg/yr)**
Sulfur Oxides	5.71E-06	4.00E+00	7.39E-06	1.85E-01	6.91E-03	4.56E+01	6.05E-06	7.26E-03	**4.98E+01**
Nitrogen Oxides	1.52E-05	1.06E+01	2.07E-05	5.17E-01	2.40E-03	1.58E+01	4.16E-06	4.99E-03	**2.70E+01**
Carbon Monoxide	4.70E-06	3.29E+00	2.01E-05	5.03E-01	6.00E-04	3.96E+00	1.75E-03	2.10E+00	**9.85E+00**
Exhaust Hydrocarbons	7.22E-07	5.05E-01	4.31E-06	1.08E-01	NCA		6.42E-04	7.71E-01	**1.38E+00**
Particulate Matter	6.91E-07	4.83E-01	3.04E-06	7.59E-02	2.40E-04	1.58E+00	1.59E-05	1.91E-02	**2.16E+00**
Carbon Dioxide	1.49E-03	1.04E+03	2.24E-03	5.59E+01	2.66E+00	1.75E+04	1.17E-02	1.40E+01	**1.87E+04**
Total Organic Carbon (TOC)	NCA		NCA		6.67E-05	4.40E-01	NCA		**4.40E-01**
Non-methane TOC	NCA		NCA		4.08E-05	2.69E-01	NCA		**2.69E-01**
Methane	NCA		NCA		2.59E-05	1.71E-01	NCA		**1.71E-01**
Nitrous Oxide	NCA		NCA		1.32E-05	8.71E-02	NCA		**8.71E-02**
Polycyclic Organic Matter (POM)	NCA		NCA		3.96E-07	2.61E-03	NCA		**2.61E-03**

Notes:

NCA = No characterization data available.

[1] U.S. EPA Nonroad Emissions Model, U.S. EPA National Vehicle and Fuel Emissions Laboratory, draft version, June 1998.

[2] Emissions factor for tractors, in kg/L = [emissions factor in lbs/hour x 0.4536 kg/lb]/57.8 L/hr fuel consumption

[3] Emissions factor for generators, in kg/L = [emissions factor in lbs/hour x 0.4536 kg/lb]/12.1 L/hr fuel consumption

[4] U.S. EPA Office of Air and Radiation. *Compilation of Air Pollutant Emission Factors. AP-42*, Volume II, Mobile Sources, Fourth Edition. September 1985.

[5] Emissions factor for heaters, in kg/L = [emissions factor in lbs/gallon x 0.4536 kg/lb/3.78 liters/gal]/1.6 L/hr fuel consumption

[6] Emissions factor for snowmobiles, in kg/L = [emissions factor in lbs/hour x 0.4536 kg/lb]/1.2 L/hr fuel consumption

Table C-5. Estimated Air Emissions from Fuel Combustion Sources During Resupply Traverses Conducted in Alternative E

Air Pollutant	Tractors		Generators		Heaters		Snowmobiles		Total Emissions (kg/yr)
	Fuel Usage: 58 L/hr; 700,000 L/yr		Fuel Usage: 12 L/hr; 25,000 L/yr		Fuel Usage: 1.5 L/hr; 6,600 L/yr		Fuel Usage: 1 L/hr; 1,200 L/yr		
	Emissions Factor (kg/L) [1][2]	**Emissions (kg/yr)**	**Emissions Factor (kg/L) [1][3]**	**Emissions (kg/yr)**	**Emissions Factor (kg/L) [4][5]**	**Emissions (kg/yr)**	**Emissions Factor (kg/L) [1][6]**	**Emissions (kg/yr)**	
Sulfur Oxides	5.71E-06	4.00E+00	7.39E-06	1.85E-01	6.91E-03	4.56E+01	6.05E-06	7.26E-03	**4.98E+01**
Nitrogen Oxides	1.52E-05	1.06E+01	2.07E-05	5.17E-01	2.40E-03	1.58E+01	4.16E-06	4.99E-03	**2.70E+01**
Carbon Monoxide	4.70E-06	3.29E+00	2.01E-05	5.03E-01	6.00E-04	3.96E+00	1.75E-03	2.10E+00	**9.85E+00**
Exhaust Hydrocarbons	7.22E-07	5.05E-01	4.31E-06	1.08E-01	NCA		6.42E-04	7.71E-01	**1.38E+00**
Particulate Matter	6.91E-07	4.83E-01	3.04E-06	7.59E-02	2.40E-04	1.58E+00	1.59E-05	1.91E-02	**2.16E+00**
Carbon Dioxide	1.49E-03	1.04E+03	2.24E-03	5.59E+01	2.66E+00	1.75E+04	1.17E-02	1.40E+01	**1.87E+04**
Total Organic Carbon (TOC)	NCA		NCA		6.67E-05	4.40E-01	NCA		**4.40E-01**
Non-methane TOC	NCA		NCA		4.08E-05	2.69E-01	NCA		**2.69E-01**
Methane	NCA		NCA		2.59E-05	1.71E-01	NCA		**1.71E-01**
Nitrous Oxide	NCA		NCA		1.32E-05	8.71E-02	NCA		**8.71E-02**
Polycyclic Organic Matter (POM)	NCA		NCA		3.96E-07	2.61E-03	NCA		**2.61E-03**

Notes:
NCA = No characterization data available.
[1] U.S. EPA Nonroad Emissions Model, U.S. EPA National Vehicle and Fuel Emissions Laboratory, draft version, June 1998.
[2] Emissions factor for tractors, in kg/L = [emissions factor in lbs/hour x 0.4536 kg/lb]/57.8 L/hr fuel consumption
[3] Emissions factor for generators, in kg/L = [emissions factor in lbs/hour x 0.4536 kg/lb]/12.1 L/hr fuel consumption
[4] U.S. EPA Office of Air and Radiation. *Compilation of Air Pollutant Emission Factors. AP-42*, Volume II, Mobile Sources, Fourth Edition. September 1985.
[5] Emissions factor for heaters, in kg/L = [emissions factor in lbs/gallon x 0.4536 kg/lb/3.78 liters/gal]/1.6 L/hr fuel consumption
[6] Emissions factor for snowmobiles, in kg/L = [emissions factor in lbs/hour x 0.4536 kg/lb]/1.2 L/hr fuel consumption

Table C-6. Estimated Air Emissions From Fuel Combustion Sources During Scientific Traverses

	Tractors		**Generators**		**Heaters**		**Snowmobiles**		
	Fuel Usage: 30 L/hr; 30,000 L		Fuel Usage: 12 L/hr; 6,000 L		Fuel Usage: 1.5 L/hr; 3,000 L		Fuel Usage: 1 L/hr; 575 L		
Air Pollutant	**Emissions Factor (kg/L) [1][2]**	**Emissions (kg)**	**Emissions Factor (kg/L) [1][3]**	**Emissions (kg)**	**Emissions Factor (kg/L) [4][5]**	**Emissions (kg)**	**Emissions Factor (kg/L) [1][6]**	**Emissions (kg)**	**Total Emissions (kg)**
Sulfur Oxides	6.19E-06	1.86E-01	7.39E-06	4.43E-02	6.91E-03	2.07E+01	6.05E-06	3.48E-03	**2.10E+01**
Nitrogen Oxides	1.60E-05	4.80E-01	2.07E-05	1.24E-01	2.40E-03	7.20E+00	4.16E-06	2.39E-03	**7.81E+00**
Carbon Monoxide	4.22E-06	1.27E-01	2.01E-05	1.21E-01	6.00E-04	1.80E+00	1.75E-03	1.01E+00	**3.05E+00**
Exhaust Hydrocarbons	9.66E-07	2.90E-02	4.31E-06	2.59E-02	NCA		6.42E-04	3.69E-01	**4.24E-01**
Particulate Matter	9.35E-07	2.81E-02	3.04E-06	1.82E-02	2.40E-04	7.20E-01	1.59E-05	9.13E-03	**7.75E-01**
Carbon Dioxide	1.62E-03	4.85E+01	2.24E-03	1.34E+01	2.66E+00	7.97E+03	1.17E-02	6.72E+00	**8.04E+03**
Total Organic Carbon (TOC)	NCA		NCA		6.67E-05	2.00E-01	NCA		**2.00E-01**
Non-methane TOC	NCA		NCA		4.08E-05	1.22E-01	NCA		**1.22E-01**
Methane	NCA		NCA		2.59E-05	7.78E-02	NCA		**7.78E-02**
Nitrous Oxide	NCA		NCA		1.32E-05	3.96E-02	NCA		**3.96E-02**
Polycyclic Organic Matter (POM)	NCA		NCA		3.96E-07	1.19E-03	NCA		**1.19E-03**

Notes:
NCA = No characterization data available.
[1] U.S. EPA Nonroad Emissions Model, U.S. EPA National Vehicle and Fuel Emissions Laboratory, draft version, June 1998.
[2] Emissions factor for tractors, in kg/L = [emissions factor in lbs/hour x 0.4536 kg/lb]/29.1 L/hr fuel consumption
[3] Emissions factor for generators, in kg/L = [emissions factor in lbs/hour x 0.4536 kg/lb]/12.1 L/hr fuel consumption
[4] U.S. EPA Office of Air and Radiation. *Compilation of Air Pollutant Emission Factors. AP-42*, Volume II, Mobile Sources, Fourth Edition. September 1985.
[5] Emissions factor for heaters, in kg/L = [emissions factor in lbs/gallon x 0.4536 kg/lb/3.78 liters/gal]/1.6 L/hr fuel consumption
[6] Emissions factor for snowmobiles, in kg/L = [emissions factor in lbs/hour x 0.4536 kg/lb]/1.2 L/hr fuel consumption

Table C-7. Detailed Air Emissions from Logistical Support Aircraft

				Emission Rates [4]			Emissions (kg/year)			
Characteristic Pollutant	**Missions per year [1]**	**Flight Hours below 60^0S**	**Additional Idling Time (hr) [3]**	**LTO (kg/LTO)**	**Idling (kg/hr)**	**Flight (kg/hr)**	**LTO**	**Additional Idling**	**Cruise Flight**	**Total**
Aircraft: LC-130 (4 Engine Turboprop, Engine Manufacturer: Detroit Diesel Allison Division of General Motors, Model T56)										
Alternative A										
Sulfur Oxides	69	397	69	0.73	0.8	3	101	55	1,190	**1,346**
Nitrogen Oxides	69	397	69	4.35	4	24.6	600	276	9,760	**10,636**
Carbon Monoxide	69	397	69	14.68	31.6	7.4	2,026	2,180	2,936	**7,142**
Exhaust Hydrocarbons	69	397	69	9.2	20.8	1.2	1,270	1,435	476	**3,181**
Particulates	69	397	69	1.98	2.8	6.2	273	193	2,460	**2,926**
Alternative B										
Sulfur Oxides	35	201	35	0.73	0.8	3	51	28	604	**683**
Nitrogen Oxides	35	201	35	4.35	4	24.6	305	140	4,951	**5,395**
Carbon Monoxide	35	201	35	14.68	31.6	7.4	1,028	1,106	1,489	**3,623**
Exhaust Hydrocarbons	35	201	35	9.2	20.8	1.2	644	728	242	**1,614**
Particulates	35	201	35	1.98	2.8	6.2	139	98	1,248	**1,484**
Alternative C										
Sulfur Oxides	35	201	35	0.73	0.8	3	51	28	604	**683**
Nitrogen Oxides	35	201	35	4.35	4	24.6	305	140	4,951	**5,395**
Carbon Monoxide	35	201	35	14.68	31.6	7.4	1,028	1,106	1,489	**3,623**
Exhaust Hydrocarbons	35	201	35	9.2	20.8	1.2	644	728	242	**1,614**
Particulates	35	201	35	1.98	2.8	6.2	139	98	1,248	**1,484**
Alternative D										
Sulfur Oxides	67	385	67	0.73	0.8	3	98	54	1,156	**1,307**
Nitrogen Oxides	67	385	67	4.35	4	24.6	583	268	9,477	**10,328**
Carbon Monoxide	67	385	67	14.68	31.6	7.4	1,967	2,117	2,851	**6,935**
Exhaust Hydrocarbons	67	385	67	9.2	20.8	1.2	1,233	1,394	462	**3,089**
Particulates	67	385	67	1.98	2.8	6.2	265	188	2,389	**2,841**
Alternative E										
Sulfur Oxides	69	397	69	0.73	0.8	3	101	55	1,190	**1,346**
Nitrogen Oxides	69	397	69	4.35	4	24.6	600	276	9,760	**10,636**
Carbon Monoxide	69	397	69	14.68	31.6	7.4	2,026	2,180	2,936	**7,142**
Exhaust Hydrocarbons	69	397	69	9.2	20.8	1.2	1,270	1,435	476	**3,181**
Particulates	69	397	69	1.98	2.8	6.2	273	193	2,460	**2,926**

Table C-7. Detailed Air Emissions from Logistical Support Aircraft

				Emission Rates [4]			Emissions (kg/year)			
Characteristic Pollutant	**Missions per year [1]**	**Flight Hours below 60^{0}S**	**Additional Idling Time (hr) [3]**	**LTO (kg/LTO)**	**Idling (kg/hr)**	**Flight (kg/hr)**	**LTO**	**Additional Idling**	**Cruise Flight**	**Total**

Notes:

N/A = Not Applicable. NA = Not Available.

[1] Intercontinental missions comprise one round trip to Antarctica and have one landing/takeoff (LTO) cycle below 60^{o}S; Intracontinental flights have two LTO cycles below 60^{o}S.

[2] Intercontinental flight hours represent number of flight hours below 60^{o}S; assumed to be 50 percent of the total flight hours.

[3] Represents extra aircraft idling at the South Pole, assumed to be 1.0 hours per mission. Routine aircraft idling is included in LTO emissions.

[4] Presented in Table 4-10 of the *2002 Permit Amendments* (RPSC, 2002).

APPENDIX D
PUBLIC COMMENTS ON THE DRAFT COMPREHENSIVE ENVIRONMENTAL EVALUATION (CEE) and NSF RESPONSES

The Notice of Availability for public review of the draft EIS was published in the *Federal Register* on October 23, 2003. Via a website link, the draft EIS was made available for review and public comment. Comments received on the draft CEE and the responses to those comments are included in this appendix. If needed, the sections or pages of the final CEE that have been modified as a result of comments received are identified in the responses.

The following respondents provided comments on the draft CEE; NSF responses follow the comments from each respondent:

Australian Antarctic Division

German Federal Environmental Agency

Antarctica New Zealand

The Antarctic and Southern Ocean Coalition

Antarctic Treaty Consultative Meeting (ATCM)/Council on Environmental Protection (CEP) Members

Input provided by John H. Wright, Project Manager, South Pole Traverse Proof of Concept, Raytheon Polar Services Company

Australian Comments on Draft CEE for Development and Implementation of Surface Traverse Capabilities in Antarctica

Dear Fabio

Australia has sought input from interested stakeholders in Australia on the USA's draft CEE for the proposed development and implementation of surface traverse capabilities in Antarctica. Below are Australia's initial comments, prior to consideration of the draft CEE at ATCM XXVII/CEP VII.

- The document is not clear about the proposed commencement date for the activity, but notes that proving trials have commenced and are likely to continue over the next few austral summers. The timing aspect could be more clearly explained in the introductory section, noting in particular that a notional commencement date affects the date of circulation of the Final CEE under Annex I Article 3;
- Noting the open-ended nature of the activity, the CEE could address a framework for progress reporting once the activity has commenced, as reflected in Resolution 2 (1997). The *Master Permit* reporting process, described in Section 7.3, could be an efficient basis for this;
- There is relatively little consideration of the cumulative impacts [Article 3(2)(f)] of the 'permanent' traverse route between McMurdo and the South Pole, as the prime example in the CEE;
- Reference is made to a number of relevant procedural documents (e.g. the *USAP Master Permit*, *Field Camp Oil Spill Response Guidebook*, *Standard Operating Procedure for Placement, Management and Removal of Materials Cached at Field Locations*), however, copies or synopses of these documents are not appended, nor links to them identified/provided;
- While the environmental analysis does seem sound, the focus on direct impacts tends to be more on the impacts on science and operations than the environment;
- The document suggests a net gain environmentally through reduced fuel consumption, but also suggests that resources (ie aircraft) would be freed up to allow expansion of the program. A table or graph drawing together the fuel aspects of the various alternatives and including the status quo (ie aircraft) fuel figures would assist in consideration of this aspect;
- There is no contact name/address information [Annex I Article 3(2)(l)];
- The tables supporting Section 6 are well set out and assist with the consideration of the nature, scale, and likelihood of environmental impacts;
- Noting that many Parties (including Australia) have raised concerns with, and tried to improve, traverse waste management practices in traverse-related

projects discussed at recent CEP meetings, we commend the intention expressed in this CEE to avoid wastewater discharge "to the maximum extent practical" , and to release only wastewater into the environment and only under specified conditions.

I am happy to discuss any of these issues with you prior to the CEP meeting.

Best wishes,

Tom Maggs
A/g Manager, Environmental Policy and Protection Section
Australian Antarctic Division

Response to Comments from the Australian Antarctic Division (AAD)

AAD-1
Comment: The document is not clear about the proposed commencement date for the activity, but notes that proving trials have commenced and are likely to continue over the next few austral summers. The timing aspect could be more clearly explained in the introductory section, noting in particular that a notional commencement date affects the date of circulation of the Final CEE under Annex I Article 3.

Response: It is unknown at this point if or when a traverse capability will be used by the USAP for routine re-supply applications. The Proof of Concept engineering study is in progress and has completed its second year of field work to evaluate traverse methods and a potential route between McMurdo and South Pole Stations. Although much valuable data has been gained by the Proof of Concept study to date, development of a route and the expertise to transport cargo to the South Pole is ongoing. At least two more years will be needed to thoroughly test the feasibility of the traverse transport mechanism for the re-supply of the South Pole Station, and if deemed suitable, then a schedule will be developed for its application.

AAD-2
Comment: Noting the open-ended nature of the activity, the CEE could address a framework for progress reporting once the activity has commenced, as reflected in Resolution 2 (1997). The *Master Permit* reporting process, described in Section 7.3, could be an efficient basis for this

Response: The *Master Permit* reporting process will continue to be used to document conditions in the USAP governed by U.S. environmental regulations (45 CFR §671). In particular, the USAP will report annually on the management of Designated Pollutants used at all facilities, the disposition of wastes, and the identification of all substances released to the Antarctic environment. The scope of the *Master Permit* reporting process is inclusive of all fixed and mobile (traverses) USAP facilities.

AAD-3
Comment: There is relatively little consideration of the cumulative impacts [Article 3(2)(f)] of the 'permanent' traverse route between McMurdo and the South Pole, as the prime example in the CEE

Response: At this point, it has not been determined if a "permanent" route between McMurdo and the South Pole is feasible and will be utilized by the USAP. Assuming a route can be developed as described in the CEE, potential cumulative impacts include: (1) the release of exhaust gas emissions to the atmosphere, (2) the deposition of particulate matter from exhaust gas emissions along the traverse route, (3) the release of greywater and urine at areas along the route which will be used as traverse crew rest stops (human solid waste [sanitary] will be incinerated not discharged), and (4) the release of unrecoverable items used for the traverse operations (e.g., bamboo stakes, marker flags). In addition, the regular use of a route will continue to alter the terrain, generate noise, and slightly diminish the intrinsic wilderness value along the profile of the route. These impacts have been identified in the CEE and based on observations of traverses performed by other Treaty nations, the cumulative impacts may be more than minor or transitory but very localized in proximity to the traverse route itself.

AAD-4
Comment: Reference is made to a number of relevant procedural documents (e.g. the *USAP Master Permit, Field Camp Oil Spill Response Guidebook, Standard Operating Procedure for Placement, Management and Removal of Materials Cached at Field Locations*), however, copies or synopses of these documents are not appended, nor links to them identified/provided

Response: The USAP will provide links to the documents which are available electronically such as the *USAP Master Permit*. Legacy documents such as the *Field Camp Oil Spill Response Guidebook* are only available in hard copy formats and will be converted into electronic versions when the existing documents become obsolete and require updating. In addition, many of the USAP environmental documents are extremely large. For example, the *USAP Master Permit* and *Annual Amendments* identify all USAP permitted activities and include listings of products and materials containing Designated Pollutant constituents (hazardous materials) which are stored and used in the USAP. The list of materials containing Designated Pollutants is over several hundred pages long.

AAD-5
Comment: While the environmental analysis does seem sound, the focus on direct impacts tends to be more on the impacts on science and operations than the environment

Response: Equal emphasis was given to identifying and evaluating the direct impacts of the proposed action on science, operations, as well as the environment. The results of this analysis indicated that there would be no nature conservation (biota) issues of concern, releases to the environment (wastewater, exhaust gas emissions) would be negligible, and even though the overall impact of the action would be more than minor or transitory, the net effect would not cause widespread adverse environmental effects. On the other hand, the proposed action could cause substantive impacts to science and operations but these effects would be mitigated through careful planning and scheduling.

AAD-6
Comment: The document suggests a net gain environmentally through reduced fuel consumption, but also suggests that resources (i.e. aircraft) would be freed up to allow expansion of the program. A table or graph drawing together the fuel aspects of the various alternatives and including the status quo (i.e. aircraft) fuel figures would assist in consideration of this aspect

Response: The following table provides estimates of the expected quantity of fuel that may be consumed by airlift or traverse resources under representative conditions to annually transport a specific amount of cargo (2 million kg) from McMurdo Station to the South Pole. The table illustrates the differences in fuel usage if traverse resources are used to transport varying portions of the total annual cargo load. If a traverse mechanism is deemed feasible for the re-supply of the South Pole Station, the USAP currently believes that the optimum use of this resource would involve the transport of approximately 40 percent of the cargo by traverse and the remaining cargo and all of the personnel would be conveyed by aircraft.

Fuel Needed to Transport Cargo (2 million kg) to the South Pole from McMurdo Station

Usage [1]		**LC-130 Aircraft [2]**		**Traverse [3]**		**Total Fuel Consumed (liters)**
Aircraft	**Traverse**	**No. of Roundtrip Flights**	**Fuel Consumed (liters)**	**No. of Tractor Roundtrips**	**Fuel Consumed (liters)**	
100%	0	169	2,915,000	0	0	2,915,000
80%	20%	136	2,332,000	18	360,000	2,692,000
60%	**40%**	**100**	**1,726,000**	**36**	**730,000**	**2,456,000**
40%	60%	68	1,166,000	54	1,080,000	2,246,000
20%	80%	34	583,000	72	1,440,000	2,023,000
0	100%	← Not Feasible →				

Notes: BOLD = Optimal Traverse Configuration

[1] Percent distribution of cargo (2 million kg) transported to the South Pole from McMurdo Station via aircraft and traverse resources. Based on data presented in Analysis of McMurdo to South Pole Traverse as a means to Increase LC-130 Availability in the USAP (draft CEE Appendix A).

[2] Assumes that each LC-130 flight can transport 11,800 kg of cargo/fuel and will consume 17,200 liters of fuel to complete a roundtrip flight to the South Pole.

[3] Assumes that (roundtrip) traverse resources will consume 90,000 liters of fuel for each 100,000 kg of cargo/fuel delivered to the South Pole.

AAD-7

Comment: There is no contact name/address information [Annex I Article 3(2)(l)]

Response: Contact Name:

Dr. Polly Penhale
National Science Foundation, Office of Polar Programs
4201 Wilson Blvd., Suite 755S
Arlington, VA 22230
Telephone: 01 703 292 7420
Email: ppenhale@nsf.gov

AAD-8

Comment: The tables supporting Section 6 are well set out and assist with the consideration of the nature, scale, and likelihood of environmental impacts

Response: No Action Required

AAD-9

Comment: Noting that many Parties (including Australia) have raised concerns with, and tried to improve, traverse waste management practices in traverse-related projects discussed at recent CEP meetings, we commend the intention expressed in this CEE to avoid wastewater discharge “to the maximum extent practical” , and to release only wastewater into the environment and only under specified conditions

Response: As a result of the ongoing Proof of Concept evaluation, the USAP has determined that it will process rather than discharge all human solid waste (sanitary) in the field using incinerator toilets. If the incinerator toilets on a particular traverse mission are not useable, the human solid waste will be packaged and transported to a supporting station for disposition. Greywater resulting from habit support activities (bathing, food preparation) and urine may be discharged to the ice sheet at locations when the traverse stops for rest breaks.

In addition, sanitary liquid wastes will only be discharged in the path created by the traverse vehicles. Snow and ice areas adjacent to the traverse route will remain untouched to the maximum extent practical. If the USAP decides to repeatedly use a traverse route for re-supply missions, designated areas will be established to park traverse vehicles during rest stops. In this way, the number of areas where sanitary liquid waste is discharged will be limited.

German Federal Environmental Agency

Opinion on the Comprehensive Environmental Evaluation "**Development and Implementation of Surface Transverse Capabilities in Antarctica," National Science Foundation (NSF) – USA**

Current situation

The National Science Foundation (NSF) has prepared a study with a view to facilitating a decision on the development and implementation of surface transverse capabilities by the USA in Antarctica (referred to in the text of the CEE as "the proposed action").

To this end, an environmental impact assessment for the international cooperative process prescribed under Art. 8 and Annex I Art. 3 para. 3 of the Protocol on Environmental Protection to the Antarctic Treaty (PEP) was prepared.

The Federal Environmental Agency has made the assessment accessible to the public as prescribed under Art. 16 para. 1 and para. 2 of the German Act Implementing the Environmental Protection Protocol (AUG) and is forwarding the following German opinion to the States Parties to the Protocol.

Evaluation

The CEE provides a sound information base incorporating international experience and fulfils the objective of a study of this kind.

The structure and methodology, including evaluation methodology, meet the customary international standard for environmental impact studies. The relevant aspects of Annex I of the Protocol on Environmental Protection to the Antarctic Treaty were comprehensively taken into account, as were the USA's internal regulations on environmental protection. We found nothing in the report that contradicted the Protocol on Environmental Protection.

Since there are no relevant biota in the areas in question, no environmental assets relevant to nature conservation are affected by the planned traverses.

The proposed way of dealing with sewage seems practicable; the volumes to be disposed of along the traverses seems negligible.

The conclusions of the CEE are plausible and comprehensible, particularly the point that although the traverses will have an impact along their actual route that is more than minor or temporary, they will not cause widespread adverse effects. Similarly, the evaluation that the advantages of supporting the scientific work far outweigh the disadvantages for the Antarctic environment brought about by building and operating the traverses is understandable.

Germany endorses the USA’s CEE on traverses in Antarctica. Having said that, we assume that, in the case of specific traverse projects, special CEEs will be drawn up on the basis of the actual routes taken.

The traverses should not be made available for uncontrolled mass tourism or adventure tourism. There is no reason to object to guests travelling with supply or scientific convoys.

The use of bamboo canes to mark traverses should be kept to a minimum.

The CEE seems suitable for use by other countries as a basis for preparing their own environmental impact studies on traverses in Antarctica.

Response to Comments from the German Federal Environmental Agency (GFEA)

GFEA-1

Comment: [The reviewer noted that "we found nothing in the report that contradicted the Protocol on Environmental Protection". The reviewer also noted that "no environmental assets relevant to nature conservation (biota) are affected by the planned traverses and "the proposed way of dealing with sewage seems practicable". The reviewer agree with the conclusion of the CEE that impacts associated with traverses "will not cause widespread adverse effects" and advantages of supporting the scientific work far outweigh the disadvantages for the Antarctic environment . Germany endorses the USA's CEE on traverses in Antarctica".] Having said that, we assume that, in the case of specific traverse projects, special CEEs will be drawn up on the basis of the actual routes taken.

Response: No specific action is required but it is true that any routes, activities, or resources that are needed to conduct or support traverse activities and are beyond the scope of activities identified in this CEE, would be subject to supplemental environmental review.

GFEA-2

Comment: The traverses should not be made available for uncontrolled mass tourism or adventure tourism.

Response: Analogous to the model employed by the USAP to discourage the use of airstrips at McMurdo Station and elsewhere by tourist operators or private individuals except for emergencies, the U.S. will not support nor condone the use of any U.S. developed and maintained traverse routes or resources by any nongovernmental organizations in Antarctica. Specifically, the objectives and level of activity of the United States Antarctic Program (USAP) are set forth in President Reagan's directive of February 5, 1982. Achievement of USAP objectives, which center upon the conduct of a balanced program of scientific research and include cooperative activities with Antarctic programs of other governments, requires the full commitment of the operational and logistics capabilities available to the USAP. The U.S. Government is not able to offer support or any other services to private expeditions, U.S. or foreign, in Antarctica.

In emergency situations, the U.S. is prepared to attempt, in accordance with international law and humanitarian principles, the rescue of private expedition personnel provided that there are no unacceptable risks posed to U.S. personnel and the rescue can be accomplished within the means available to the United States. Such emergency assistance would be limited to the rescue of private expedition personnel and their evacuation would be undertaken in a manner which, in the judgment of the United States, offered the least risk to U.S. personnel, equipment, and scientific programs. Once such rescue has been effected, the U.S. would consider its assistance terminated and would under no circumstances provide support for the continuation of the expedition.

Private expeditions, therefore, should be self-sufficient and are encouraged to carry adequate insurance coverage against the risk of incurring financial charges or material losses in the Antarctic. The National Science Foundation, as manager of the USAP, reserves the right to seek, in accordance with international and domestic law, recovery of all direct and indirect costs of any such emergency search and rescue.

GFEA-3
Comment: The use of bamboo canes to mark traverses should be kept to a minimum.

Response: The use of bamboo stakes and flags to mark the traverse route and delineate potential hazards (crevasses) will be kept to a minimum. One must remember that the ice sheet is constantly moving and therefore absolute positioning coordinates such as those derived from GPS may be of limited value in delineating conditions on the surface of the transient ice sheet. Using the McMurdo Station to South Pole route as an example, the first half of the route, McMurdo to the Leverett Glacier, crosses the Ross Ice Shelf in an orientation which is generally oblique to the movement of the ice sheet. In this area, the ice sheet may move up to 1 to 2 m per day. As a result, bamboo stakes and markers placed on the surface will obviously move with the ice sheet and will be effective in delineating the route and hazards. Because of the movement of the ice sheet, the route markers may have to be periodically reset to straighten the route and compensate for the curvature in the path over time. Currently, it has not been determined how frequently the route markers will have to be reset.

GFEA-4
Comment: The CEE seems suitable for use by other countries as a basis for preparing their own environmental impact studies on traverses in Antarctica.

Response: No Action Required.

Antarctica New Zealand

We have referred the two draft Comprehensive Environmental Evaluations (CEEs) prepared and circulated by the United States and to be considered at the seventh meeting of the Committee for Environmental Protection (CEP VII) to our environmental experts. A summary of the key comments and issues raised is provided below for your information in advance of the CEP meeting. Please note that more detailed technical comments will be provided by our CEP delegation during the course of the meeting next week.

1. Development and implementation of surface traverse capabilities in Antarctica

The nature and scale of the proposed activity fully justifies the preparation of a draft CEE, and the United States is to be complimented for commencing this process and completing a thorough and detailed document.

This draft CEE covers both the development of a general traverse capability in Antarctica and the surface re-supply of South Pole station. Our preference is for draft CEEs to relate to specific activities, rather than general concepts. This approach is foreseen in Annex I of the Protocol and allows the impacts associated with specific activities to be clearly defined and analysed. This has certainly been the case with all previous CEEs that have been forwarded to the CEP. The location of activities is an important component of the analysis of environmental impacts including assessing the nature of such of impacts. Every future traverse activity could potentially be different in nature, location, extent, duration and intensity. The reasoning behind producing a draft CEE for possibly unknown events is not immediately apparent.

The draft CEE provides detailed information on the likely direct, biophysical impacts and the value of the proposal (although, again, in a fairly generic and conceptual manner). Further consideration could be given to indirect and in particular cumulative impacts of the proposed activities. Given the types of locations that traverses are likely to occur in, consideration could be given to identifying and evaluating impacts on wilderness and aesthetic values.

2. Project Ice Cube *[NOTE: responses to these comments will be included in the final CEE for Project IceCube*]. The United States is to be commended for producing a draft CEE for this project. This draft CEE is comprehensive in its description of the activity, as well as in its assessment of potential impacts and mitigating options. In our view the draft CEE is consistent with the requirements of Annex I to the Protocol and with the CEP's EIA Guidelines. It is a large project of long duration and we agree that a CEE is the appropriate level of EIA for this project. The draft CEE is of a very high standard.

We also agree with the general conclusion of the document that the potential scientific gain from the research far outweighs the significant but localised environmental impacts.

[Trevor Hughes, APU/ENV]

Response to Comments from Antarctica New Zealand (ANZ)

ANZ-1
Comment: The nature and scale of the proposed activity fully justifies the preparation of a draft CEE, and the United States is to be complimented for commencing this process and completing a thorough and detailed document.

Response: No Response Required

ANZ-2
Comment: This draft CEE covers both the development of a general traverse capability in Antarctica and the surface re-supply of South Pole station. Our preference is for draft CEEs to relate to specific activities, rather than general concepts. This approach is foreseen in Annex I of the Protocol and allows the impacts associated with specific activities to be clearly defined and analysed. This has certainly been the case with all previous CEEs that have been forwarded to the CEP. The location of activities is an important component of the analysis of environmental impacts including assessing the nature of such of impacts. Every future traverse activity could potentially be different in nature, location, extent, duration and intensity. The reasoning behind producing a draft CEE for possibly unknown events is not immediately apparent.

Response: The CEE was intended to evaluate the USAP's development of a traverse capability for use either on re-supply (cargo hauling) missions or as a platform for the performance of scientific research. The scope of the environmental evaluation focused on impacts associated with the mechanical aspects of overland traverse activities over snow and ice-covered areas and away from coastal zones or areas inhabited biological communities. In this respect, the CEE assessed very specific aspects (air emissions, wastewater releases, terrain alteration, etc.) associated with these types of typical traverse activities. To quantify potential impacts, a traverse scenario was developed for the re-supply of the Amundsen-Scott Station. The operating conditions and resulting impacts evaluated in this CEE are <u>representative</u> of specific traverse activities and therefore are applicable to the South Pole traverse example as well as other traverses proceeding on different routes but in similar environmental settings in Antarctica. The USAP will perform supplemental environmental reviews, as needed, to identify and characterize impacts potentially occurring in unique environments or as a result of unconventional traverse methods not addressed in this CEE.

ANZ-3
Comment: The draft CEE provides detailed information on the likely direct, biophysical impacts and the value of the proposal (although, again, in a fairly generic and conceptual manner). Further consideration could be given to indirect and in particular cumulative impacts of the proposed activities. Given the types of locations that traverses are likely to occur in, consideration could be given to identifying and evaluating impacts on wilderness and aesthetic values.

Response: Equal emphasis was given to identifying and evaluating the direct impacts of the proposed action on science, operations, as well as the environment. The results of this analysis indicated that there would be no nature conservation (biota) issues of concern, releases to the environment (wastewater, exhaust gas emissions) would be negligible, and even though the overall impact of the action would be more than minor or transitory, the net effect would not cause widespread adverse environmental effects. On the other hand, the proposed action could cause substantive impacts to science and operations but these effects would be mitigated through careful planning and scheduling.

At this point, it has not been determined if a "permanent" route between McMurdo and the South Pole is feasible and will be utilized by the USAP. Assuming a route can be developed as described in the CEE, potential cumulative impacts include: (1) the release of exhaust gas emissions to the atmosphere, (2) the deposition of particulate matter from exhaust gas emissions along the traverse route, (3) the release of greywater and urine at areas along the route which will be used as traverse crew rest stops (human solid waste [sanitary] will be incinerated not discharged), and (4) the release of unrecoverable items used for the traverse operations (e.g., bamboo stakes, marker flags). In addition, the regular use of a route will continue to alter the terrain, generate noise, and slightly diminish the intrinsic wilderness value along the profile of the route. These impacts have been identified in the CEE and based on observations of traverses performed by other Treaty nations, the cumulative impacts may be more than minor or transitory but very localized in proximity to the traverse route itself.

The Antarctic and Southern Ocean Coalition

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COMMENTS ON

US Draft Comprehensive Environmental Evaluation (CEE)

Development and implementation of surface traverse capabilities in Antarctica

April, 2004

Documentation

The US Draft CEE examined comprised 142 pages – made up of a main text of 101 pages and three Appendices of 22, 11 and 8 pages respectively. The copy examined was downloaded from the National Science Foundation web-site in early March 2004.

Commentary

1. ASOC is pleased to see, and to comment upon this Draft CEE.

2. The activity proposed - in terms of its area of operation - may be the largest activity proposed since either the adoption or entry-into-force of the *Protocol on Environmental Protection to the Antarctic Treaty*, and this CEE has accordingly to address a larger area than ever previously considered by a CEE.

3. The nature and scale of the proposed activity fully justifies the preparation of a CEE, and the United States is to be complimented for commencing this process. The preparation of any CEE is a substantial undertaking, requiring the commitment, skill and time of a number of people. While it is in the nature of commentaries that they focus upon perceived omissions or shortfalls, these comments are directed to assisting, rather than berating, those charged with the CEE's development.

4. The Draft CEE formally addresses the mandatory obligations under Article 8 and Annex I of the Protocol. It is generally in compliance with the mandatory requirements specified in Article 3 of Annex I – two apparent omissions (one substantive and one minor) are identified below (point 6).

5. However, while mandatory obligations are covered as headings in the Draft CEE, in some instances the actual coverage appears less substantive than might be expected (see points 7, 8). It would also be appropriate to cast the obligations addressed in the CEE more widely

than merely the obvious Annex I (see the Draft at 1.2). There are certainly connections to, inter alia, generic obligations under Article 3 (Principles) and Annex III (Waste disposal and waste management).

6. The mandatory "description of the initial environmental reference state with which predicted changes are to be compared …" (Annex I, Art 3.2(b)) appears not to be addressed either formally (the term *initial environmental reference state* does not appear), or substantively. This obviously needs to be done. While the web-based nature of the document allows one to track back to the preparer of the Draft CEE, the document itself does not appear to include the contact details required (Art 3.2(l)).

7. The consideration of likely direct impacts is the strongest part of impacts consideration (as it is across the Antarctic EIA case-history) – but even here the focus tends to be more the impacts upon science and operations than upon the environment, and the text tends also to include reference to mitigating factors. The arguments may have merit, but they are perhaps misplaced and tend to displace the core interest in environmental effects normal for an EIA.

8. However, consideration of possible indirect/second-order, and cumulative impacts is even weaker. Indirect impacts (6.3.8, 6.4.8) comprise a total of three paragraphs, and these don't consider indirect impacts in the manner required under Annex I. Cumulative impacts (6.3.9, 6.4.9) get only two paragraphs. Given the spatial extent of this proposal, the diverse logistics considered (across surface traverse and air operations), and the sorts of arguments mounted in the Draft CEE for the proposed activity, it seems reasonable to assume that indirect and/or cumulative impacts may be significant issues. Plainly if – to take just one scenario – surface traverse freed up LC-130s to expand the USAP science reach, or the nature of its science activity, elsewhere, this may be an appreciable indirect impact. That impact may or may not be justifiable, and it may or may not be environmentally significant, but it surely warrants consideration. Possible use of traverse routes by tourist or other NGO entities is raised, but inconclusively, and given the rapid increases in types of tourism in Antarctica, the mere existence of this new route will no doubt whet some appetites. There is no indication of US intentions in relation to such use. A useful model on this would be the long practice of the US of discouraging use of airstrips at McMurdo and elsewhere by tourist operators except for emergencies.

9. Another indirect impact is the possible consequence of any new air operations and air networks that might be developed if US aircraft are freed from channel flights to the Pole for other operators, including other national operators. There is a developing air network across Antarctica, and any substantial change in the air-reach of the largest national operator may be expected to have consequences for this. While there are plainly limits to how far one state and one EIA can go in relation to indirect impacts, some additional consideration is reasonable to expect to find in this CEE.

10. A qualification may now be appropriate to the observation that direct impacts are better addressed than other impacts (point 7). Biophysical impacts are seriously addressed, and the Draft CEE contains a lot of data from the available models and experience. But biophysical impacts, although clearly important, are not the only issue. Article 3 of the Protocol

establishes a range of values – including wilderness and aesthetic values and value for scientific research. The last is well covered (indeed perhaps more of the science case is presented in this Draft CEE than is strictly necessary for an EIA – but better too much than too little). But the non material values are not given adequate coverage. They warrant decent consideration anyway, but since a major source of concern about the US traverse has been because of the route/road argument – and the fact of the significance of routes for conceptions and classification of wilderness internationally – something substantial seems called for here. The word *wilderness* certainly appears a number of times, but there is no substantive consideration – certainly no drawing from the massive literature or various methodologies used globally and within the United States.

11. A rather profound inconsistency runs through the Draft CEE in relation to the consequences of a successful surface traverse. It is argued that this offers advantages of an economic, logistic, scientific and environmental nature – basically that the footprint is reduced if one substitutes surface for air traverse to Pole. This sounds likely, and attractive. But running parallel through the Draft CEE (and explicitly stated in various places (including 3.1 and Appendix A)) are arguments that if fewer aircraft are required for Pole support, these become available for enhanced air support of other science and logistic operations *elsewhere in Antarctica*. Again, this sounds quite likely. But surely one cannot have one's cake and eat it? In the absence of some explanation in the Draft CEE, it would seem that what might be proposed is merely a switching of routes, not a fundamental reduction in aircraft use. If that is the case, then it should not be suggested that there are fuel (and therefore environmental) savings. It might be a zero-sum-game.

12. ASOC would be pleased to discuss any of these points further.

Response to Comments from the Antarctic Southern Ocean Coalition (ASOC)

ASOC-1
Comment: The activity proposed - in terms of its area of operation - may be the largest activity proposed since either the adoption or entry-into-force of the Protocol on Environmental Protection to the Antarctic Treaty, and this CEE has accordingly to address a larger area than ever previously considered by a CEE.

Response: The scope of the proposed action focuses on the development of the capability to conduct traverse operations in Antarctica on an as-needed basis and in a safe, effective, and efficient manner. At this point, the USAP has not determined if the use a traverse mechanism to supplement current airlift resources is feasible and practical for the re-supply of the Amundsen-Scott Station or any other facility. Even if the USAP decides to proceed and re-supply the South Pole using a combination of traverse and airlift resources, the USAP does not believe that the traverse mechanism will represent the "largest activity proposed since either the adoption or entry-into-force of the Protocol on Environmental Protection to the Antarctic Treaty." The proposed activity, if used for the re-supply of the Amundsen-Scott Station, would involve several traverses to the South Pole per year from McMurdo Station and would not require the construction of any new stations or major facilities. Any activities or resources needed to conduct or support traverse activities beyond the scope of activities identified in the CEE, would be subject to supplemental environmental review.

ASOC-2
Comment: [The reviewer notes that specific comments will follow this general comment]. It would also be appropriate to cast the obligations addressed in the CEE more widely than merely the obvious Annex I (see the Draft at 1.2). There are certainly connections to, inter alia, generic obligations under Article 3 (Principles) and Annex III (Waste disposal and waste management).

Response: The Antarctic Conservation Act of 1978 (Public Law 95-541) which includes Part 671 – Waste Regulation, are the implementing requirements applicable to the United States Antarctic Program. These U.S. regulatory requirements are consistent with The Protocol on Environmental Protection to the Antarctic Treaty (1991). In compliance with these U.S. regulations and therefore the Protocol, the CEE repeatedly identifies the *USAP Master Permit* as a primary term of reference for environmental compliance in Antarctica. The Master Permit is consistent with and generally exceeds the obligations of Article 3 and Annex III and provides comprehensive detail describing all USAP actions involving the use and storage of Designated Pollutants (i.e., hazardous materials), the disposition of wastes, and the management of any substance intentional or accidentally released to the Antarctic environment.

ASOC-3
Comment: The mandatory “description of the initial environmental reference state with which predicted changes are to be compared …” (Annex I, Art 3.2(b)) appears not to be addressed either formally (the term initial environmental reference state does not appear), or substantively. This obviously needs to be done.

Response: The initial environmental reference state, also referred to as the initial environmental state and the affected environment, is described in section 5.0 of the CEE.

ASOC-4

Comment: The consideration of likely direct impacts is the strongest part of impacts consideration... but even here the focus tends to be more the impacts upon science and operations than upon the environment, and the text tends also to include reference to mitigating factors.

Response: Equal emphasis was given in the CEE to identifying and evaluating the direct impacts of the proposed action on science, operations, and the environment. The results of this analysis indicated that there were no nature conservation (biota) issues of concern, releases to the environment (wastewater, exhaust gas emissions) would be negligible, and even though the overall impact of the action would be more than minor or transitory, the net effect would not cause widespread adverse environmental effects. In addition, various mitigating measures to minimize and prevent adverse environmental impacts would be incorporated into the design of the proposed action and therefore were considered critical components in the impact evaluation process.

ASOC-5

Comment: [the following is a continuation of the previous comment]. However, consideration of possible indirect/second-order and cumulative impacts is even weaker [weaker than consideration of likely direct impacts].

Response: The scope of the CEE involves the USAP's development of the capability to operate re-supply and research-related traverses on an as-needed basis. The extent this capability may be utilized in the future, if at all, will be variable depending on the annual scientific research and logistical needs of the USAP. As such, the indirect, second order, and cumulative impacts resulting from the implementation of the traverse capability cannot be determined at this time with any reasonable level of certainty. Nonetheless, using the South Pole re-supply scenario as an example, it is anticipated that there will not be any significant indirect and second order impacts to the environment. Indirect and second impacts may effect station operations but to no greater extent than the current cargo transport mechanisms. The use of traverse capabilities, particularly if deployed repeatedly along the same route, will have a cumulative impact on the environment (see response to comment AAD-3) which is expected to be more than minor or transitory but as noted in the CEE, the cumulative impacts will be localized to the immediate vicinity of the route.

ASOC-6

Comment: Possible use of traverse routes by tourist or other NGO entities is raised, but inconclusively, and given the rapid increases in types of tourism in Antarctica, the mere existence of this new route will no doubt whet some appetites.

Response: Analogous to the model employed by the USAP to discourage the use of airstrips at McMurdo and elsewhere by tourist operators or private individuals except for emergencies, the U.S. will not support nor condone the use of any U.S. developed and sponsored traverse routes or resources by any nongovernmental organizations in Antarctica. Further detail on this subject is provided in the response to comment GFEA-2.

ASOC-7

Comment: Another indirect impact is the possible consequence of any new air operations and air networks that might be developed if US aircraft are freed from channel flights to the Pole for other operators, including other national operators.

Response: If the Proof of Concept evaluation determines that transport by traverse is technically and logistically feasible, the U.S. may elect to use the traverse mechanism to augment existing airlift capability for the re-supply of the Amundsen-Scott Station. The use of the traverse capability to transport cargo for re-supply missions could potentially make available future airlift resources to support other infield scientific research programs. However, it must be realized that the U.S.'s annual budget for Antarctic operations is relatively constant and if a portion of the budget is used to fund traverse operations then logistical funds may not be available to operate airlift resources at pre-traverse levels. Therefore, it is likely that traverse capabilities, if employed, would result in a net decrease in the USAP's use of airlift resources and would not imply the development of new air operations or air networks.

ASOC-8

Comment: Article 3 of the Protocol establishes a range of values – including wilderness and aesthetic values and value for scientific research. The last is well covered ... but the non material values are not given adequate coverage. They warrant decent consideration anyway, but since a major source of concern about the US traverse has been because of the route/road argument – and the fact of the significance of routes for conceptions and classification of wilderness internationally – something substantial seems called for here.

Response: Wilderness values are attributes, which are generally associated with land areas that are unmodified, wild, uninhabited, remote from human settlement and untamed and an antidote to modern urban pressures. Wilderness and aesthetic values are complex concepts comprised of values as yet not captured by language. An evaluation of impacts of the proposed action on the wilderness and aesthetics values of Antarctica must recognize the vastness and solitude of the continent. For example, a route to the South Pole from McMurdo Station would be approximately 1,600 km in length and 10 m wide. This represents an area of approximately 16 km^2 or 0.00001% of the total land area in Antarctica. If one considers a 1 km wide buffer zone on either side of the traverse route, the total amount of wilderness area that could be potentially affected by a South Pole traverse route is 3,200 km^2 or 0.023% of the continent.

Taking into consideration the temporal variable of traverse operations, a loaded traverse train may operate at an average velocity of 8 km/hr and may only be visible from a fixed vantage point for two hours or less. Assuming a traverse train passes this vantage point once every three weeks, the rate of incursion to a receptor is 0.4% during the austral summer season and zero (0.0%) during the winter.

It is recognized that the proposed action will slightly diminish the wilderness and aesthetic values of Antarctica but the extent of this degradation is minimal and greatly offset by the value of this resource to USAP science and operations. In addition, the cumulative impact on the potential degradation of the wilderness value will be extremely low since very few Treaty nations or visitors inhabit the area along the McMurdo to South Pole traverse route, particularly on the Polar Plateau.

ASOC-9
Comment: In the absence of some explanation in the Draft CEE, it would seem that what might be proposed is merely a switching of routes, not a fundamental reduction in aircraft use. If that is the case, then it should not be suggested that there are fuel (and therefore environmental) savings.

Response: The development of a traverse capability would allow the USAP more flexibility in selecting optimum transport mechanisms best suited for the movement of particular types of cargo. The USAP does not intend to completely replace airlift resources but merely supplement the use of aircraft for particular applications, such as the re-supply of South Pole Station, if feasible. If traverse capabilities are used as a complement to airlift resources, the net result would be that cargo could be transported more efficiently using less fuel and producing fewer exhaust gas emissions than if transported solely by aircraft. If a traverse mechanism is deemed feasible for the re-supply of the South Pole Station, the USAP currently estimates that approximately 40 percent of the total annual cargo to the Pole would be optimally transported by traverse with the remaining material and all personnel conveyed by aircraft (see fuel consumption table presented in the response to comment AAD-6). Within budgetary constraints, the use of traverse capabilities may allow some airlift resources to be reprogrammed for other applications on an as-needed basis but will likely result in a net decrease in the USAP's use of airlift resources compared to 2004 levels.

The following excerpts were derived from the **Council on Environmental Protection** (CEP) Report prepared during the Antarctic Treaty Consultative Meeting (ATCM) in Cape Town, South Africa (2004).

Comment-1: France noted that it was unfortunate that the draft CEE, circulated in English, had not been translated into the other official languages.

Comment-2: Australia and other Parties complimented the U.S. for the draft CEE, noting the value of matrices to the CEP in analyzing the aspects of an activity, evaluating its likely impacts, and providing advice to the ACTM.

Comment-3: New Zealand welcomed the fact that the U.S. plans to further expand the consideration of cumulative and indirect impacts in the final CEE.

Comment-4: New Zealand noted that the draft CEE considered both the specific South Pole traverse but also Antarctic traverses in general. They asked the U.S. to explain the reasoning behind this approach to the draft CEE and noted that Annex I of the Protocol required environmental impact assessment of specific activities.

Comment-5: The United Kingdom welcomed the reduction in the number of flights expected to result from the traverse operation, and requested information on the reduction of overall fuel consumption.

Comment-6: The UK also noted that the EIA procedures would not in all cases prevent the use of the traverse by NGOs.

Comment-7: CEP requested fuller information and clarification on the overall reduction of fuel use expected to result from the move to support the South Pole Station by surface traverse.

Comment-8: CEP requested fuller information and clarification on the potential indirect impacts including:

- Impacts associated with consequential availability of aircraft
- The potential impacts of traverse operations on the other national programs

Comment-9: CEP requested text clarifying the scope of the document, by elaborating on the application of the final CEE to surface traverse activities generally.

Response to Comments from ATCM/CEP Organizations

ATCM-1
Comment: France noted that it was unfortunate that the draft CEE, circulated in English, had not been translated into the other official languages.

Response: The CEE was only circulated in English because the procedures for its transmission were unclear at the time the CEE was submitted.

ATCM-2
Comment: Australia and other Parties complimented the U.S. for the draft CEE, noting the value of matrices to the CEP in analyzing the aspects of an activity, evaluating its likely impacts, and providing advice to the ACTM.

Response: No Action Required

ATCM-3
Comment: New Zealand welcomed the fact that the U.S. plans to further expand the consideration of cumulative and indirect impacts in the final CEE.

Response: See response to comments AAD-3, AAD-5, ASOC-4, ASOC-5, ASOC-7, ANZ-3

ATCM-4
Comment: New Zealand noted that the draft CEE considered both the specific South Pole traverse but also Antarctic traverses in general. They asked the U.S. to explain the reasoning behind this approach to the draft CEE and noted that Annex I of the Protocol required environmental impact assessment of specific activities.

Response: The CEE was intended to evaluate the USAP's development of a traverse capability for use either on re-supply (cargo hauling) missions or as a platform for the performance of scientific research. The scope of the environmental evaluation focused on impacts associated with the mechanical aspects of overland traverse activities over snow and ice-covered areas and away from coastal zones or areas inhabited biological communities. In this respect, the CEE assessed very specific aspects (air emissions, wastewater releases, terrain alteration, etc.) associated with typical traverse activities. To quantify potential impacts, a traverse scenario was developed for the re-supply of the Amundsen-Scott Station. The operating conditions and resulting impacts evaluated in this CEE are <u>representative</u> of specific traverse activities and therefore are applicable to the South Pole traverse example as well as other traverses proceeding on different routes but in similar environmental settings in Antarctica. The USAP will perform supplemental environmental reviews, as needed, to identify and characterize impacts potentially occurring in unique environments or as a result of unconventional traverse methods not addressed in this CEE.

ATCM-5

Comment: The United Kingdom welcomed the reduction in the number of flights expected to result from the traverse operation, and requested information on the reduction of overall fuel consumption.

Response: See response to comments AAD-6, ASOC-1, ASOC-7

ATCM-6
Comment: The UK also noted that the EIA procedures would not in all cases prevent the use of the traverse by NGOs.

Response: See response to comments GFEA-2, ASOC-6

ATCM-7
Comment: CEP requested fuller information and clarification on the overall reduction of fuel use expected to result from the move to support the South Pole Station by surface traverse.

Response: See response to comments AAD-6, ASOC-9

ATCM-8
Comment: CEP requested fuller information and clarification on the potential indirect impacts including:

- Impacts associated with consequential availability of aircraft
- The potential impacts of traverse operations on the other national programs

Response: See responses to comments AAD-3, AAD-5, ASOC-4, ASOC-5, ASOC-7

ATCM-9
Comment: CEP requested text clarifying the scope of the document, by elaborating on the application of the final CEE to surface traverse activities generally.

Response: See response to comments AAD-1, ANZ-2, ASOC-1, ASOC-9

Input provided by John H. Wright, Project Manager, South Pole Traverse Proof of Concept, Raytheon Polar Services Company

RPSC-1
Observation: Although, the benefits of double walled tanks are well known, it has been recognized during the Proof of Concept that for traverse applications, double walled tanks are not desirable because it is difficult to reliably detect failures of the inner wall in double wall systems and initiate corrective actions. In addition, it has been also recognized during the Proof of Concept that secondary containment structures such as external containment vessels are not feasible for use with fuel transport tanks during traverse operations. Under the conditions that are being evaluated during the Proof of Concept, the shear weight of a secondary containment structure on each fuel transport tank would require another tractor in the fleet to handle the aggregate additional weight.

Based on the Proof of Concept and observations of traverse operations performed by other Treaty nations, the USAP will use containers for traverse activities that are structurally compatible with their contents and able to withstand the physical and environmental (e.g., temperature) conditions to be encountered during the traverse. In addition, the USAP will regularly inspect storage tanks to detect leaks or potential weaknesses in the containers and have available empty vessels which can be used if emergency transfers are necessary.

Action: The draft CEE will be revised on pages 4-7, 4-12, 6-10, 6-18, 7-3, 7-6, and 7-7 to reflect leak prevention and corrective action measures applicable to traverse operations as evaluated during the Proof of Concept.