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

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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)

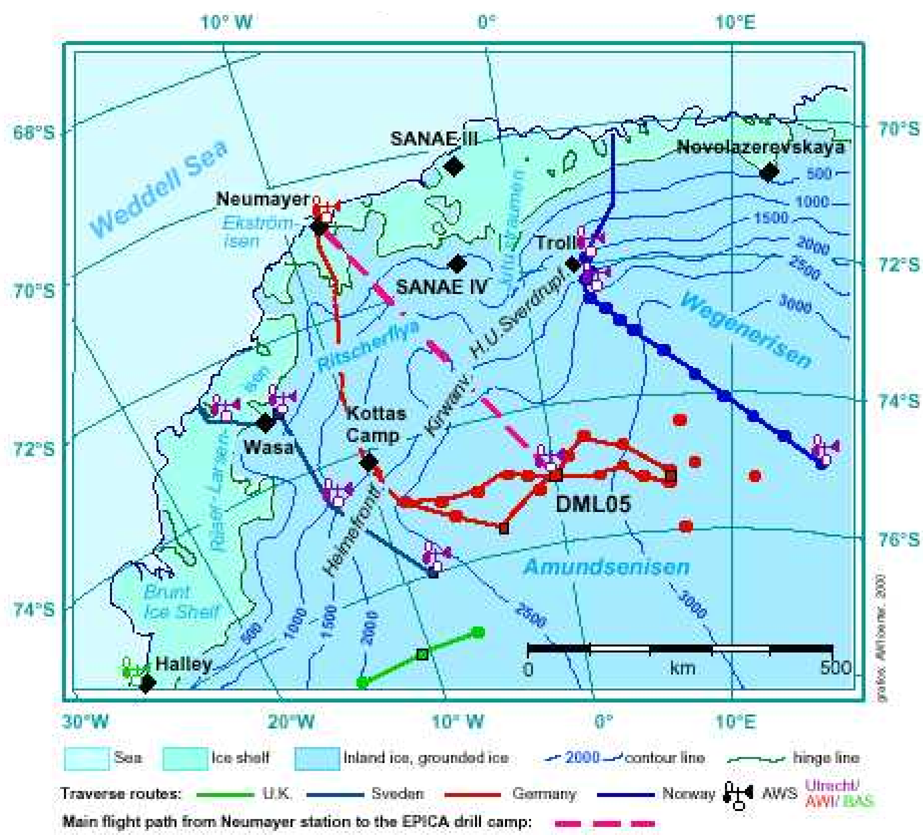
Figure 2-2. Re-supply Traverse for Concordia Station

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

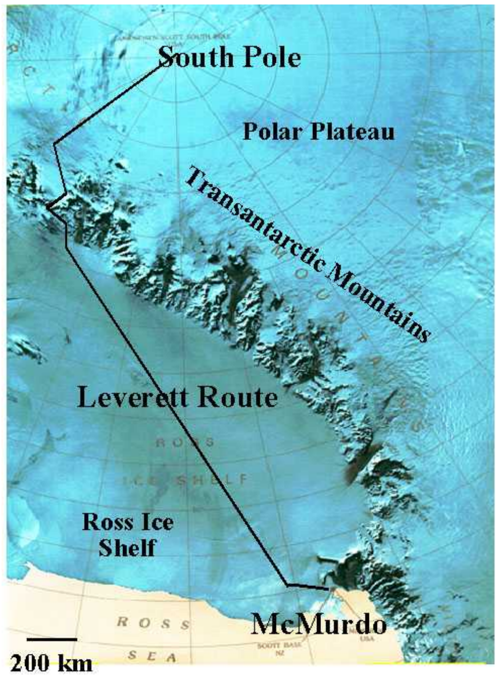


Source: Comprehensive Environmental Impact Evaluation for Recovering a Deep Ice Core in Dronning Maud Land, Antarctica (reference 18)

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

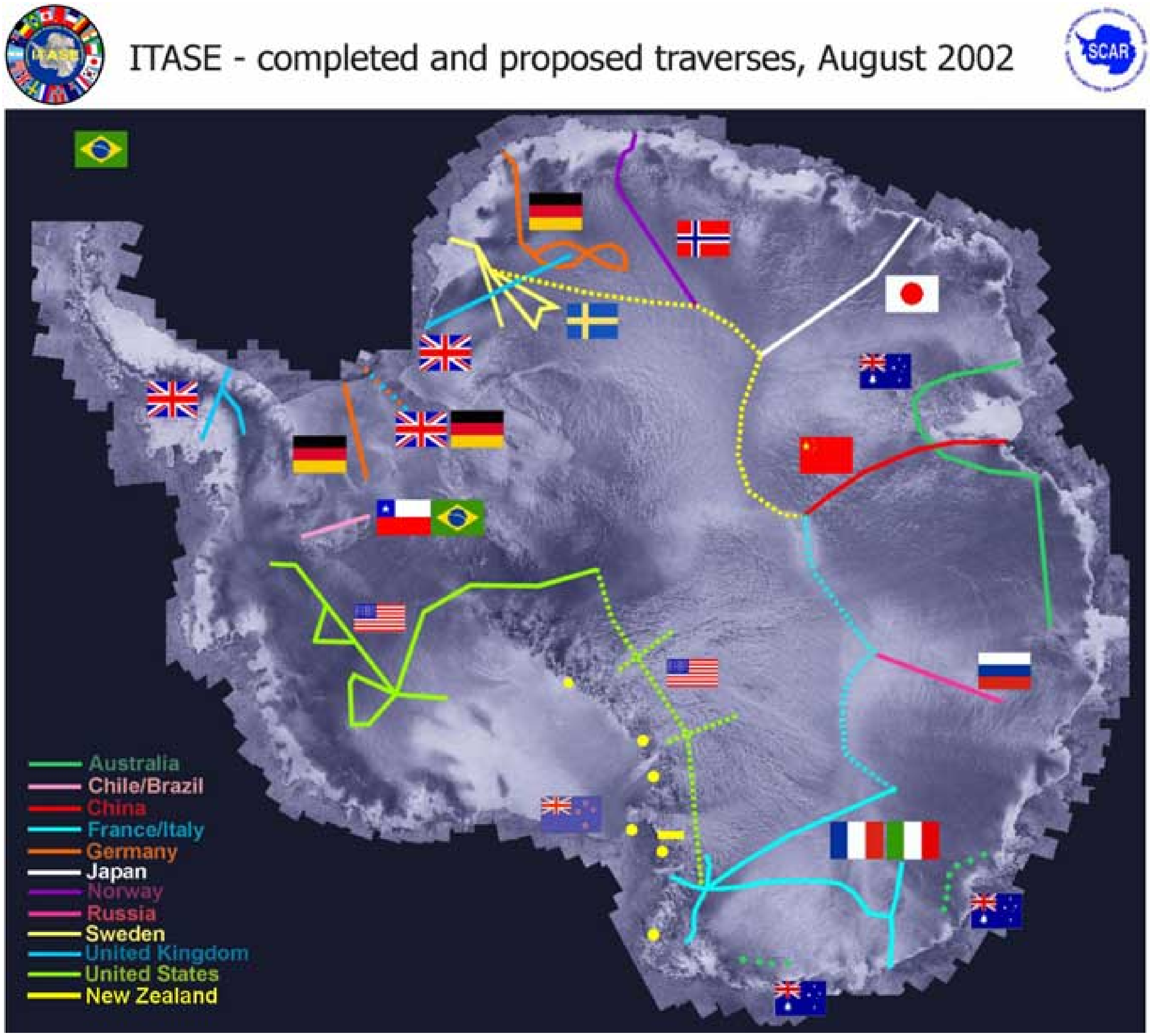
Table 2-2. Summary of Scientific Traverses and Surface-based Surveys in Antarctica

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.

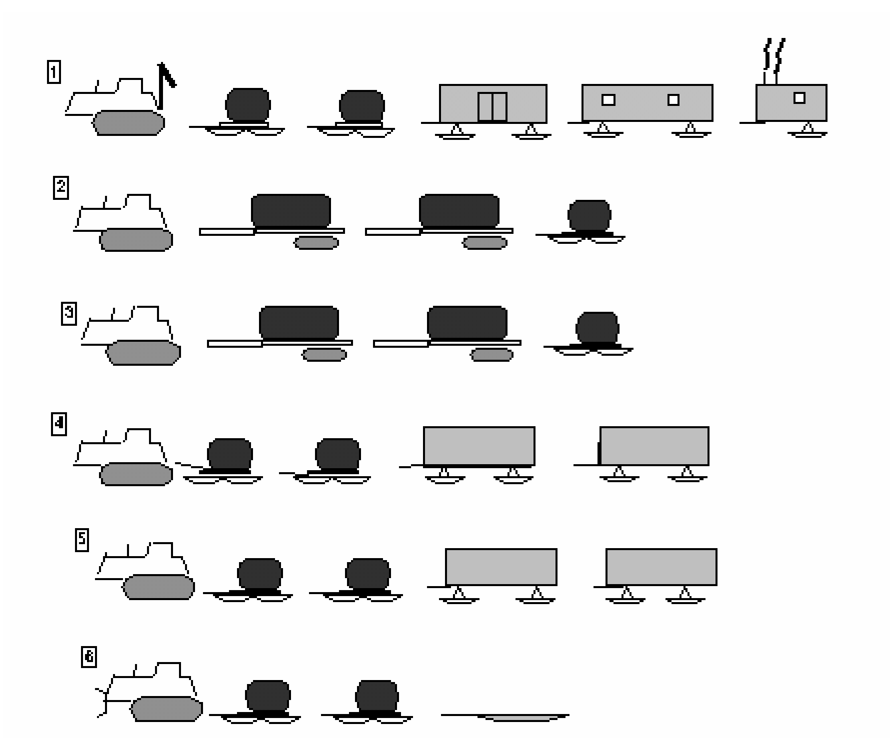
4.3.3 Operating Factors

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.