15.0 APPENDICES

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APPENDIX A

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

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

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Introduction

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

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

Prior Studies

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

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

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Transantarctic Mountains

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

McMurdo Shear Zone

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

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

Feasibility

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

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

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

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

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


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

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

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

Description of Traverse Option

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

Prior Results

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

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

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

- Recognizing that fuel is the single largest commodity delivered to South Pole, and that it represents a concentrated and easily configured payload, it is assumed that traverse equipment will be optimized for fuel delivery. To wit, the tracked trailers will be have ample fuel storage capacity to fully load the trailer. The fuel tank(s) will be segmented, have secondary containment, and will be placed to minimize the height of the trailer's CG and to allow modular or loose loads to be placed on the trailer as well.
- Each tractor will be linked to more than one trailer for the traverse. The standard configuration will be one tractor pulling two 42-ft trailers. In some cases a tractor may pull a specialized trailer or sled plus one or more 42-ft tracked trailers.

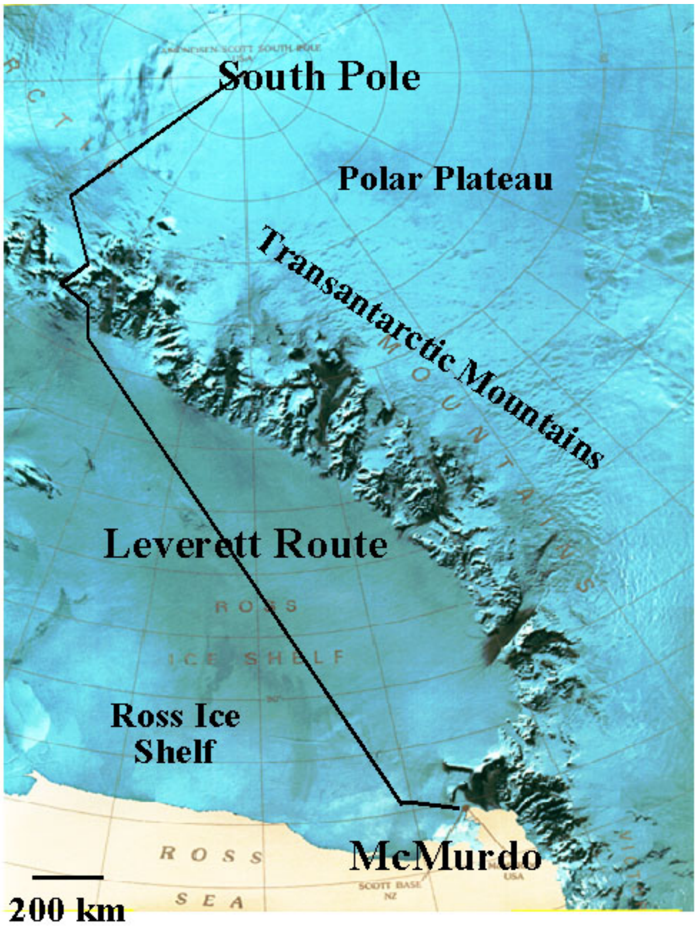

Figure 2. Traverse route using the Leverett Glacier for access from the Ross Ice Shelf to the Polar Plateau.

- A round-trip traverse will require 222 hours of driving to reach the South Pole (66% of total driving time) and 113 hours to return to McMurdo (33%). The tractors consume 15.3 gal/hr, meaning the outbound leg will use 3400 gallons of fuel, with 1727 gallons burned to return. Each tractor will leave McMurdo towing a total payload (gross load minus tare weights) of 95,000 lb. It will arrive at South Pole with 63,800 lb, of which 60,125 lb can be left as delivered payload (the remaining 3675 lb is fuel needed for a portion of the return trip).

New Details

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

Table 1. Potential daily traverse operating patterns.

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

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

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

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

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

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

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

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

Table 2. Proposed annual traverse schedule.

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

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

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

Contingency Considerations


Figure 3. USAP Challenger 65 utility tractor.

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

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


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

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

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

Timeline for Development

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

Impact of Traverse Operation on Current USAP

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

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

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

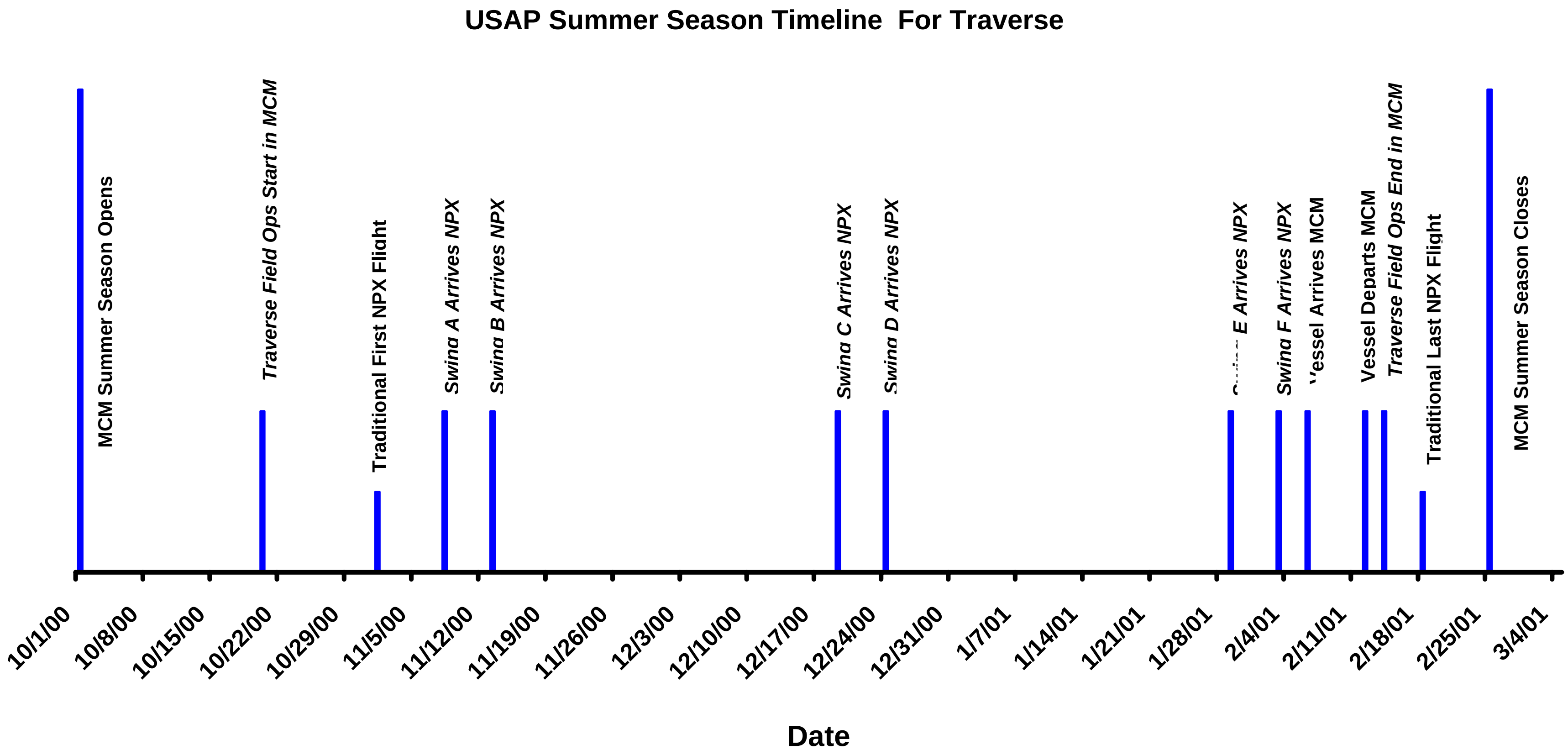

Figure 5. Traditional USAP summer season showing timing of traverse operations as given in Table 2.

Evaluation of Risk

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

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

Direct and Indirect Benefits Associated with the Traverse

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

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

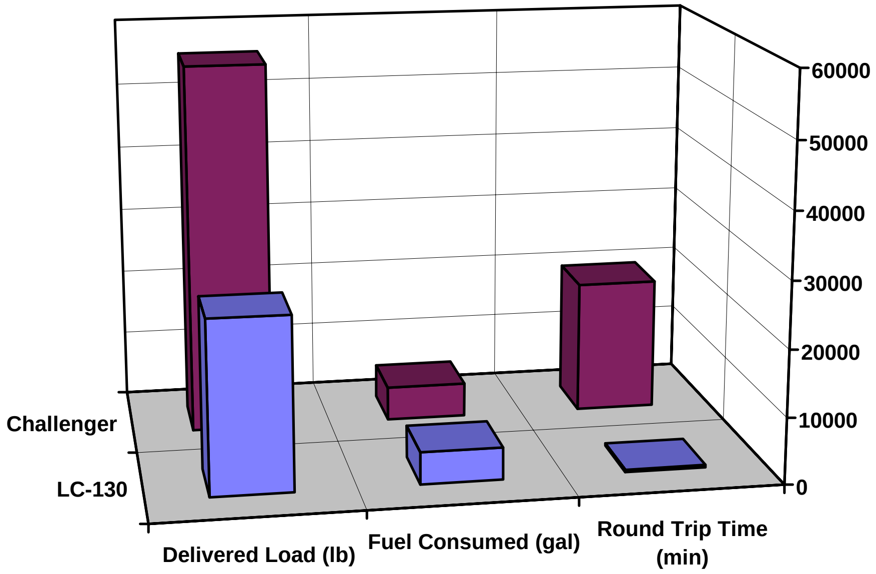

Figure 6. Comparison of delivery statistics for LC-130 and single tractor.

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

Table 8. Analysis of risk.

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

Table 8. Analysis of risk (continued).

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

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

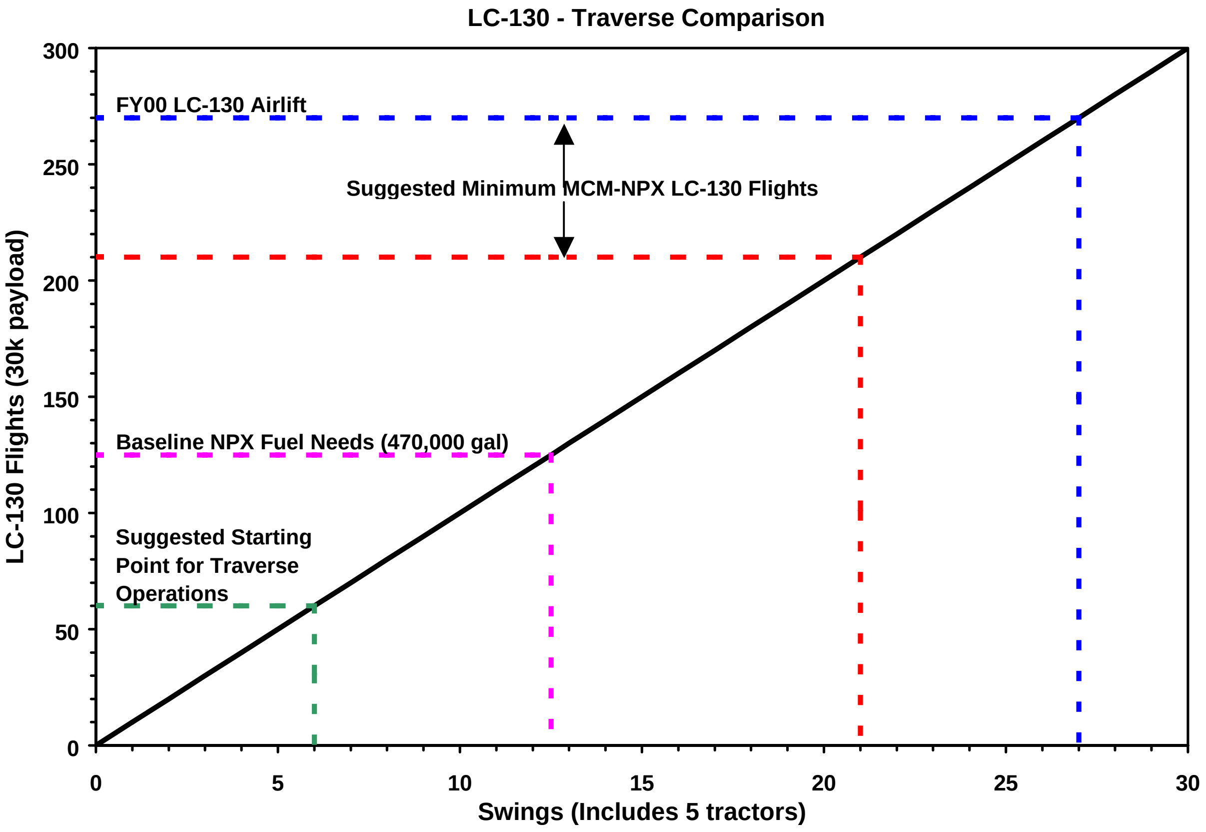

Figure 7. Potential for Traverse Contribution to Reduced LC-130 Airlift.

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

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

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

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

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

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

Analysis and Conclusions

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

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

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

Table 9. Economic analysis of Traverse Option

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

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

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

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

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

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APPENDIX B

US ITASE 2002-2003 FIELD REPORT

US ITASE 2002-2003 Field Report

Prepared in the field and submitted by:
Paul Andrew Mayewski
Institute for Quaternary and Climate Studies
University of Maine

On behalf of the 2001-2002 US ITASE traverse team.

Summary

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

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

Introduction

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

Members of the 2002-2003 US ITASE Field Team

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

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

Brief Description of US ITASE 2002-2003 LogisticActivities

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

*300 m collected by ICDS SPRESO team for US ITASE

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

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

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

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

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

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

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

Heavy Oversnow Vehicles

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

Heavy oversnow vehicle recommendations for future traverses:

(1) One mechanic's position should be maintained for each heavy vehicle.
(2) The older Challenger should be fitted with a rear winch and cable, heavy-duty hitch, and counter weights similar to the newer Challenger as requested in our 2001-02 field report.
(3) As requested in our 2001-02 report blockage problems for engine screens in freezing fog and diamond dust conditions should be investigated to prevent overheating and 1-3 km frequency stops to clear screens in fog conditions. This may be resolved through the addition of pusher fans or reversible fans.
(4) The older Challenger has a 60" wide axle (including spacers) and the newer Challenger has an 80" wide axle. The newer Challenger negotiated turns far more easily (by 100s of m) when pulling sleds than the older Challenger. The reduced turning capacity of the older Challenger resulted in the train bogging down several times. Further the wider axle Challenger cut a path outside that of following Berco sleds allowing the latter to cut through untouched snow, reducing ground clearance problems.

Heavy Oversnow Sleds and Permanent Shelters

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

A description of the use for each sled follows:

(1) Berco 1 ("Blue Room") served as a science facility (warm space for computers and wet chemistry preparation) plus berthing for up to 9 people. The Blue Room has a solar/wind powered system with a bank of 10 batteries. Shallow radar and kinematic GPS profiling was carried out in this structure during the travel legs.
(2) Berco 2 afforded kitchen space. Seating for 14-15 is possible during special dinners, and up to 10 "comfortably" on a routine basis. The kitchen also

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

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

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

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

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

Heavy oversnow sled and permanent shelter recommendations for future traverses:

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

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

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

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

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

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

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

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

Snowmobiles

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

Snowmobile Recommendations for 2002-2003:

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

Fuel and Power

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

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

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

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

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

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

(6) Solar and wind power systems were significantly improved this year. The wind power system operated efficiently for the first time since it was installed in 2000-01. However, the battery bank for the solar systems did not weather well over the winter. The kitchen 3000 watt power inverter failed necessitating transfer of the 1800 watt system from the Polar Haven.

(7) US ITASE requested two small solar systems for the 2002-03 season. Parts were made available, but they had to be constructed in the field. Further the components were not always suitable to handling in the cold because of size, type, or placement.

Fuel and power recommendations for future traverses:

(1) Heating fuels that operate at low temperatures should be introduced for field use.

(2) Battery banks for solar power arrays in the Blue Room and kitchen should not be left to over winter in the deep field.

(3) Considerably more support should be given by Raytheon to the development and construction of solar and wind power systems. We utilized several small and large systems. While improving each year – the systems could be more fully and efficiently utilized.

Air Support including Fuel Drops

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

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

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

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

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

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

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

Air support recommendations for future traverses:

(1) Fuel drums should be filled to the specified 4” to improve fuel delivery efficiency.

(2) Once US ITASE vehicles and sleds are fully deployed US ITASE can be supported by a maximum of six C130 flights per season or by Twin Otter and C130 airdrops. Continual change and exchange of sleds and vehicles, and construction of shelters that could be replaced by CONEX containers has necessitated considerably more flight allocation than necessary.

Light Sleds

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

(1) three Nansen sleds for camp activities, snowmobile work, and a 2” ice core platform

(2) one Maudheim for the 3’ ice core drill and ice core sampling equipment

(3) one Polar Associate to carry snowmobiles

(4) one Maudheim for tools, Herman Nelson, Challenger spares and fluids

(5) one Komatik (Zebowski) for deep radar (Pope Mobile)

(6) one Komatik for Polar Pooper

(7) two Komatiks for empty drums and science cargo – both were returned to McMurdo from Byrd after the first attempt to Site 1 because they functioned like snow anchors

(8) one Komatik for the ATM shelter – this sled was eventually mounted on a Berco because it too acted like a snow anchor.

Special Note: Unfortunately Berco #5 was used for science equipment formerly on Komatiks and the ATM Komatik reducing dramatically the potential for retrograding empty fuel barrels. Some barrels were discarded of necessity en route (with the knowledge of the NSF Rep McMurdo).

Light sled recommendations for future traverses:

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

Ice Coring Equipment

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

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

Ice coring equipment recommendations for future traverses:

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

Crevasse Detection Equipment

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

Crevasse detection equipment recommendations for future traverses:

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

Polar Pooper

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

Camping Equipment

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

Communications

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

Communications recommendations for future traverses:

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

US ITASE Outreach

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

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

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

Acknowledgements

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

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

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

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

APPENDIX C

AIR EMISSIONS FROM FUEL COMBUSTION SOURCES

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

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

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

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

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

Notes:

NCA = No characterization data available.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Notes:

NCA = No characterization data available.

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

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

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

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

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

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

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

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

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

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

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

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

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

Notes:

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

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

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

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

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

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

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

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

Australian Antarctic Division

German Federal Environmental Agency

Antarctica New Zealand

The Antarctic and Southern Ocean Coalition

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

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

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

Dear Fabio

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

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

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

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

Best wishes,

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

Response to Comments from the Australian Antarctic Division (AAD)

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Notes: BOLD = Optimal Traverse Configuration
[1] Percent distribution of cargo (2 million kg) transported to the South Pole from McMurdo Station via aircraft and traverse resources. Based on data presented in Analysis of McMurdo to South Pole Traverse as a means to Increase LC-130 Availability in the USAP (draft CEE Appendix A).
[2] Assumes that each LC-130 flight can transport 11,800 kg of cargo/fuel and will consume 17,200 liters of fuel to complete a roundtrip flight to the South Pole.
[3] Assumes that (roundtrip) traverse resources will consume 90,000 liters of fuel for each 100,000 kg of cargo/fuel delivered to the South Pole.

AAD-7
Comment: There is no contact name/address information [Annex I Article 3(2)(l)]

Response: Contact Name:

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

AAD-8
Comment: The tables supporting Section 6 are well set out and assist with the consideration of the nature, scale, and likelihood of environmental impacts

Response: No Action Required

AAD-9
Comment: Noting that many Parties (including Australia) have raised concerns with, and tried to improve, traverse waste management practices in traverse-related projects discussed at recent CEP meetings, we commend the intention expressed in this CEE to avoid wastewater discharge

“to the maximum extent practical” , and to release only wastewater into the environment and only under specified conditions

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

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

German Federal Environmental Agency

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

Current situation

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

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

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

Evaluation

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

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

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

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

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

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

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

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

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

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

GFEA-1

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

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

GFEA-2

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

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

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

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

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

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

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

Response: No Action Required.

Antarctica New Zealand

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

1. Development and implementation of surface traverse capabilities in Antarctica

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

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

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

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

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

[Trevor Hughes, APU/ENV]

Response to Comments from Antarctica New Zealand (ANZ)

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

Response: No Response Required

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

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

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

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

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

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COMMENTS ON

US Draft Comprehensive Environmental Evaluation (CEE)

Development and implementation of surface traverse capabilities in Antarctica

April, 2004

Documentation

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

Commentary

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

ASOC-1

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

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

ASOC-2

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

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

ASOC-3

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

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

ASOC-4
Comment: The consideration of likely direct impacts is the strongest part of impacts consideration... but even here the focus tends to be more the impacts upon science and operations than upon the environment, and the text tends also to include reference to mitigating factors.

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

ASOC-5
Comment: [the following is a continuation of the previous comment]. However, consideration of possible indirect/second-order and cumulative impacts is even weaker [weaker than consideration of likely direct impacts].

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

ASOC-6
Comment: Possible use of traverse routes by tourist or other NGO entities is raised, but inconclusively, and given the rapid increases in types of tourism in Antarctica, the mere existence of this new route will no doubt whet some appetites.

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

ASOC-7

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

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

ASOC-8

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

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

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

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

ASOC-9

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

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

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

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

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

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

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

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

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

Comment-7: CEP requested fuller information and clarification on the overall reduction of fuel use expected to result from the move to support the South Pole Station by surface traverse.

Comment-8: CEP requested fuller information and clarification on the potential indirect impacts including:

- Impacts associated with consequential availability of aircraft
- The potential impacts of traverse operations on the other national programs

Comment-9: CEP requested text clarifying the scope of the document, by elaborating on the application of the final CEE to surface traverse activities generally.

Response to Comments from ATCM/CEP Organizations

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

Response: The CEE was only circulated in English because the procedures for its transmission were unclear at the time the CEE was submitted.

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

Response: No Action Required

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

Response: See response to comments AAD-3, AAD-5, ASOC-4, ASOC-5, ASOC-7, ANZ-3

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

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

ATCM-5

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

Response: See response to comments AAD-6, ASOC-1, ASOC-7

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

Response: See response to comments GFEA-2, ASOC-6

ATCM-7
Comment: CEP requested fuller information and clarification on the overall reduction of fuel use expected to result from the move to support the South Pole Station by surface traverse.

Response: See response to comments AAD-6, ASOC-9

ATCM-8
Comment: CEP requested fuller information and clarification on the potential indirect impacts including:

- Impacts associated with consequential availability of aircraft
- The potential impacts of traverse operations on the other national programs

Response: See responses to comments AAD-3, AAD-5, ASOC-4, ASOC-5, ASOC-7

ATCM-9
Comment: CEP requested text clarifying the scope of the document, by elaborating on the application of the final CEE to surface traverse activities generally.

Response: See response to comments AAD-1, ANZ-2, ASOC-1, ASOC-9

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

RPSC-1
Observation: Although, the benefits of double walled tanks are well known, it has been recognized during the Proof of Concept that for traverse applications, double walled tanks are not desirable because it is difficult to reliably detect failures of the inner wall in double wall systems and initiate corrective actions. In addition, it has been also recognized during the Proof of Concept that secondary containment structures such as external containment vessels are not feasible for use with fuel transport tanks during traverse operations. Under the conditions that are being evaluated during the Proof of Concept, the shear weight of a secondary containment structure on each fuel transport tank would require another tractor in the fleet to handle the aggregate additional weight.

Based on the Proof of Concept and observations of traverse operations performed by other Treaty nations, the USAP will use containers for traverse activities that are structurally compatible with their contents and able to withstand the physical and environmental (e.g., temperature) conditions to be encountered during the traverse. In addition, the USAP will regularly inspect storage tanks to detect leaks or potential weaknesses in the containers and have available empty vessels which can be used if emergency transfers are necessary.

Action: The draft CEE will be revised on pages 4-7, 4-12, 6-10, 6-18, 7-3, 7-6, and 7-7 to reflect leak prevention and corrective action measures applicable to traverse operations as evaluated during the Proof of Concept.