THE UNITED STATES IN ANTARCTICA

Report of the U.S. Antarctic Program External Panel

Cover: “Cathedral Berg At Night,” ©1994 by Neelon Crawford.

This photograph of a heavily eroded iceberg was made on the evening of June 23, 1994. R/V *Polar Duke*, from which the picture was taken, was about 60 miles south of the Antarctic Circle, in the Bellingshausen Sea at 67°26’77.6” S. 70°05’39.9” W. The highest points of the berg tower more than 100 feet above the waterline and the length of the visible portion of the berg is on the order of 400 feet. The berg presumably calved off one of many glaciers on the Antarctic Peninsula, but in fact could have traveled a far greater distance to this location. Some of the berg’s ice may have been formed hundreds of thousands or even millions of years earlier.

Inside Back Cover: Polar stratospheric clouds are illuminated by the Sun in the Antarctic Spring. Photo © by James Mastro.

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Washington, D. C.
April 1997

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National Science Foundation, Arlington, Virginia 22230.

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This document represents the final report of the United States Antarctic Program External Panel. The report has the unanimous approval of all 11 panel members and draws upon our collective experience which includes some 44 individual trips to Antarctica involving visits to all three U. S. stations, each research ship, support icebreakers and numerous field sites. As a panel, we visited McMurdo Station and South Pole Station and toured support facilities at Christchurch. We received approximately 70 briefings and conducted 80 "one-on-one" meetings with individuals involved in virtually all aspects of the Antarctic Program. Over 200 inputs were received in response to our request for "public comments."

During visits to McMurdo and the Pole, the Panel conducted informal "Town Meetings" and was the beneficiary of numerous comments by members of those communities having first-hand experience in day-to-day operations. We are most appreciative of the candor and professionalism with which we were treated by all those with whom we came into contact, and in particular the members of the National Science Foundation who so expertly and constructively supported our efforts.

We believe the U. S. Antarctic Program is well managed, involves high quality science and is important to the region as well as to the United States. We also believe that in the current budget environment, costs must be reduced, preferably through increased efficiency and "reinvention," but, if not, through reduced scope. Recommendations are offered herein to help ensure the continued viability of the program into the 21st century.

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1.0 Executive Summary

Antarctica is the coldest, driest, windiest, remotest, and highest (on average) continent. The United States has been involved continuously in Antarctic projects for over 40 years. The U. S. Antarctic Program External Panel (hereafter "the Panel") perceives that the U. S. Antarctic Program (USAP) has three principal justifications and objectives: presence, science, and stewardship. National prestige is involved in participation in activity in Antarctica, particularly at the South Pole, much as there is in involvement in the space program.

The stated U. S. policy toward Antarctica is that the continent should be maintained as a peaceful territory, free of national claims and available for the benefit of all humankind. The Antarctic Treaty system has created a political environment in Antarctica that today is largely characterized by cooperation and mutual understanding. Nonetheless, seven nations have made claims to parts of Antarctica, some overlapping, and potential disagreements remain an underlying reality.

The substantial U. S. presence in Antarctica is viewed by the Panel as a critical, perhaps the most critical, element in assuring the region's continued political stability. In addition, working in cooperation with many nations, the U. S. plays an important role in preserving a fragile and nearly pristine ecological system which serves as an indicator of future environmental trends throughout the planet.

Because of the unique physical conditions in Antarctica, the continent also is a one-of-a-kind scientific laboratory for the investigation of phenomena which range from the microscopic to the Earth-shaping. Following are examples of the latter:

- The character and causes of the Antarctic ozone hole have served as an early warning of the threat to the planet's ozone shield. Understanding ozone depletion and the impact of the resultant increase in surface ultraviolet radiation is crucial to predicting the future stability of Earth's ecosystems.
- Global warming is a complex and controversial topic, but there is no controversy about the benefits to be gained through understanding and detecting whether or not we are experiencing a systematic and unprecedented warming. The polar regions are integral to this process and perhaps leading indicators of it. Ice-core records show a correlation between warming and greenhouse gas increases over hundreds of thousands of years. Recent measurements at South Pole and elsewhere show that human-caused increases in greenhouse gases are higher than any others observed over this same period of time. Further measurements at the South Pole are critical to understanding the consequences of this change.
- West Antarctica, with its ice cover, is separated from East Antarctica and its massive ice sheet by the Transantarctic Mountains. Geophysics conducted in recent years in West Antarctica has shown that the West Antarctic Ice Sheet disappeared and re-grew after it had initially formed. Understanding the history and dynamics of this phenomenon will help us know the potential for ice sheet collapse and associated sea-level rise. Should such an event occur, the resultant total rise in sea level would be approximately 20 ft. Even an order of magnitude smaller rise, at the rate believed possible by glaciologists, would drastically impact the coasts of the world.
- The South Pole is the site of the cleanest air that can be found in the world today. Measurements of atmospheric gases and aerosols there are critical to understand the chemistry of the clean atmosphere and to unambiguously detect global human influences (e.g., trends in key greenhouse gases such as methane and carbon dioxide).
- Certain parts of Antarctica are uniquely suited to the recovery of meteorites, some of whose origin can be traced to the planet Mars. Recent discoveries have suggested the possibility that primitive forms of life once existed on Mars. The implications of such a discovery, if confirmed, are profound.

Data collected to understand many of these and related phenomena show fluctuations caused by extraneous influences over various time scales (seasonal, annual, decadal, etc.). However, conclusions drawn from these studies are valid only with continuous and regular sampling to build statistical confidence. Many Antarctic measurements have been made for decades, and the continuity of this scientific record is vital.

In carrying out its Antarctic program, the U. S. maintains year-round facilities at three locations on the continent, operates two ice-capable research vessels, and supports temporary field sites, some consisting of no more than one or two tents or a robotic instrument capsule. U. S. activities in Antarctica are currently budgeted and managed by the National Science Foundation (NSF) as principal agent for the U. S. Government.

Changing circumstances, particularly federal funding pressures, have resulted in a major ongoing realignment of support functions in the Antarctic, including the withdrawal of the U. S. Navy from its historic key roles in early exploration and, since the 1950s, research support. As the Navy withdraws, the Department of Defense is shifting heavy-lift (LC-130) air transport functions to the Air National Guard, and the NSF is transferring many other functions to civilian contractors. As a result, this is a particularly significant period, not only in terms of the need for intense management attention, but also as an opportunity to search for new means of reducing costs and re-inventing ways of conducting Antarctic activities.

A consequence of the NSF's traditional focus on the conduct of science, together with the character of the federal budgeting process — which, unlike commercial practice, does not ordinarily include a depreciation account to provide for the renewal of fixed assets — is that aging U. S. facilities in Antarctica are costly to maintain and, in some cases, of arguable safety. The Panel believes that the U. S. would not send a ship to sea or a spacecraft to orbit in the condition of many of the facilities in Antarctica — and especially those at the South Pole. The efforts of the individuals assigned responsibility for operating these facilities are heroic — nonetheless, steps need to be taken without delay to remedy the existing conditions.

The cost of constructing a replacement South Pole station has been recently estimated to be in the range of $150M-$200M and would take about eight years to budget and build. The Panel believes the station design which has been under consideration should be reduced in size and cost and that significant additional savings must be generated in the Antarctic program to offset a substantial fraction of the cost of a replacement facility.

The Panel has offered a series of 12 specific recommendations, each of which is discussed in this report and all of which are aggregated in Appendix IV. Overall conclusions of the Panel are as follows:

- The geopolitical importance heretofore assigned to a permanent U. S. presence in Antarctica, particularly at the South Pole, appears fully warranted. This consideration, *in itself*, justifies a year-round presence at several locations, including a moderate-sized facility at the Pole, along with necessary supporting infrastructure.
- The research being performed in Antarctica is comparable in its high quality and relevance to that being supported elsewhere by the NSF. The research utilizes the unique environment of Antarctica and addresses significant scientific issues with important human consequences, including evolution of the ozone hole, search for possible traces of life from Mars, stability of the ice sheet and its impact on sea level, and numerous other matters.
- The Antarctic program is well managed, and the competence and commitment of the individuals with whom the Panel met were impressive. The ongoing transfer of management and support responsibilities — from the Navy to the Air National Guard and from the Navy to the NSF and its contractors — demands an intense level of diligence.
- Impressive cost-reduction actions have been taken in recent years and further opportunities exist for additional savings. Among the latter are: further privatizing support operations in Antarctica, eventually under a single prime managing contractor; making total program cost (explicitly including support costs) a factor in selecting which research proposals are to be approved; placing head-count limits on the number of people traveling to Antarctica; discouraging multiple trips in a single season except under extraordinary circumstances; improving telecommunications capability to permit more science to be performed remotely; and so forth.
- Corrective actions that recently have been implemented have resolved or mitigated many of the previously documented waste recovery concerns at McMurdo Station, although additional long-term work remains to be accomplished.
- Further life-extension efforts devoted to the existing South Pole facility are neither cost effective nor conducive to the effective operation of a remote station.
- Communications to and from Antarctica, and especially the South Pole, although much improved in recent years, are dated and tenuous and require improvement to meet the standards of a modern research facility — including communications support of robotic operations as well as logistics management.
- Joint research projects with other nations and international partnering in providing transportation are flourishing and deserve to be encouraged in order to reduce costs where possible and to strengthen cooperation among nations. Joint ownership of core facilities, however, does not appear to be in the best interest of the U. S. role in promoting political stability.
- The quality of many U. S. facilities in Antarctica, and particularly at the South Pole, is not in keeping with the standard reasonably expected of a nation of America's stature and, in several respects, the facilities are becoming increasingly unsafe. Funds specifically appropriated in the FY97 budget to rectify the most extreme safety, health and environmental concerns at the South Pole are very important, but do not address the underlying problems of an aging, three-station system in a life-threatening environment.
- The Panel recommends that the NSF Office of Polar Programs (OPP) reduce the number of field projects in Antarctica during the South Pole facility reconstruction phase and encourage related science in the U. S. This is the most equitable way to help fund the replacement and should have the least impact on Antarctic science.

The Panel's principal conclusion is that the South Pole Station needs to be replaced soon for economic, safety and operational reasons and that modest upgrades are needed at Palmer and McMurdo Stations. The Panel understands that urgent safety shortcomings at South Pole Station will be resolved with the application of $25M funded in FY97. Other renovations (a minimum of $15M at Palmer and McMurdo Stations) and replacement of South Pole Station should be funded by a downsizing of the previously proposed new South Pole Station design, reducing the cost to $125M excluding $5M of interim expenses to keep the existing station functional until replacement; a cumulative reallocation of $20M from science grants and science support over FY98-FY02; and the generation of savings of at least $30M through cost reduction actions already underway, augmented by the recommendations contained in Section 7. Although this represents a considerable reduction in new funding needs relative to previous estimates, it still produces a cumulative shortfall of $95M over the five-year period during which the replacement South Pole Station is to be funded. It is the conclusion of the Panel that these residual funds are not to be found within the resources of the USAP without severely undermining the viability of the science program and degrading health and safety conditions.

2.0 Introduction

The role of the NSF in the U. S. Antarctic Program was formally delineated in Presidential Memorandum 6646 issued on February 5, 1982, in which the following decisions were presented:

- The U. S. Antarctic Program shall be maintained at a level providing an active and influential presence in Antarctica designed to support the range of U. S. Antarctic interests.
- This presence shall include the conduct of scientific activities in major disciplines; year-round occupation of the South Pole and two coastal stations; and availability of related necessary logistics support.
- Every effort shall be made to manage the program in a manner that maximizes cost effectiveness and return on investment.

The memorandum also stated that the NSF should budget for and manage the entire United States national program in Antarctica, including logistic support activities, so that the program may be managed as a single package. It was directed that the NSF should draw upon the support capabilities of other government agencies on a reimbursable basis, and commercial support and management facilities should be used where they are cost effective and not detrimental to the national interest.

Three year-round research facilities have been constructed in Antarctica that remain today: McMurdo Station near the Ross Ice Shelf in 1955, Amundsen-Scott Station at the South Pole in 1956, and Palmer Station by the Antarctic Peninsula in 1965. An ice-strengthened research/transport ship and a research icebreaker also were acquired. Since the 1960s the backbone of the program's air transport has been a fleet of ski-equipped C-130 aircraft designated LC-130s. University-based and Federal agency research are supported at the rate of about 125 projects each year. The cost of this inclusive program of infrastructure and science is compared with the cost of U. S. Arctic research programs in Exhibit 1.

Beginning in 1989, the Office of Polar Programs of the National Science Foundation initiated a South Pole Redevelopment Project. The replacement research facilities that had been built at the geographic South Pole in the 1970s were overcrowded and at the end of their design life, having been constructed for an expected life of 15 to 20 years and for a population of 34 men. The station, dedicated in 1975, has 30-year-old structural and environmental technology and supported 172 men and women during this year's austral summer. A facilities evaluation recently conducted by an Alaska-based consultant, Kumin Associates, concluded that

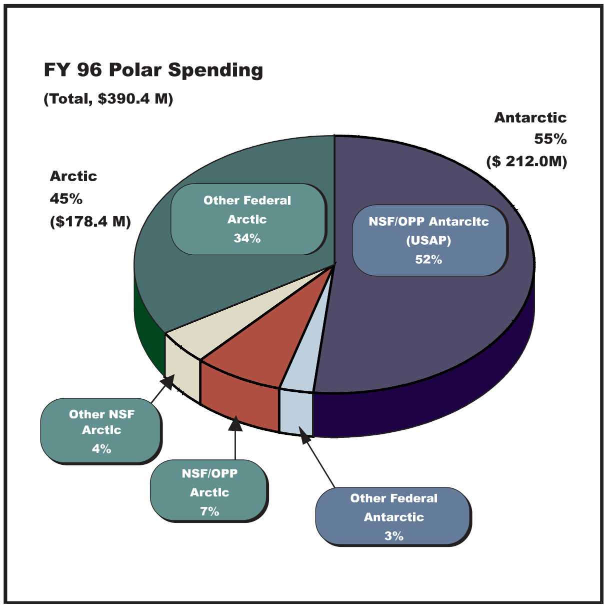


Exhibit 1

Federal Spending for Polar Research. Because the Arctic contains U. S. sovereign territory (Alaska) and the Antarctic does not, the U. S. Government administers research differently in the two polar regions. In the populated Arctic, a dozen Federal agencies perform or sponsor research within the existing infrastructure characteristic of populated states in the U. S. In the Antarctic, which has no indigenous population or infrastructure, the National Science Foundation funds most of the nation's research and research support, and it coordinates land-based research of other agencies.

within eight to ten years most buildings and several utility systems at the South Pole will have reached the end of their useful life. As the buildings and utilities become more unreliable, safety risks, costs and interruptions to ongoing research will increase. A building code inspection in 1993 revealed over 300 deficiencies of varying degrees of significance. NSF's Polar Safety and Health Officer has implemented numerous administrative controls to reduce safety risks, but additional safety controls will be required as the facilities continue to age, further reducing the efficiency of scientists and operational personnel and increasing costs.

The South Pole Redevelopment Project was reviewed in 1994 by a Non-Advocate Review Panel chaired by Colonel Palmer Bailey of the U. S. Army Corps of Engineers Cold Regions Research and Engineering Laboratory. The panel concluded that there was a need to redevelop the South Pole Station and that the program presented by the Office of Polar Programs to do so was well conceived and based on reasonable and appropriate assumptions. Questions were raised about the possibility of reducing the number of people at the Pole by expanding automation and telescience. Continued input from the user community, as well as from public interest organizations dealing with environmental issues, was encouraged by the Non-Advocate Review Panel. It found that the overall architectural concept of the existing South Pole Station was sound and practical but expressed concern over continued dependence on the sub-snow arches and the use of drifting, aged geosynchronous satellites for communications. The panel concluded by stating that the NSF had a sound concept and a fully adequate plan for replacement of South Pole Station and encouraged the NSF to move forward with the program.

The South Pole Redevelopment Project which would replace the existing station was next reviewed from a scientific perspective by a Blue Ribbon Panel chaired by H. Guyford Stever. In June, 1994, the Stever panel reported its findings that NSF supports scientific programs at the South Pole that 1) can be conducted only at the South Pole, or 2) can be done better there than elsewhere on Earth, or 3) can be done there at lower cost than conducting corresponding research in space. The panel noted that the South Pole provides a unique environment for research in several aspects: location at the rotational axis and proximity to the magnetic axis; circulation of the atmosphere; uninterrupted observation during dark and light periods; cleanliness of the atmosphere; low-water vapor content; the existence of a continental-sized block of extraordinarily transparent ice; a unique tectonic location; low levels of electromagnetic interference; a unique environment for seismology; and a high elevation with flat terrain. The Stever panel concluded that science is the primary justification for the U. S. presence at the South Pole, but substantial non-scientific national values are served as well. Included are international environmental leadership, educational inspiration, and support for responsible governance of a non-sovereign territory.

The Stever panel stated that there was serious need to:

- introduce safer facilities that meet modern construction codes;
- improve the efficiency of the power and heating systems;
- improve the available room for increasingly complex equipment and increased volumes needed for garage space;
- provide reasonable working and living quarters for scientists and support staff;
- reverse the trend whereby the environment has on occasion been degraded; and
- store fuel in a manner which is environmentally responsible.

In September 1995 the Senate Appropriations Committee on the Veterans Administration, Housing and Urban Development, and Independent Agencies, aware that the NSF was considering a South Pole Redevelopment Project, requested the National Science and Technology Council to review U. S. Antarctic Policy. The Panel requested the review to:

> *"...examine the validity of the policy contained in Memorandum 6646, namely the need for a year-round presence, the need for three stations, and the roles of NSF, the Department of Defense, and other Government agencies. The review should examine the policy in the context of the value of the science performed in Antarctica and other U. S. interests. Finally, the review should address the affordability of continued U. S. presence in Antarctica in light of the severe budget environment, and examine options for reducing annual logistical and operational budget needs. At a minimum, budget saving options should include greater international cooperation, less than a year-round human presence, and closing of one or more of the stations."*

The National Science and Technology Council (NSTC) transmitted its report to Congress on April 26, 1996. The report prepared by NSTC's Committee on Fundamental Science determined:

> *"...from a policy perspective the NSTC finds that maintaining an active and influential presence in Antarctica, including year-round operation of the South Pole Station, is essential to U. S. interests.*
>
> *"...that the National Science Foundation has implemented U. S. policy in an effective manner, especially by substantially improving environmental stewardship, by broadening the science program, and by privatizing some operational elements of the Program to reduce costs.*
>
> *"...the USAP research program is of very high quality and of great interest to a broad scientific community.*
>
> *"...that, at the current level of investment, the USAP is cost effective in advancing American scientific and geopolitical objectives and, from a science perspective, [should] support the continuation of three stations with year-round presence.*
>
> *"...the USAP should give highest priority to correcting critical health, safety, and environmental issues at the current [South Pole] Station.*
>
> *"...that an external panel be convened by NSF to explore options for sustaining the high level of USAP science activity under realistic constrained funding levels."*

In response to the NSTC recommendation for an external panel, the Director of the NSF established the U. S. Antarctic Program External Panel on August 16, 1996, and provided Terms of Reference (Appendix II). The Director charged the Panel to "...examine and make recommendations concerning the stations and logistics systems that support the science while maintaining appropriate environmental, safety, and health standards; the efficiency and appropriateness of the management of these support systems; and how and at what level the science programs are implemented. The panel's views and recommendations should include consideration of eventual replacement of the South Pole Station and other infrastructure."

The Director of the NSF also asked the Panel to provide advice on how the USAP can maintain a high quality research program while implementing the U. S. policy in Antarctica under realistic budget scenarios. One scenario the Panel was asked to consider was an overall budget freeze for the USAP science program and for all infrastructure support, including the South Pole Station. It was stated that supplemental funding from other federal agencies or from other sources within NSF was not necessarily to be assumed. The Panel was asked to consider approaches used by other agencies and the private sector in operating remote facilities, as well as new technologies such as robotics that could yield further efficiencies and cost savings. Finally, the Panel was asked to identify areas in which substantial increases in program effectiveness would result from resource reallocation or short-term changes in budget profiles, including capital investments, that could lead to reductions in life-cycle costs.

The present document is the final report of the U. S. Antarctic Program External Panel. It addresses such issues as the need for a U. S. year-round presence in Antarctica, the quality and uniqueness of research programs being conducted in Antarctica under U. S. auspices, and the adequacy of facilities which support on-going and projected activities. It presents 22 specific findings and 12 recommendations that address the budget and management issues raised in the NSF's Terms of Reference.

3.0 Antarctica— The Environment

Antarctica is composed of two major, geologically distinct parts bridged by a vast ice sheet (Exhibit 2). East Antarctica, the larger of the two, is roughly the size of the U. S. (Exhibit 3) and is composed of continental crust covered by an ice sheet that averages 1.6 miles thick. Rock exposures are limited to isolated coastal regions and to alpine elevations in the 2,000-mile long Transantarctic Mountains. West Antarctica, the smaller portion, is a mosaic of small blocks of continental crust covered by the West Antarctic Ice Sheet and an Andean-like mountain chain forming the Antarctic Peninsula. Most of the West Antarctic Ice Sheet is grounded below sea level, in places over 1.5 miles below sea level.

The continent itself is depressed more than half-a-mile to near sea level under the tremendous load of the ice sheet, with some regions well below sea level. The highest mountains rise to elevations of over 14,000 ft. — about the height of the U. S. Rocky Mountains.

The present Antarctic ice sheet accounts for 90 percent of Earth's total ice volume and 70 percent of its fresh water. It houses enough water to raise global sea level by 200 ft. if completely melted. The ice sheet at the Pole, nearly two miles thick, is constantly shifting, carrying the facility at the Pole along with it at the rate of about 30 ft. a year. Nearly 90 percent of the ice flowing across West Antarctica converges into ice streams that are the most dynamic, and perhaps unstable, components of the ice sheet. Recent glaciological observations have yielded evidence that some of these West Antarctic ice streams may be responding to climatic and sea level changes of the recent past, changes that could lead to more rapid retreat and global sea-level rise in the future. A few active volcanoes may also affect the ice sheet's behavior.

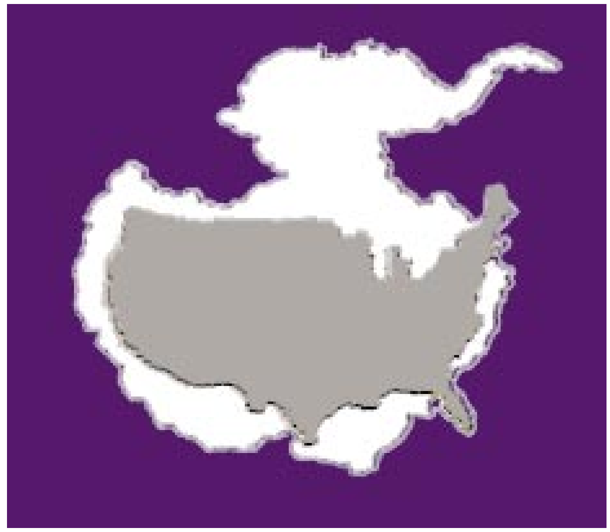


Exhibit 3

Antarctica's area of 5.4 million square miles makes it 1.5 times the size of the conterminous U. S.

The Antarctic climate offers a formidable challenge to those who venture there in quest of scientific knowledge. It is the coldest, driest, highest (on average) and windiest continent on Earth. Absolute humidity is lower than on the Sahara. Annual snowfall in much of the interior is less than two inches. Winds that flow down the surface of the ice sheet toward the coast (katabatic winds) commonly reach speeds of 80 miles per hour, and maximum measured wind speeds have exceeded 180 miles per hour. Changes in the weather are dramatic: winds shift from calm to full-gale in a brief period of time. A drop of 65°F was once recorded in 12 minutes. Earth's lowest surface temperature (-126.9°F) was recorded at Russia's Vostok Station in the interior of Antarctica. Coastal locations in summer occasionally rise above the freezing point (Exhibit 4).

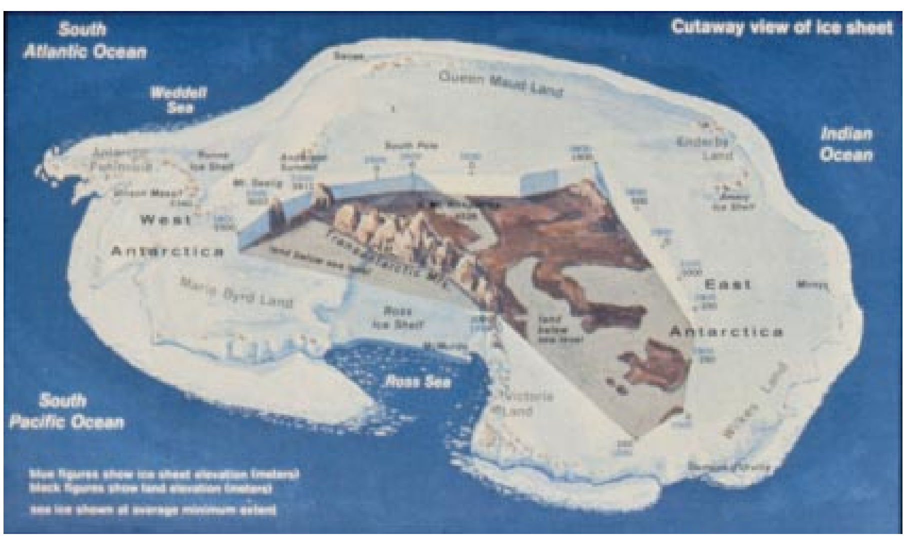


Exhibit 2

Antarctica, with cutaway showing ice sheet and bedrock.

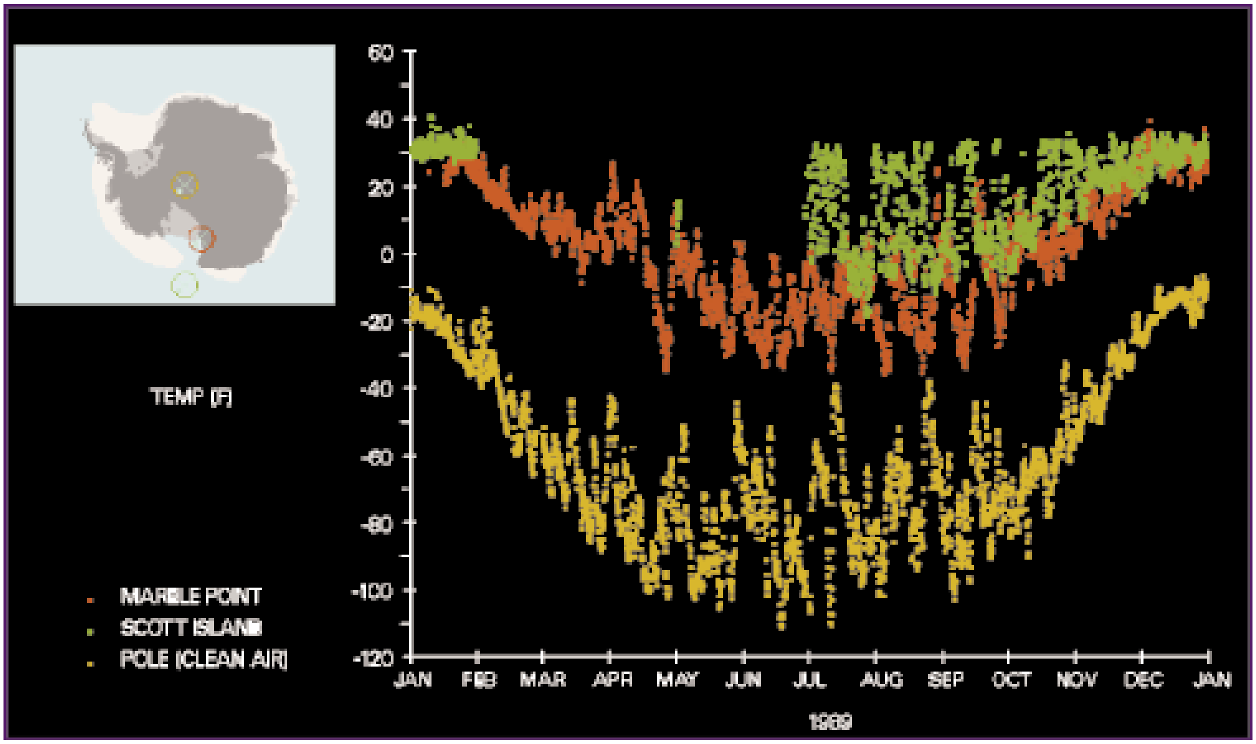


Exhibit 4

Antarctic temperatures. Spring and fall, in polar terms, are more aptly morning and evening twilight. Particularly in the continental interior, the temperature drops quickly when the Sun sets in March, and rises with the Sun's rise in September. This graph shows temperatures in 1989 at three locations — the clean air facility at South Pole Station (90°S), the helicopter fuel depot at Marble Point (78°S, across the sound from McMurdo), and on Scott Island (66°S) in the southern ocean. The data were collected by unattended automatic weather stations and transmitted by satellite every two minutes to the University of Wisconsin in Madison, from where they were sent by request over the Internet to a winterer at McMurdo Station, who produced this graph as part of an evaluation of latitudinal temperature variations. The graph shows that, at South Pole in 1989, both summer and winter temperatures happened to come close to the station's historic recorded extremes of 7°F and -117°F.

At the South Pole, the nights are six months long, extending from sunset on March 21 to sunrise on September 21. A lake (Lake Vostok) buried 11,000 ft. under the ice is the size of North America's Lake Huron.

Offshore cyclones occur with little warning. Winds typically reach hurricane strength within an hour and persist for several days. A concentration of storm formation and/or intensification occurs at approximately 50°S latitude and is associated with some of the most violent seas in the world ("the roaring forties"). The stretch of ocean between Antarctica and the tip of South America is considered the most hostile in the world and has claimed numerous ships over the centuries.

The stable upper atmospheric (stratospheric) air mass over the continent has been seriously altered by synthetic chemicals that arrived via natural atmospheric circulation from the world's industrial areas, resulting in the creation of the well-known Antarctic ozone hole. Ice core records provide evidence that atmospheric greenhouse gases such as carbon dioxide and methane have increased markedly during the past 200 years and are presently more prevalent than at any time in the past 160,000 years. These records also show that low temperatures of the ice age occurred when greenhouse-gas concentrations were low.

Meteorological observations have been recorded only in recent decades, and then only in scattered localities, so long-term temperature trends remain uncertain. The longest instrumental temperature records come from the relatively warm Antarctic Peninsula region, referred to by the "Frozen Chosen" as the "Banana Belt" of Antarctica. The glacial systems that occur in the Peninsular region are the most delicate in Antarctica and the most vulnerable to climatic warming. In historical time the fronts of the Larsen and George VI ice shelves, the two largest ice shelves in the region, have retreated at rates of nearly one-half mile per year. Another smaller ice shelf, the Wordie Ice Shelf, has completely vanished during the past several decades. Whether these changes are due to induced global warming or to natural (perhaps regional) climatic cycles remains uncertain.

Millions of square miles of sea ice surround Antarctica; the extent annually experiences a five-fold increase and decrease, with the winter maximum more than doubling the entire Antarctic region's area of ice coverage. Icebergs larger than the State of Connecticut have been observed. The temperature gradient associated with Antarctica's sea-ice zone is one of the strongest on Earth, and the seasonal variability in the extent of sea ice is an important regulator of the climate of the Southern Hemisphere. This is primarily because of the significant difference between sea ice and water in reflecting the sun's energy (albedo) and because the sea ice serves as a barrier to energy exchange between atmosphere and ocean. The extent of sea ice around Antarctica also regulates (and stimulates) primary productivity of microorganisms in surface waters, and the sea ice zone is one of the most dynamic biological systems on Earth. Global warming could cause a significant reduction in the extent of the sea ice; the potential climatic and biological impacts of a change remain problematic.

Ocean circulation and water mass production in the Antarctic region are unique owing to the strong influence of sea ice and ice shelves on temperature and salinity and to a virtual absence of geographic obstacles to circulation around the continent. A key ingredient of the global ocean is the very cold, saline water that forms in regions of the Antarctic's continental shelf. This water is supercooled by exposure to ice shelves (floating glacial ice still attached to the land), and its salinity is increased by salt that is expelled from freezing sea water during annual sea ice production. This water flows off the Antarctic continental shelf and into the global ocean as Antarctic Bottom Water, the coldest and saltiest water mass in the deep ocean and a primary driver in global ocean circulation (Exhibit 5). Elsewhere around Antarctica, relatively warm water masses flow onto the continental shelf and melt the undersides of ice shelves. This feedback between water masses and ice shelves is still not well understood.

Life forms on the Antarctic continent are sparse because of the severe climate. Nevertheless, biologists have found bacteria and yeast growing just 183 miles from the South Pole. A lichen was found in a sunny canyon 210 miles from the Pole, and a blue-green alga was observed in a frozen pond 224 miles from the Pole. Microbes related to lichens colonize in green and brown layers just beneath the surface of rocks facing the Sun. Mosses and liverworts grow in some ice-free areas along the coast. Two species of flowering plants — a grass and an herb — grow along the Antarctic Peninsula.

The native land animals are limited to arthropods (insects and the like), of which 76 species have been discovered. Nearly all of these species are found only in Antarctica. These springtails, midges and mites generally live along the coast among plant colonies. The southernmost known animal, a mite, has been found 315 miles from the South Pole.

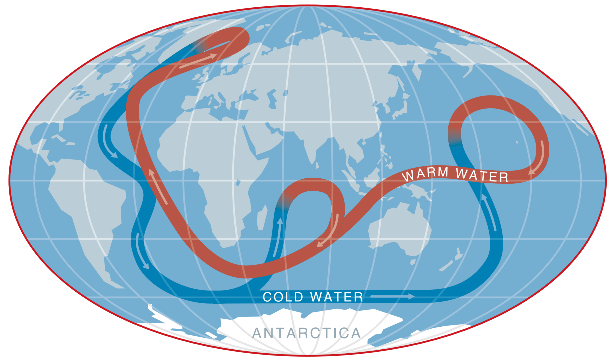


Exhibit 5

How Antarctic ice affects world climate. Think of the Antarctic ice sheet as Earth's refrigeration unit: It exerts a major two-way control over today's global environment. First, the ice sheet (along with sea ice that surrounds it in the southern ocean) reflects back into space about 80 to 85 percent of the Sun's energy that hits it. So icy Antarctica, which records the lowest temperatures on Earth, helps to reduce the world's overall heat budget. Second, the near-freezing meltwater that runs off the ice sheet, along with the water from melting icebergs, falls to the ocean floor and moves northward. This surge affects deep-sea circulation, which in turn influences climate. A major meltdown would raise sea level worldwide and could modify weather patterns. Drawing source: February 1997 © Popular Science (Infographic © 1997 by John Grimwade).

Sea life, in contrast to the land, is bounteous. The immense numbers of birds and seals that live in Antarctica are, properly speaking, sea animals. They spend most of their time in or over the water, where they get their food. These animals come ashore only to breed.

About 45 species of birds live south of the Antarctic Convergence (Exhibit 6). Of the seven penguin species, two — the emperor and the Adélie — are distributed widely around the entire coastline. Gentoo and chinstrap penguins occupy Antarctic Peninsula coasts. The population of birds in the Antarctic is estimated to be 350 million, of which about half are penguins. The total weight of birds is estimated in excess of 400,000 tons — greater than the combined weight of Antarctic seals and whales.

Four species of seals breed almost exclusively in the Antarctic — the Weddell, crabeater, leopard, and Ross. Other species include the fur seal and the huge elephant seal. Most populous is the crabeater, estimated at 50 million to 75 million. Leopard and Weddell seals number 250,000 to 500,000 each.

Fishes peculiar to the Antarctic include the Antarctic cod and the icefish. These and other fishes

Exhibit 6

A year in the life of an emperor penguin

At a height of 4 feet, emperors are the largest of the world's 17 penguin species. They can weigh 90 pounds. Only 42 colonies, all in the Antarctic, are known, and the total emperor population is an estimated 200,000 breeding pairs — a small fraction of Antarctica's 180 million penguins.

January-March. It's late summer, and the birds are at sea fattening up on a diet of 95 percent fish, 3 percent squid, and 2 percent krill.

March-April. The penguins walk "inland" across the frozen sea, taking a week or more to go 60 to 100 miles to the traditional colony site.

May-June. It takes 5 to 8 weeks to walk across the ice, select a mate, and, for the female, lay the single 1-pound egg. She incubates it for several hours, keeping it warm in a brooding pouch that is a fold of skin just over her feet, then transfers it to her mate who proceeds to balance the egg on top of his feet for weeks to keep it from freezing. Twelve hours later she goes back to the open sea, having lost 20 to 25 percent of her weight since leaving it, her only source of food.

Late May-August. It's winter. The male incubates the egg in the dark of winter at temperatures as low as minus 70°F. He loses about 7 ounces of fat a day during the 64-day incubation. Chicks hatch in July and August. Despite not having eaten for 4 months, the male is able to feed the chick from his own gut. In a feat of timing and navigation, the female returns within a few days of the hatching.

August-September. The male goes to sea, crossing the sea ice at its winter maximum, perhaps hundreds of miles. There, he replenishes his fat, while the female feeds the chick for three to four weeks. After a month the male returns and takes over chick duty.

October-November. The chick remains on the feet of the adults nearly 6 weeks. Then the parents leave the chicks unguarded. Chicks form crèches, huddling together to stay warm. During this time the parents go back and forth between the sea and the colony.

August-late December. The chick fledges about five months after hatching. During this time it is fed on average every 16 days, receiving 30 percent of its body weight at each meal. Satellite tracking of some adults has shown that their feeding journeys can take them 900 miles. Emperors are the world's deepest diving birds, reaching depths of 2,070 feet and staying under water as long as 18 minutes.

December-January. The adults desert the chicks when they are about five months old. The chicks weigh 22-23 pounds, about 45 percent of the adult's summer weight,. The ice now carries them to sea, and they will not return to breed for five years. Meanwhile, the adults fatten up at sea and return to the ice to molt, a process that takes three to four weeks.

February-March. The breeding adults now have just three to four weeks to fatten before starting their long trek across the sea ice begin again their remarkable breeding program.

—text after Zegrahm News, © 1997; photo © Galen Rowell, Mountain Light Photography, 1995.

have developed proteins in their blood that enable them to live in sea water as cold as 28°F — that is, below the freezing temperature of fresh water. There is abundant and varied bottom life (starfish, urchins, shellfish) in most coastal waters.

Aside from phytoplankton (marine plants), a singularly important member of the Antarctic marine food chain is krill. This crustacean looks like a small shrimp and exists in huge numbers; vast swarms stretching several miles in length have been observed from ships, and some biologists believe the krill population may exceed 5 billion tons. Krill eat phytoplankton and small marine animals and in turn are eaten in great numbers by squid, birds, seals, and whales. There is evidence that depletion of the ozone layer affects phytoplankton productivity, and may therefore affect krill and the entire southern ocean food chain.

Overall, the Antarctic environment is compelling yet formidable (Exhibit 7) and it provides a unique surrounding in which to conduct research — some of which has great relevance for life throughout the globe.

The Antarctic is dramatically different from the Arctic, as Exhibit 8 shows.

Exhibit 7

Antarctic Meltdown

Nine tenths of the world's ice is piled up in Antarctica. If it were to melt, sea level would rise some 200 feet, dramatically altering the shape of the U. S., among other countries. Scientific research has not established either the history of the ice sheet's former fluctuations or its future. The dynamicists infer an ice sheet that may have receded as recently as three million years ago, but the stablists think it has been generally unchanged for the last 10 to 15 million years. This "infographic" by John Grimwade is from the cover story entitled "Antarctic Meltdown," by Beth Livermore, in the February 1997 issue of Popular Science.

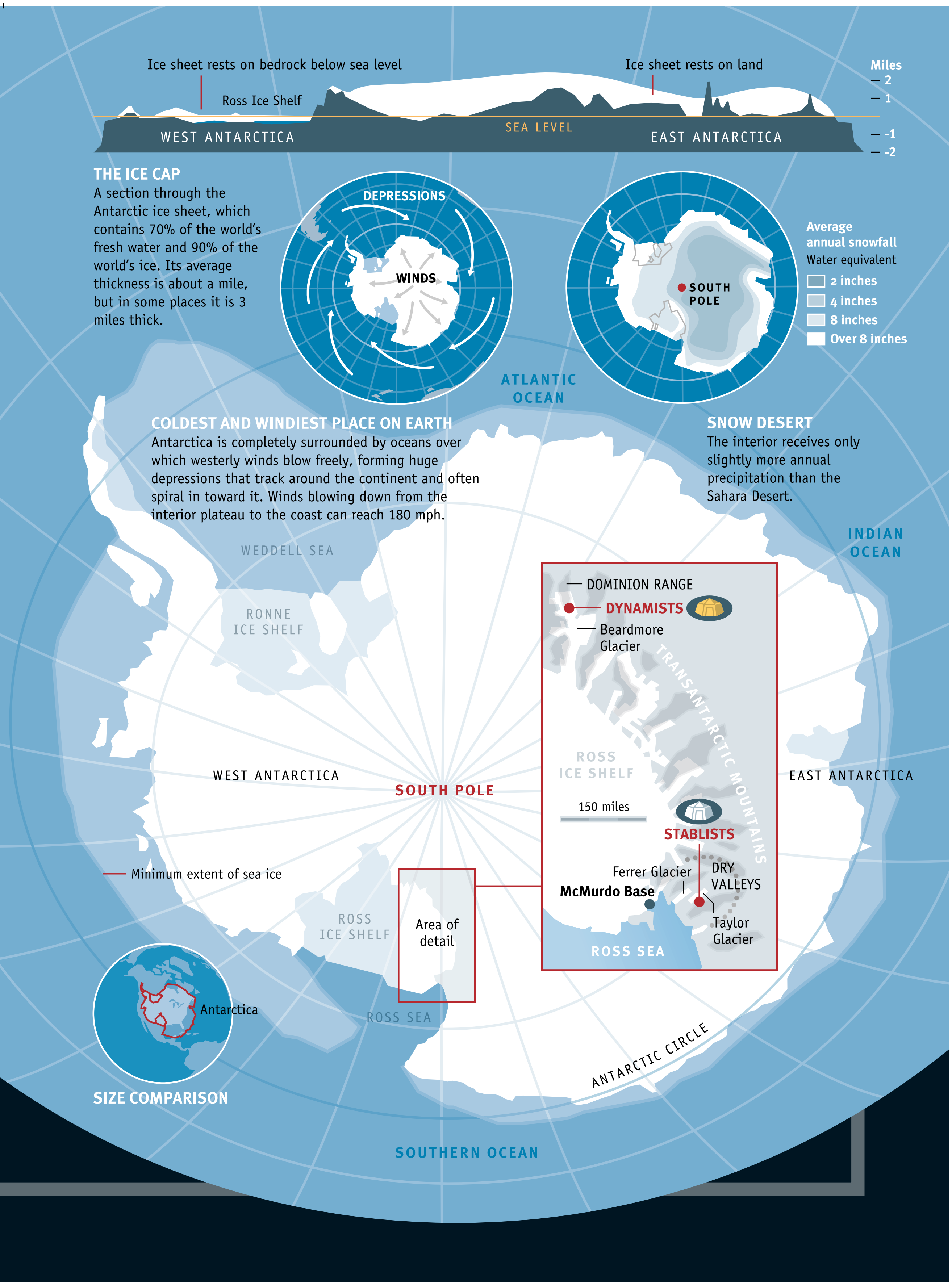

Ice sheet rests on bedrock below sea level
Ross Ice Shelf
Ice sheet rests on land
Miles
2
1
-1
-2
WEST ANTARCTICA
SEA LEVEL
EAST ANTARCTICA
THE ICE CAP
A section through the Antarctic ice sheet, which contains 70% of the world's fresh water and 90% of the world's ice. Its average thickness is about a mile, but in some places it is 3 miles thick.
DEPRESSIONS
WINDS
SOUTH POLE
Average annual snowfall
Water equivalent
2 inches
4 inches
8 inches
Over 8 inches
ATLANTIC OCEAN
COLDEST AND WINDIEST PLACE ON EARTH
Antarctica is completely surrounded by oceans over which westerly winds blow freely, forming huge depressions that track around the continent and often spiral in toward it. Winds blowing down from the interior plateau to the coast can reach 180 mph.
SNOW DESERT
The interior receives only slightly more annual precipitation than the Sahara Desert.
INDIAN OCEAN
WEDDELL SEA
RONNE ICE SHELF
DOMINION RANGE
DYNAMISTS
Beardmore Glacier
TRANSANTARCTIC MOUNTAINS
ROSS ICE SHELF
150 miles
STABLISTS
Ferrer Glacier
DRY VALLEYS
McMurdo Base
Taylor Glacier
ROSS SEA
WEST ANTARCTICA
SOUTH POLE
EAST ANTARCTICA
Minimum extent of sea ice
ROSS ICE SHELF
Area of detail
Antarctica
ROSS SEA
ANTARCTIC CIRCLE
SIZE COMPARISON
SOUTHERN OCEAN

Exhibit 8

South Pole/North Pole. Both of the Earth's polar regions are cold, and they share other characteristics that distinguish them from the planet's temperate and tropical regions. Yet, the two regions also are dramatically different from each other, as this list shows. The map depicts the world 21,000 years ago, when the Ice Age had extended the polar ice sheets, particularly in the north, far beyond their present boundaries. Map furnished by Woods Hole Oceanographic Institution.

Antarctic	**Arctic**
—— NATURAL FEATURES——	
• Continent surrounded by ocean, winds, and circumpolar ocean currents, uninterrupted by land masses.	• Ocean surrounded by continents.
• Icebergs derived from glaciers and shelf ice year-round and may measure in excess of 25 cubic miles.	• Icebergs derived from glaciers, seasonal, measured in cubic yards.
• Sea ice annual, outward growth more than doubles continent size, annual thickness to 8 ft.	• Sea ice multi-year, circulates in polar gyre, annual thickness to 5 ft.
• 97.6 percent of land ice covered in almost unbroken South Polar ice sheet.	• Land ice in limited areas; largest Greenland ice sheet.
• Elevation at South Pole 9,300 ft. above sea level; bedrock only 100 ft. above sea level.	• Elevation at North Pole 3 ft. of sea ice; bedrock 1,400 ft. below sea level.
• South Pole mean annual temperature — -58°F; permanent meteorological and astrophysical research station.	• North Pole mean annual temperature – 0°F; no research station.
• Beaches rare; narrow deep continental shelf backed by vertical ice cliffs.	• Beaches and shallow extensive continental shelf.
• Frozen ground mostly limited to ice-free areas.	• Frozen ground extensive, over 1,500 ft.
—— PLANTS AND ANIMALS ——	
• No tundra, no tree line. Subantarctic zone marked by Antarctic Convergence.	• Tundra well developed, extensive, marked by a tree shrubline.
• Crustaceous lichens at 82° lat; 2 species of flowering plants at 66°–70° S lat; vegetation primarily lichens and mosses.	• 90 species of flowering plants at 82° N lat, 450 species at 66°–77°N lat.
• Free-living arthropods include insects (2), mites (150), Collembolla (6).	• Free living arthropods include Arachnids, crustaceans, insects, and myriapods numerous and common.
• No terrestrial mammals.	• Terrestrial mammals include musk ox, reindeer, caribou, fox, hare, wolf, lemming, bears, etc.
• Marine mammals limited to whales and porpoises (14) and seals (4).	• Marine mammals include whales and porpoises (18), seals (7), amphibious mammals (1).
• Bird species (19) 70°–80° S lat.	• Bird species (107) at 75°–80° N lat.
—— HUMANITY ——	
• No record of primitive humans; no native groups.	• Native peoples with long, rich cultural record; ethnic groups circumarctic.
• Population south of 60° S sparse, scattered at scientific stations. No exploitation of terrestrial resources.	• Human population 60° N, in excess of 2 million, modern settlements, widespread exploitation and technological development.
• Crossing of Antarctic Circle by James Cook, January 17, 1773.	• Crossing of Arctic Circle prehistoric.

4.0 Antarctica— Past and Present

Antarctica history is rich in adventure and science, yet human activity in the region extends back in time only about 200 years. In fact, most of what is known about Antarctica has been discovered in the present century.

4.1 Early Antarctic Activity

4.1.1 Exploration Remote, inaccessible, and inhospitable, Antarctica was the last continent to be discovered, and knowledge of the south polar region was accumulated slowly. Until the present century the interior of Antarctica was unknown, and even the continental margins had been seen in only a few places. Of the world's 61,000 nonfiction papers and books published about the Antarctic since the earliest papers dating from the 1600s, 91 percent have been published since 1951. However, the historian Kenneth J. Bertrand (*Americans in Antarctica 1775-1948*, American Geographical Society, 1971) writes that "the success of recent operations in unveiling Antarctica with the aid of modern technology does not negate the importance of earlier efforts. Present accomplishments have been built on the past, developed step by step since 1674, sometimes haltingly and sometimes failing."

Explorations have been conducted for a variety of motives and sometimes accidentally, as was the case of the first discovery south of the Antarctic Convergence (where temperate and polar waters meet) — of South Georgia in the 1670s when a commercial ship was blown off course. The true nature of the Antarctic as a frigid region of ice and snow was convincingly proved for the first time by the second voyage of the English navigator, Captain James Cook, between 1772 and 1775 (Exhibit 9). Until then, there was general belief in a large, still undiscovered continent in the southern hemisphere suitable for European settlement. Cook circumnavigated Antarctica, much of his course south of 60°S, and crossed the Antarctic Circle in three places. He failed to sight any part of the Antarctic continent, but disproved conclusively the existence of the mythical continent "Terra Australis Incognita" at latitudes north of 60°S. Mariners who followed Cook into high southern latitudes were attracted to the harsh environment by his reports of great numbers of whales and seals, particularly the latter.

In 1820-1821 the American sealer Nathaniel B. Palmer of Stonington, Connecticut, saw the Antarctic Peninsula from his sloop *Hero* and met the Russian Captain Thaddeus Bellingshausen commanding the two ships *Vostok* and *Mirnyy* on a major national expedition that circumnavigated Antarctica eastward. Three other great national expeditions were made between 1819 and 1843 by the French Admiral Dumont d'Urville, who discovered the Adélie and Clarie coasts in 1840; by U. S. Navy Lieutenant Charles Wilkes, who mapped 1,500 miles of Antarctica's coast south of Australia in 1839-1840, proving Antarctica a continent; and by Britain's Sir James Clark Ross, who discovered the Ross Sea, Ross Island, and the Ross Ice Shelf in 1841.

Historians have not settled the question of who was first to see land in Antarctica. British, Russian, and U. S. ships all were in the Antarctic Peninsula area in the early 1820s, and the first sighting occurred during that time. The first documented landing on the continent was on 24 January 1895, when the Norwegian whaling ship *Antarctic* landed a party at Cape Adare on the northern Ross Sea. The party consisted of Captain Leonard Kristensen, second mate Carstens Borchgrevinck, and H. J. Bull, who wrote a book about their adventure. Bull called being first on the Antarctic mainland "both strange and pleasurable," although he thought the crew would have preferred to find a Right Whale "even of small dimensions."

In 1895 a resolution by the Sixth International Geographical Congress in London promoted Antarctic exploration and set into motion a series of expeditions known now as the "Heroic Era." Before World War I halted this activity, 16 exploring expeditions from Australia, Belgium, England, France, Germany, Japan, Norway, Scotland and Sweden (but not the U. S.) had visited Antarctica. This activity is exclusive of whalers, discussed below. The magnitude of this activity was unprecedented for Antarctica, and, considering the state of technology and size of the world's population and wealth, it probably was greater than that of the mechanical age that followed and comparable to the operations initiated with the International Geophysical Year (IGY), 1957-1958. The best known of the Heroic Age expeditions were those led by Roald Amundsen (Norway) and Robert F. Scott (England), who separately reached the geographic South Pole (and were the first to do so) a few weeks apart on 14 December 1911 and 17 January 1912, respectively (Exhibit 10).

U. S. Antarctic activity in this century began with Richard E. Byrd's hugely popular, privately financed, expeditions in 1928-1930 and 1933-1935. Byrd's success led to Congressional appropriations of $10,000 in 1939 and $340,000 in 1940 (totaling about $4.1M in 1997 dollars) for the U. S. Antarctic Service, organized as a civilian entity under four cabinet agencies. Intended to be permanent but curtailed to a single winter and two summers because of World War II, the field work in 1939-1941 nevertheless was the largest Antarctic expedition up to that time, and it produced discoveries in a number of research disciplines.

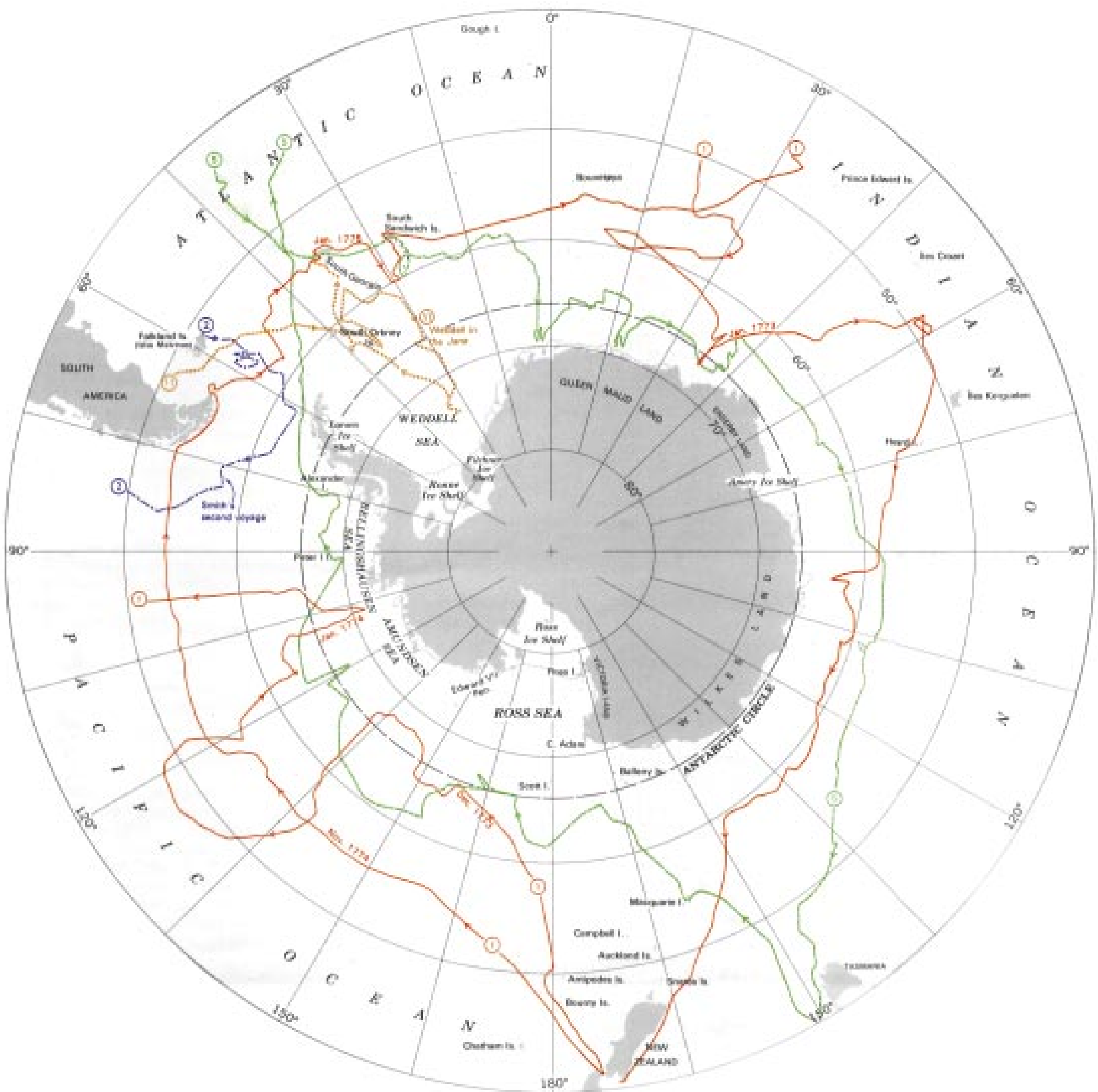


Exhibit 9

Cook's voyage. Between 1772 and 1820 explorers neared but did not discover the Antarctic continent. Of greatest significance were the three expeditions of Captain James Cook, Great Britain, who in 1772-1775 established that a continent must exist south of his southern-most penetrations. "That there may be a Continent or large tract of land near the Pole, I will not deny," he wrote on 5 February 1775. "On the contrary I am of the opinion there is, and it is probable that we have seen a part of it. The excessive cold, the many islands and vast floats of ice all tend to prove that there must be land to the South." Shown are the cruise tracks of (1) Cook; (2) Captain William Smith, Great Britain, 1819; (5) Captain Thaddeus Bellingshausen, Russia, 1820; and (11) Captains James Weddell and Matthew Brisbane, Great Britain, 1823. Source: Antarctic Map Folio Series, 1975.

Exhibit 10

Attainment of the South Pole. Roald Amundsen's and Robert Scott's teams' arrivals at the South Pole in December 1911 and January 1912 concluded humankind's quest for the highest southern latitude, which had begun centuries earlier with the voyages of Drake, Cook, and others. Personal and national prestige motivated both Amundsen — whose tent and flag stand here — and Scott, whose party this is. "Thus we plant thee, beloved flag, at the South Pole," Amundsen said, "and give to the plain on which it lies the name of King Haakon VII's Plateau." Scott and his party, arriving second, were bitterly disappointed to miss "the reward of priority." They died on the return trek to the coast, having carried 31 pounds of geological specimens to the very end. The photograph shows, left to right, Evans, Wilson, Oates and Scott.

After the War the U. S. Navy Antarctic Developments Project (Operation Highjump) in 1946-1947 was then (and remains) by far the largest Antarctic expedition, with more than 4,700 naval and marine personnel, 44 observers, 13 ships, and a number of aircraft. The expedition sighted more than 1.5-million square miles of Antarctica, half of it previously unexplored, and took 15,000 aerial trimetrogon (mapping) photographs. The following season the U. S. Navy Second Antarctic Developments Project (Operation Windmill) used ship-based helicopters to get geodetic ground control for the Highjump photographs. The expedition contributed to production of the first medium-scale maps of the region and influenced decisions regarding locations of stations for the International Geophysical Year the following decade. At a time when other nations had embarked on programs of permanent bases, the U. S. Navy Second Antarctic Developments Project also was a vehicle for continuing the U. S. presence in Antarctica.

4.1.2 Sealing, Whaling, and Fishing British sealers first crossed the Antarctic Convergence in 1778, and Americans in about 1792. Profits were enormous. Around 1797 the *Neptune* of New Haven, a ship worth perhaps $3,000, gathered 45,000 skins at the Falklands and Juan Fernandez, sold them for $90,000 in Canton, bought Chinese goods there and sold them for $260,000 in New York. As subantarctic seals were decimated the sealers pushed farther south. In 1820-1821, at least 30 American, 24 British, and 1 Australian vessels were hunting seals in the South Shetlands. The next year the numbers were perhaps doubled. Landings were said to have been made on the Antarctic Peninsula, the South Orkney Islands were discovered, and at least one and maybe three Americans traveled as far south as 66°S on the west side of the Antarctic Peninsula. James Weddell (British) discovered the Weddell Sea. Fur seals and then elephant seals (for their oil) were reduced almost to extinction by the mid-1800s, at which point the sealers for all practical purposes abandoned this activity. In 1978 the Antarctic Treaty nations agreed to prohibit the taking of fur, elephant and Ross seals, and to limit the annual catch of various other species. No seal hunting has taken place in the Antarctic since 1964 and the populations of fur and elephant seals have significantly regenerated themselves in the last half of the 20th century.

Whaling began in Antarctic waters in the 19th century. The industry enlarged greatly in the early 1900s, when steamships, harpoon guns, and shore processing stations (notably at South Georgia) were introduced. During the 1912-1913 season 10,760 whales were caught. After that time nearly all the whales caught in the world were taken in Antarctic waters. In 1931, the peak year, 40,199 whales were caught in the Antarctic, while 1,124 were caught in the rest of the world. The whaling industry declined after 1960. In the 1980-1981 season fewer than 6,000 whales were caught in the Antarctic; all were Minke whales, a relatively small-sized species. In 1994 the member nations of the International Whaling Commission declared Antarctic waters a whale sanctuary in which no commercial whaling is allowed (Exhibit 11).

Commercial fishing was begun by the Soviet Union in 1967, and in 1971 a Soviet fleet of 40 trawlers and support ships in the southern ocean landed an estimated 300,000 tons — mostly cod, herring, and whiting. In 1995-1996 ten nations landed 115,188 tons, of which 91 percent was krill and the rest finfish. Japan was the principal participant with more than half the catch; the other substantial fishers were Poland and Ukraine. This catch continued modest annual increases since 1993, but well below those taken during the years up through 1990-1991, when the Soviet Union disbanded its long-distance fleet.

Two American firms have engaged in crabbing in recent years, but the unfavorable economics of this activity have resulted in both companies abandoning their efforts.

The Antarctic fishery, a tiny fraction of the world's total annual catch of about 80 million tons, is regulated

Exhibit 11

The biggest environmental impact? In whaling's record year, 1931, that deliberate human action in the Antarctic managed to remove about two million tons of living whale biomass from the marine ecosystem. It is an ironic measure of humans' global reach that this amount is estimated to have been exceeded threefold by that resulting from the existence of the ozone hole, which was caused unintentionally by natural atmospheric transport of industrial chemicals to the Antarctic stratosphere. Because of the ozone hole, enough additional ultraviolet radiation from the Sun reaches the ocean surface to reduce the productivity of marine microorganisms in Antarctic waters by an amount estimated by experimental work to be seven million tons of carbon fixation annually. Here, an instrument that monitors the amount of ultraviolet radiation reaching the surface is operated at Palmer Station.

by the Antarctic Treaty's 1982 Convention for the Conservation of Antarctic Marine Living Resources.

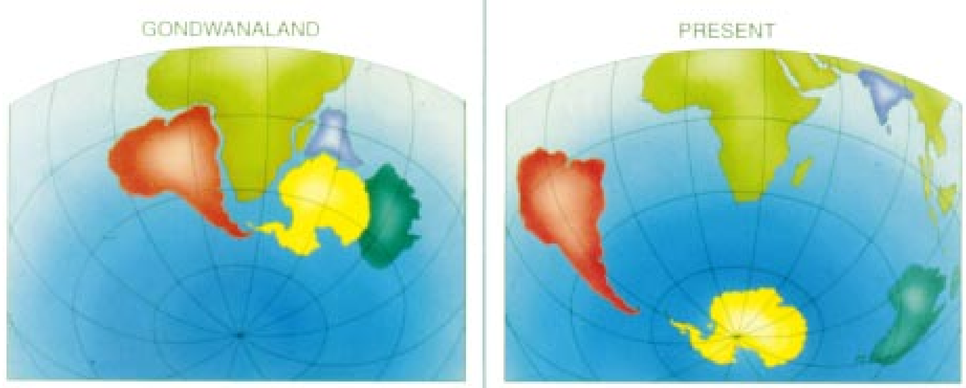
4.1.3 Mineral Resources The issue of exploitation of mineral resources in Antarctica is addressed in Article 7 of the Protocol on Environmental Protection to the Antarctic Treaty: "Any activity relating to mineral resources, other than scientific research, shall be prohibited." U. S. Public Law 104-227, the "Antarctic Science, Tourism, and Conservation Act of 1996," implements the provisions of the Protocol. President Clinton signed it into law on October 2, 1996. The Protocol will enter into force when all nations that signed it in 1991 deposit their instruments of ratification. There is no assurance that some nations will not challenge the agreement in the event of a major discovery of mineral reserves in Antarctica.

Based on current knowledge of the continent's geological setting, the chance that valuable mineral deposits exist in Antarctica appears reasonably high. Prior to approximately 200 million years ago, Antarctica was the centerpiece of a large Southern Hemisphere supercontinent, Gondwana, that included what is today South America, Africa, Madagascar, peninsular India, Antarctica, Australia, and New Zealand (Exhibit 12). The wide distribution of mineral resources across these other Gondwanan continents, including base metals and precious stones, implies that similar deposits probably exist in Antarctica. But with rare exception, the areas that are most likely to contain mineral deposits are covered by the ice sheet. The occurrence of major hydrocarbon deposits in Antarctica is uncertain because deep drilling has not been conducted on the continental shelf; however, the geological evolution of the Antarctic continental margin has resulted in the development of large sedimentary basins with known source rocks for hydrocarbons and likely reservoirs to store these hydrocarbons. Given the prevailing conditions, it is improbable that *chance* discoveries of mineral deposits will be made in Antarctica. Rather, exploration for mineral deposits would require a dedicated, costly program, including in many cases the development of new technologies.

In his book *Cold: The Record of an Antarctic Sledge Journey*, Dr. Laurence M. Gould states that he "had rather go back to Antarctica and find a fossil marsupial than three gold mines." It is unrealistic to think that this philosophy will always prevail, especially if the global demand for mineral resources continues to escalate. Scientific research will undoubtedly lead to better assessment of Antarctica's resources and to better technology for exploiting these resources. To date, the U. S. has played a key oversight role in evaluating geological and geophysical research in Antarctica and in encouraging the exchange of geophysi-

Exhibit 12

The pivotal position of Antarctica in the ancient supercontinent Gondwanaland can be seen in these illustrations. The supercontinent began to rift and break up 180 million years ago.



cal and geological data, all while precluding the commercial exploitation of Antarctica.

4.1.4 Territorial Claims Seven nations have asserted claims to pie-shaped sectors of Antarctica bounded by longitudinal lines: Great Britain (claim made formally in 1926), New Zealand (1923), Australia (1936), Norway (1939), Chile (1940), Argentina (no formal date), and France (1924). The initial claims were based on discovery, adjacency, or decree, and all but one of the claims extend from north of the coast to the South Pole. Three claims overlap. One sector is unclaimed. The claims occasionally have led to conflict; on 2 February 1952 the Argentine navy fired on the British when they tried to land at Hope Bay. Conflicts over other remote areas have not been unknown, including the U.K./Argentina war over the Falklands as recently as 1982. Other nations have acted to make claims, but not asserted them; for example, Germany sent an expedition for this purpose in 1938, and in 1939 Lincoln Ellsworth, heading his second Antarctic expedition (the first was a transantarctic flight in 1935), dropped from his plane a brass cylinder containing a note claiming territories for the U. S. "so far as this act allows."

Other than the claimant states, most nations do not recognize Antarctic claims. U. S. non-recognition, a cornerstone of the nation's Antarctic policy, dates to 1924, when Secretary of State Charles Evans Hughes wrote that discovery of lands unknown to civilization "does not support a valid claim of sovereignty unless the discovery is followed by an actual settlement of the discovered country." In 1934 the Assistant Secretary of State added: "I reserve all rights which the U. S. or its citizens may have with respect to this matter." President Franklin D. Roosevelt reaffirmed the U. S. stance in 1939: "The U. S. has never recognized any claims of sovereignty over territory in the Antarctic regions asserted by any foreign state." In 1947 Dean Acheson, then Under Secretary of State, wrote that the U. S. "has not recognized any claims of any other nations in the area and has reserved all rights which it may have in the area."

Despite the Antarctic Treaty provision that "no acts or activities taking place while the present Treaty is in force shall constitute a basis for asserting, supporting, or denying a claim to territorial sovereignty in Antarctica," some signatories have taken what appear to be assertive steps. For example, both Argentina and Chile publish their claimed Antarctic sectors on their official national maps, and both have established hotels and post offices. Chile has placed whole families in residence at its Antarctic stations, with schools, banks, and other evidence of "effective occupation," including the birth of a child. An Argentinian child was born at Argentina's Esperanza Station in the late 1970s.

4.1.5 International Geophysical Year The IGY, 1 July 1957 to 31 December 1958, was a cooperative endeavor by scientists throughout the world to improve their understanding of the Earth and its environment. Much of the field activity took place in Antarctica, where 12 nations established some 60 research stations. Laurence M. Gould, who was Richard E. Byrd's chief scientist in Antarctica in the 1920s and 1930s and later chaired the National Academy of Sciences Polar Research Board and served on the National Science Board, called the IGY the most comprehensive scientific program ever undertaken and the first attempt at a total study of the environment. "No field of geophysics," he wrote in 1958, "can be understood or complete without specific data available only from this vast continent and its surrounding oceans."

The U. S. established six Antarctic IGY research stations: Little America (on the Ross Ice Shelf), Hallett (in Victoria Land), South Pole and Byrd (in Marie Byrd Land), plus Wilkes (on the coast of Wilkes Land, East Antarctica) and Ellsworth (on the Filchner Ice Shelf). Naval Air Facility, McMurdo Sound (now McMurdo Station), was set up as a logistics base from which to supply South Pole. Studies were directed toward geophysics and upper atmospheric physics and complemented simultaneous observations around the globe. Long traverses were made to collect data in glaciology, seismology, gravimetry, and meteorology. Geological and biological samples were also collected, although these disciplines were not formally part of the IGY (Exhibit 13).

4.1.6 Antarctic Treaty International cooperation in the IGY stimulated the Antarctic Treaty, signed by the 12 Antarctic IGY nations at Washington, D.C., in 1959 and entered into force in 1961. The treaty establishes a legal framework for the area south of 60°S, which includes all of Antarctica. There are two types of Antarctic Treaty parties. Consultative nations, now 26 in number (Exhibit 14), are empowered to meet periodically and to influence operation of the treaty. Acceding nations, of which there now are 17, agree to abide by the treaty, but, not being among the original signatories and not having substantial programs in Antarctica, do not participate in the consultative process.

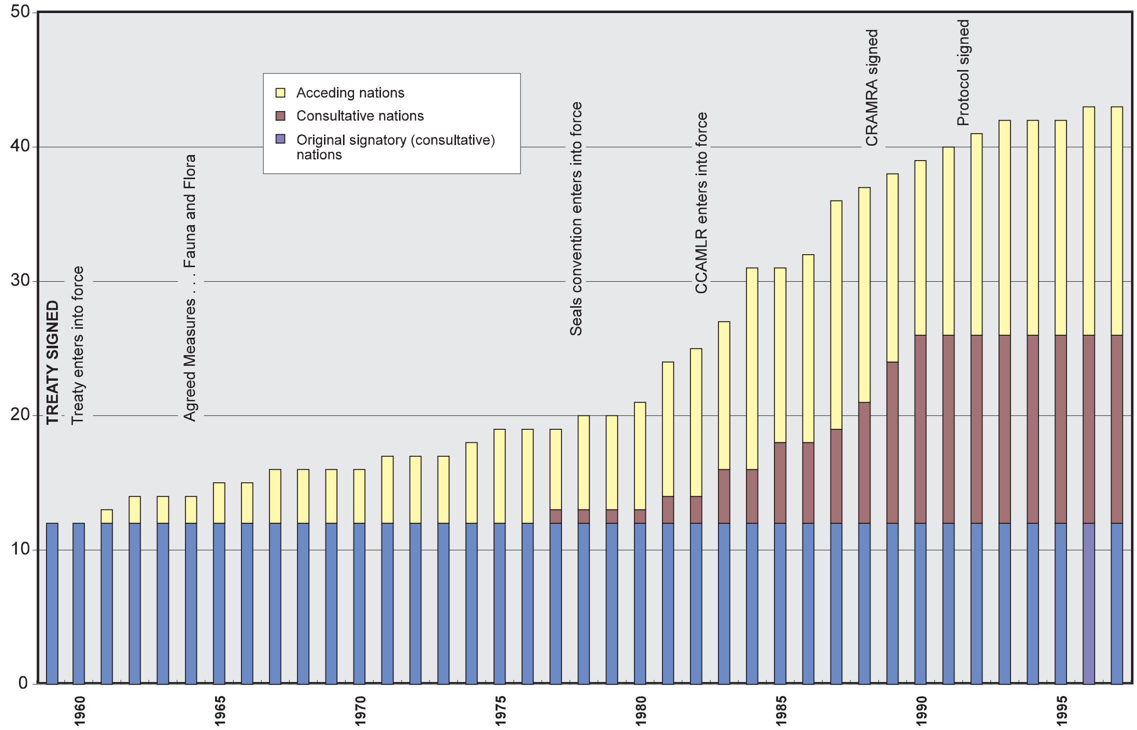
The treaty provides that Antarctica shall be used for peaceful purposes only; it prohibits military operations except in support of peaceful activities. It provides that freedom of scientific investigation and cooperation shall continue and that nations shall exchange program plans, personnel, observations, and results. The treaty seeks to resolve the issue of territorial claims by simply not recognizing, disputing, or

Exhibit 13

Year-round stations serve as research and data collection centers and as support depots for temporary summer camps, traverses, and airborne data collection. In 1995, a typical recent year, 17 nations operated 37 year-round stations. During the intensive 18-month International Geophysical Year (1957-1958), 12 nations operated about 60 year-round stations in Antarctica. Most stations receive their personnel and supplies by ship. Only Marambio (Argentina), Frei (Chile), Rothera (U. K.), McMurdo (U. S.), and Mirnyy (Russia) can land wheeled airplanes. Most Antarctic stations have been established on the coast. Only Russia and the United States have operated year-round stations in the interior over the long term. Russia has closed all but three stations since the breakup of the former Soviet Union.

establishing claims; and it prohibits assertion of new claims. It prohibits nuclear explosions and disposal of radioactive waste. It guarantees access by any treaty nation to inspect others' stations and equipment. Appendix VI further summarizes the treaty.

The consultative meetings provided for by the treaty have generated a series of recommendations, most of which have been formally adopted by the treaty nations, that provide rules for operating on and around the continent. One of the most significant is the Agreed Measures for the Conservation of Antarctic Fauna and Flora, ratified by the U. S. as Public Law 95-541, the Antarctic Conservation Act of 1978. Other advances have included the Convention for the Conservation of Antarctic Seals and the Convention on the Conservation of Antarctic Marine Living Resources. A failed recommendation of significance is the 1988 Convention on the Regulation of Antarctic Mineral Resource Activities, which would have permitted mining if the proponent were to demonstrate that the environment would not be damaged. Instead, a 1991 Antarctic Treaty meeting adopted a protocol for improved environmental protection that prohibits mining; the U. S. signed this protocol into law (PL104-227) in October 1996 and is preparing to deposit its instrument of ratification with the Antarctic Treaty system. The U. S. and other Antarctic Treaty nations are complying with the protocol on a volun-



SOURCE: NATIONAL SCIENCE FOUNDATION

Exhibit 14

Number of Antarctic Treaty nations, 1959-1997. Of the 43 nations that have signed the Antarctic Treaty, 26 are consultative (voting) nations because either they are original 1959 signatories or they perform substantial scientific research in the Antarctic. The 17 acceding nations participate in the annual Antarctic Treaty consultative meetings as observers. The treaty nations represent two-thirds of the world's human population and four-fifths of its economic output.

The 12 nations that performed Antarctic field research during the 1957-1958 International Geophysical Year signed the treaty at Washington, D. C., in December 1959. The treaty entered into force in June 1961 after these nations had deposited their instruments of ratification with the U. S. Department of State.

The 1964 Agreed Measures for the Conservation of Antarctic Fauna and Flora was particularly significant; it is only one of approximately 160 recommendations affecting management of Antarctica that have been adopted over the period covered by this graph. Another significant addition was CCAMLR, the Convention on the Conservation of Antarctic Marine Living Resources, which regulates the Antarctic fishery. CRAMRA, the Convention on the Regulation of Antarctic Mineral Resource Activities, did not achieve ratification; it was replaced by the Protocol on Environmental Protection, signed in 1991, which prohibits mining and strengthens environmental protection generally. As of early 1997, the Protocol appeared likely to achieve ratification by all 26 signing nations, after which it will enter into force.

tary basis pending its entry into force, which will occur only after all 26 of the nations initially signing the 1991 agreement ratify it.

4.1.7 National Programs Twenty-eight nations are now conducting Antarctic research programs. The activities range from summer-only seaborne expeditions that focus on particular science questions to year-round operations that span the research disciplines relevant to the Antarctic. In 1995 there were 37 year-round stations in operation: Argentina 6, Australia 3, Brazil 1, Chile 3, China 2, France 1, Germany 1, India 1, Japan 2, South Korea 1, New Zealand 1, Poland 1, Russia 5, South Africa 1, United Kingdom 4, United States 3, and Uruguay 1. Many of these nations, and other nations, operated additional summer stations and camps for research field work that is feasible only in summer.

4.2 Current U. S. Antarctic Program

Each year the USAP deploys approximately 3,500 scientists and support personnel to Antarctica and its surrounding seas to support basic research in many disciplines, including aeronomy and astrophysics, atmospheric chemistry, biology, Earth sciences, ocean and climate systems, glaciology, and environmental science. Although a far smaller effort, Antarctica also offers a promising environment for the conduct of certain types of applied research and technology development. In FY95 and FY96, U. S. researchers came from institutions in 26 states and the District of Columbia.

The budget for the (NSF) U. S. Antarctic Program is $193.5M in FY97. Of this amount $30.5M consists of grants to scientists at research institutions, $41.0M is spent on direct field support of these research projects, and the balance of $122.0M is spent on logistics and operations that provide the infrastructure enabling the U.S. presence and science. These figures reflect the high costs of working in so remote a location. Additionally, in FY97, a separate NSF account is funding a $25M emergency safety and environmental upgrade at South Pole Station.

The history of spending for the USAP is shown in Exhibit 15. Exhibit 16 presents research and operations costs assignable to each U. S. location in Antarctica. Exhibit 17 categorizes the research funding according to function.

The NSF funds and manages the following major facilities as an integrated system for the support of research and related activities in Antarctica:

4.2.1 McMurdo Station, the principal U. S. facility, on Ross Island, coast of Antarctica (peak summer population capacity 1,258; 1996 winter, 232)

The largest Antarctic station, McMurdo (Exhibit 18) is built on the bare volcanic rock of Hut Point Peninsula on Ross Island, the most southerly solid ground that is accessible by ship. It is located just 20 miles south of Mt. Erebus, an active volcano that steams continually and erupts frequently though not violently.

The station, established in December 1955, is the logistics hub of the USAP, with a harbor, landing strips on sea ice and shelf ice, and a helicopter pad. Its 85 or so buildings range in size from a small radio shack to large, three-story structures. Repair facilities, dormitories, administrative buildings, a firehouse, power plant, water distillation plant, wharf, stores, and warehouses are linked by above-ground water, sewer, telephone and power lines. The water and sewer lines are heat-taped and insulated.

The Albert P. Crary Science and Engineering Center at McMurdo was dedicated in November 1991. The laboratory is named in honor of geophysicist and glaciologist Albert P. Crary (1911-1987), the first person to set foot on both the North and South Poles. The laboratory contains state-of-the-art instrumentation to facilitate research and to advance science and technology. It contains personal computers and workstations and a local area network. It has laboratory space, analytical instrumentation and staging areas for a range of scientific disciplines. The laboratory also supports studies of snow and ice mechanics, meteorology and special activities, including environmental monitoring and enforcement. The lab has five pods built in three phases to provide 46,000 square ft. of working area. Phase I has a two-story core pod and a biology pod. Phase II has Earth sciences and atmospheric sciences pods. Phase III has an aquarium. Other facilities are maintained for atmospheric sciences and other disciplines.

Williams Field, a skiway ten miles from McMurdo on the Ross Ice Shelf, is the aerodrome for ski-equipped airplanes. Wheeled airplanes use a harder, smoother runway on sea ice in October,

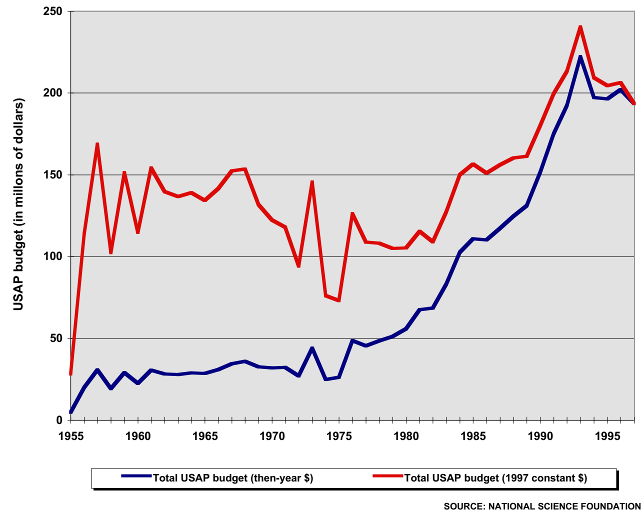


Exhibit 15

U.S. Antarctic Program funding, 1955-1997. In 1955 the U. S. began preparing for the International Geophysical Year, which took place officially from 1 July 1957 to 31 December 1958. After the IGY, the decision was made to support a continuing, or post-IGY, research program; some facilities were closed, and others were added. Budget volatility in the years 1957-1962 reflects this transition.

Fluctuations in the period 1973-1977 are caused by LC-130 procurement and budget-base transfer of costs from DOD, a continuing multi-year result of DOD's action to quantify and transfer Antarctic costs pursuant to the 1970 decision to consolidate funding for the U. S. Antarctic Program at the National Science Foundation. Part of the rise in the 1980s is attributable to completion of this process; for example, the NSF began paying the Antarctic-attributable share of military retirement costs in 1985.

The years 1990-1994 contain a five-year $85M safety, environment and health initiative. The 1993 spike contains $49M for LC-130 procurement.

This graph includes DOD, USCG, and NSF Antarctic spending for all the years shown. The graph does not include research spending by other agencies; in FY96, other agency research accounted for about three percent of the U. S. Government's total funding of Antarctic research and research support. Years shown are fiscal years.

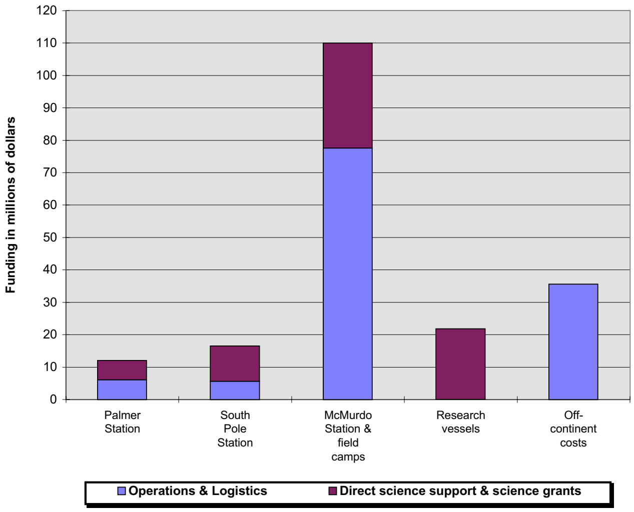


Exhibit 16

USAP FY95 funding (totaling $196M) by facility. Most of this money is spent in the U.S. for acquisitions, salaries, equipment, planning, and follow-up research at home institutions. All science-grants funds are assigned to Antarctic locations even if the research was done entirely at home institutions. The $35.5M in "off-continent costs" is for contractor and military headquarters operations in the United States and for staging facilities in Christchurch, New Zealand, and Punta Arenas, Chile.

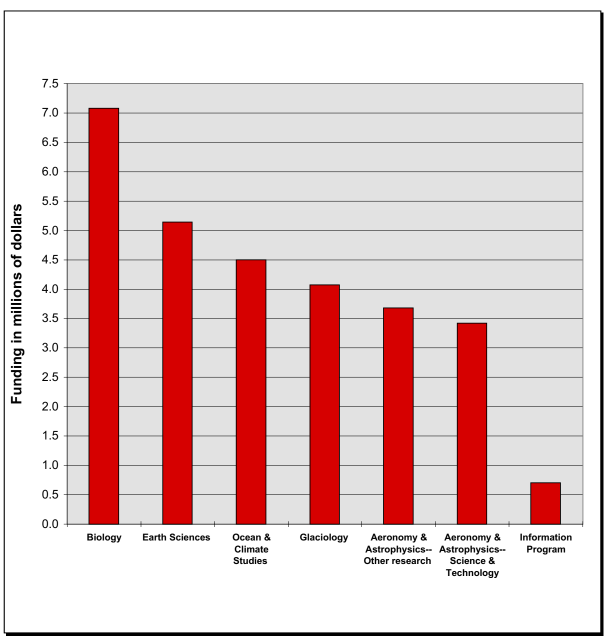


Exhibit 17

USAP FY 95 science grants to research institutions (totaling $29M) by discipline. These amounts do not include operational support in the Antarctic.

Exhibit 18

McMurdo Station. McMurdo, Antarctica's largest station, has airports and a seaport, research laboratories and support facilities. The light-colored building at the center of this photo is the Albert P. Crary Science & Engineering Center. A Coast Guard icebreaker in Winter Quarters Bay is tied to the pier, which is built of ice.. The small hut on Hut Point in the background was built by Robert F. Scott in 1902 and is protected as a historic site under the Antarctic Treaty.

November and into December, at which time the sea ice usually softens and becomes unusable. A permanent, hard-ice runway for wheeled planes, the Pegasus site on the Ross Ice Shelf, completed in 1992, can be used in all but the warmest (and, unfortunately, busiest) months (mid December to late January). Although the surface is available during the winter months, there is currently no lighting or other airfield support planned to enable winter operations.

Low and high recorded temperature extremes at McMurdo are -58°F and 46°F, respectively. Annual mean is 0°F; monthly mean temperatures range from 27°F in January to -18°F in August. Drifting snow can accumulate about four ft. per year, although the station becomes snow-free in summer. Average wind is about 11 miles per hour with a gust of 116 miles per hour having been recorded in July 1968.

Research is performed at and near McMurdo in marine and terrestrial biology, biomedicine, geology and geophysics, glaciology and glacial geology, meteorology, aeronomy, and upper atmosphere physics. Air transportation to New Zealand is frequent between October and February— the Antarctic summer. The winter population is isolated from late February to late August (Exhibit 19).

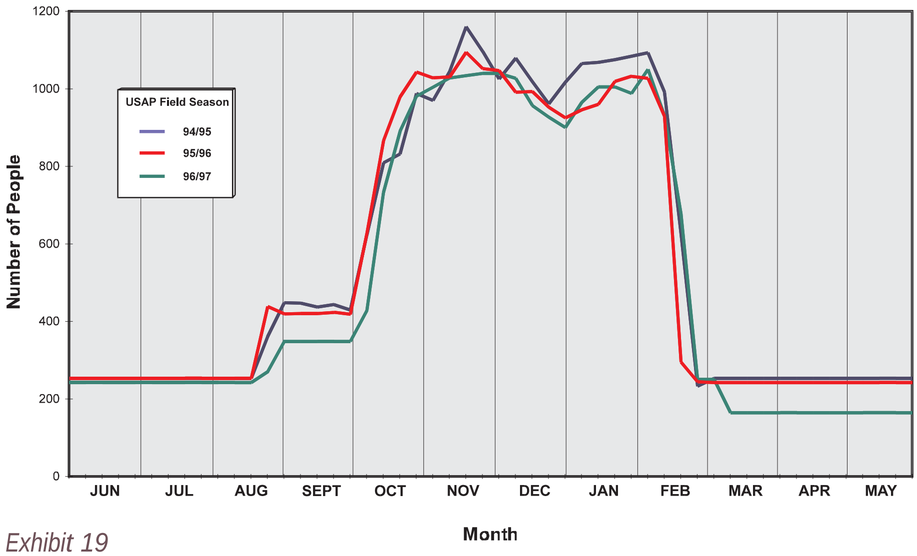


Exhibit 19

McMurdo Station annual population cycle. In August, several flights from New Zealand ("Winfly") raise McMurdo's population from its winter minimum with early science projects and an augmentation of the support staff to prepare for summer. In October the population rises quickly, and for the duration of the summer operating season people arrive and depart several times a week. In late December the "Christmas notch" coincides with the annual loss of nearby sea ice as a working platform and reflects the replacement of scientists (particularly biologists) who require it with those (such as geologists) who do not; the transition from the Fall to the Spring semesters at U.S. academic institutions also affects this population shift. In late February, when reduced daylight and plummeting temperatures make field research impractical, the population drops to the winter minimum.

The 96/97 curve (green line) shows a lower population in the 1996 Winfly period (August-September) and in the 1997 winter from March onward. This cost-saving measure has resulted from consolidation of functions. The 96/97 season also shows a USAP first — a "reverse Winfly" in late February and early March. Instead of redeploying personnel in small numbers in several LC-130 trips, the USAP used an Air Force (wheeled) C-141 to redeploy a large number of personnel on one day, increasing the efficiency of McMurdo's late-summer tasks. The C-141 used McMurdo's recently developed Pegasus glacier runway.

In these curves, populations are plotted at weekly intervals for the three years June 1994 through May 1997.

4.2.2 Amundsen-Scott Station at the geographic South Pole (peak summer population capacity 173; 1996 winter, 27)

Americans have occupied the geographic South Pole continuously since November 1956. The central facility of the South Pole Station (Exhibit 20) was rebuilt in 1974 as a geodesic dome 160 ft. wide and 50 ft. high that covers modular buildings for living and science. Adjacent to the dome are steel archways, 22-ft. high, 44 ft. across, and 830 ft. long, that house the station's main fuel supply, the power house, a medical facility, and other functions. Detached buildings house instruments for monitoring the upper and lower atmosphere and for numerous complex projects in astronomy and astrophysics. Science and berthing structures were added in the 1990s, the former mostly for astronomy, and there is a summer camp which also serves as an emergency camp during winter in case the principal facilities should be lost. The station's winter personnel are isolated between mid-February and late October.

Recorded temperature has varied between 7°F and -117°F. Annual mean is -56°F; monthly means vary from -18°F in December to -76°F in July. During the warmest month of the year, temperatures of -38°F have been recorded, making construction difficult. Average wind is 12 miles per hour; peak gust recorded was 54 miles per hour. Snowfall is about four inches of ice equivalent per year, although drifting can and does add more around buildings. The station stands at an elevation of 9,300 ft. on interior Antarctica's nearly featureless ice sheet, about 9,350 ft. thick at that location.

Research at the station includes glaciology, geophysics, meteorology, upper atmosphere physics, astronomy, astrophysics, and biomedical studies.

The station's name honors Roald Amundsen and Robert F. Scott, who reached the South Pole the austral summer of 1911-1912.

Exhibit 20

Amundsen-Scott Station Shown is the main entrance to Amundsen-Scott South Pole Station. (The sign has been discolored by diesel-powered tractors delivering supplies.)

4.2.3 Palmer Station, on Anvers Island immediately west of the Antarctic Peninsula (peak summer population capacity 43; 1996 winter, about 20)

Exhibit 21

Palmer Station, at 64°S, is north of the Antarctic Circle. It is supplied entirely by ship.

Palmer Station (Exhibit 21), on a protected harbor on the southwestern coast of Anvers Island, off the Antarctica Peninsula, is the only U. S. Antarctic station north of the Antarctic Circle. The temperature is mild, with monthly averages ranging from +18°F in July and August to +36°F in January and February. The annual mean is 27°F. The extreme range is -24°F to 48°F. It has rained every month at Palmer Station, and in the year ended October 1981 Palmer received 10 inches of rain and over 100 inches of snowfall.

The station, built on solid rock, consists of two major buildings and three small ones plus two large fuel tanks, a helicopter pad, and a dock. Construction was completed in 1968, replacing a prefabricated wood structure ("Old Palmer," established in 1965) a mile away across Arthur Harbor. Old Palmer has been disassembled and removed from Antarctica. Palmer does not have a period of winter isolation as do McMurdo and South Pole; an ice-strengthened ship can transit to and from Palmer any month of the year, generally crossing the Drake Passage from South America.

Palmer Station is superbly located for biological studies of birds, seals, and other components of the marine ecosystem. It has a large and extensively equipped laboratory and sea water aquaria. In 1990 it was designated by the NSF as a long-term ecological research site. Meteorology, upper atmosphere physics, glaciology, and geology also have been pursued at and around Palmer. The station operates in conjunction with an ice-strengthened research ship described below.

Palmer Station is named for Nathaniel Brown Palmer, a Connecticut sealer who commanded the 46-ft. sloop *Hero*, which on 16 and 17 November 1820 entered Orleans Strait and came very close to the Antarctic Peninsula at about 63°45'S. At the time, Palmer was 21-years old. Later in his life, he won wealth and fame as a pioneer clipper ship master and designer.

4.2.4 The 219-ft. ice-strengthened research ship Polar Duke (year-round)

Exhibit 22

The research ship Polar Duke *has been under charter to the U. S. Antarctic Program since 1984. It is performing a scientific mission here on the west side of the Antarctic Peninsula.*

Polar Duke (Exhibit 22), built in 1983, is an ice-strengthened research ship under charter to the Foundation since January 1985. It operates in the Antarctic Peninsula area and calls at Punta Arenas, Chile, and, occasionally other South American ports, throughout the year. The ship resupplies Palmer Station, and it performs research and research support in collaboration with the station. It has a crew of 14 and can accommodate 23 scientific personnel. *Polar Duke* cruises at 12 knots, has an endurance of 90 days, and is well equipped with laboratories, winches, a piston corer, single channel seismic gear, and other equipment for biology, geology, and geophysics.

R/V Laurence M. Gould, a purpose-built ship under construction by Edison Chouest Offshore Inc., will replace *Polar Duke* in 1997. The NSF's contractor, Antarctic Support Associates, is procuring *Gould* as a one-for-one replacement charter vessel; *Gould* is slightly larger and more capable than *Duke*.

4.2.5 The *R/V Nathaniel B. Palmer*, a 309-foot research vessel with icebreaking capability (year-round)

Exhibit 23

The research icebreaker Nathaniel B. Palmer *has an A-frame for stern trawling and facilities on the starboard side for oceanographic sampling.*

Edison Chouest Offshore Inc., Galliano, Louisiana, in 1992 built and delivered this research vessel (Exhibit 23) with icebreaking capability for use by the USAP. The ship is a highly capable platform for global change studies, including biological, oceanographic, geological, and geophysical components. It can operate safely year-round in Antarctic waters that often are stormy or covered with sea ice. It accommodates 37 scientists, has a crew of 22, and is capable of 75-day missions.

4.2.6 A U. S. Coast Guard Polar-class icebreaker (399 ft.) for icebreaking, channel tending, and supply-ship escort in McMurdo Sound and for additional support and science functions (austral summer)

Exhibit 24

USCGC Polar Sea *breaking the annual resupply channel to McMurdo Station. Photograph © 1989 Neelon Crawford.*

A Polar-class (Exhibit 24), America's most powerful icebreaker, operates annually in the Antarctic. Either the *Polar Star* or the *Polar Sea*, operated by the U. S. Coast Guard, breaks a channel through McMurdo Sound and performs other logistics tasks.

Polar-class icebreakers displace 14,700 tons. Their diesel engines provide 18,000 hp for normal operations. When required for icebreaking, gas turbines can be operated to increase the power to nearly 60,000 hp. In open water these ships cruise at 13 knots, maximum speed of 17 knots. Each ship carries two helicopters. Crew size is 154; the ship can accommodate 20 scientists.

4.2.7 Military Sealift Command ice-strengthened cargo and tank ships (one each, once per year) for cargo and fuel delivery to and waste removal from McMurdo Station.

Exhibit 25

Green Wave. *This cargo ship re-supplies McMurdo once per year at mid-summer and removes the year's accumulated collection of waste. It is not an icebreaker and requires icebreaker escort to assure entry to McMurdo's port, even in a light ice year. The pier is constructed of ice, built up in layers and reinforced with steel cable. Locally obtained aggregate paves the surface during the offload period.*

Each year an ice-strengthened tanker delivers approximately six million gallons of fuel to McMurdo Station. It is operated under contract to the Military Sealift Command.

A yearly visit by *USNS Green Wave* (Exhibit 25) or a similar ice-strengthened container ship delivers most of the cargo used at McMurdo and inland stations, and takes USAP waste to the U. S. for recycling or disposal. The ship is operated under contract to the Military Sealift Command.

4.2.8 LC-130 ski-equipped aircraft operated by the Navy and the Air National Guard (August and October-March)

Exhibit 26

LC-130 Hercules is equipped for both ski and wheel takeoffs and landings.

The LC-130 four-engine turboprop transport aircraft (Exhibit 26) is the backbone of U. S. transportation within Antarctica and also provides air service between McMurdo Station and New Zealand. The LC-130 is the polar version of the familiar C-130 cargo plane; its major unique feature is the ski-equipped landing gear which enables operation on snow or ice surfaces throughout Antarctica. The plane, introduced to the Antarctic program in 1960, also has wheels for landing on prepared hard surfaces. As discussed elsewhere in this report, the NSF's fleet of seven aircraft has been operated by the U. S. Navy. One NSF LC-130 is operated by the Air National Guard in Antarctica. Two additional LC-130s, owned and operated by the Air National Guard, also are used in the U.S. Antarctic Program. These two groups, the Navy and Air National Guard, are the only LC-130 operators in the world, and the Air National Guard is in the process of assuming operational control of all LC-130s.

The aircraft has a cargo box of 40x10x10 ft. It can, as an example, carry 27,000 pounds of personnel and/or cargo from McMurdo to South Pole (728 nautical miles), then return to McMurdo without refueling (aircraft engines are never shut down at the Pole). It cruises at 275 knots.

4.2.9 Contract operation of smaller (e.g., Twin Otter) research and support airplanes (austral summer)

When required, deHavilland Twin Otter turboprop airplanes (Exhibit 27) have been chartered for operations in Antarctica. These aircraft have proved so useful that they are now employed each summer season. Skis

Exhibit 27

Ski-equipped Twin Otter under seasonal charter to the U. S. Antarctic Program.

are fitted and the planes can land on open snow and ice. The payload and range of a Twin Otter are substantially less than those of the LC-130 but greater than those of helicopters used in the program.

4.2.10 Contract helicopter operations (austral summer)

Exhibit 28

A PHI contract helicopter being unloaded from a USAF C-5 on the sea-ice runway at McMurdo, October 1996.

Petroleum Helicopters Inc. (PHI) of Lafayette, Louisiana, in 1996 won a competitively bid contract from the NSF to provide McMurdo-based helicopter operations (Exhibit 28) as a part of the planned withdrawal of the U.S. Navy from Antarctica. The first austral summer season of operation was 1996-1997. This transition has had a favorable impact on cost and operations.

The number of personnel dedicated to McMurdo helicopter operations has decreased from 52 to 12. The aircraft complement has decreased from six Navy Hueys to four commercial helicopters: three AS350B2 Squirrels and one Bell 212 civilian Huey. The Squirrels are smaller than the Huey, carrying half the passengers and 60 percent of the maximum cargo load, but have an altitude and airspeed advantage over the medium-lift Huey.

Helicopter operations costs have decreased from $5M to $2.5M annually, with no concomitant decrease in flight hours (1,800 per season). The safety record in recent years has been excellent. The NSF anticipates a 22 percent reduction in flight hours with no decrease in effective support through such innovations as further utilizing a special fueling station established at Marble Point near to the Dry Valleys. Dry Valley science support can then be conducted without nonproductive transits to and from McMurdo's main fueling station.

The learning curve for this new commercial operation was generally as the NSF had anticipated. Subsequent season ramp-ups are expected to be more efficient, with pilot training reduced to a few hours of refresher flying in the first week of operations — assuming higher season-to-season retention and reassignments of pilots and mechanics and level of experience than was the case with military pilots.

PHI will leave its helicopters in Antarctica over the winter for the duration of the contract (five years), whereas the Navy returned some of its helicopters to California at the end of each season. This change will decrease airlift requirements for the helicopters.

The Office of Aircraft Services, Department of the Interior, provided contract acquisition support to the NSF and provides one employee at McMurdo during the operating season to perform technical contract oversight.

4.2.11 Specially equipped aircraft, balloons, and other remote-sensing platforms

Research grantees occasionally require specialized support operations in Antarctica for various types of remote sensing from aircraft, high altitude balloon operations, remotely operated underwater vehicles, etc. The NSF either approves services arranged by the grantees themselves or arranges for support of these operations by its support contractor, Antarctic Support Associates (ASA).

4.2.12 Unattended, automated weather stations and geophysical observatories

Exhibit 29

This automatic geophysical observatory is one of six deployed to various locations throughout Antarctica. The Program's 50 Antarctic weather stations are smaller devices.

The USAP automatic weather station project, conducted by the University of Wisconsin with the support of an NSF grant, places weather units in remote areas of Antarctica in support of meteorological research and operations. The data are collected by the ARGOS Data Collection System on board the National Oceanic and Atmospheric Administration series of polar-orbiting satellites. In 1995 there were 49 units at locations around Antarctica. The development of low-power computer components made possible the development of low-power automated weather units capable of operating in the extreme climate of Antarctica and the distribution of the data globally in near real time.

Automated geophysical observatories (Exhibit 29), with six installed on the Antarctic polar plateau, collect a variety of geophysical data for investigators. The Science Support Division of ASA manages this project in the field.

4.2.13 Field camps placed widely across the continent

Approximately 30 field camps are established each austral summer to support specific projects (Exhibit 30).

4.2.13.1 Major camps During some summer seasons, the U. S. establishes and operates one or more major summer research camps in areas of particular scientific interest. Typically these camps consist of Jamesways (quickly erected structures made of canvas and wood), which support a population of 40 to 60 during the November-January period. Helicopters or Twin Otter airplanes are taken to the site and used to support scientific operations. Motor toboggans also are

Exhibit 30

A typical field camp, using tents and a portable shelter.

employed. Such camps have been operated at a variety of locations: on the Siple Coast, the Shackleton Glacier, at "Beardmore South" in the central Transantarctic Mountains (1985-1986), northern Victoria Land (1981-1982), the Ellsworth Mountains (1979-1980), at Darwin Glacier in the Transantarctic Mountains (1978-1979), and in the mountains of northern Marie Byrd Land (1977-1978). Geology, geophysics, glacial-geology, glaciology, and terrestrial biology have been pursued at these camps, which often have significant international involvement (Exhibit 31).

4.2.13.2 Huts If summer research projects are expected to continue over several seasons at the same location, huts may be erected. Huts can be expected to last for several years, and they provide space, stable working areas, and comfort not achievable with tents or Jamesways. Huts have been used in recent years in Taylor Valley (an ice-free, dry valley in southern Victoria Land) for study of lake ecosystems, at Cape Crozier on Ross Island for population and behavioral studies of penguin rookeries, and near the summit of Mount Erebus for volcanology. Resupply and transport are by helicopter or tracked vehicle from McMurdo Station.

4.2.13.3 Tents Small parties requiring temporary shelter use single- or double-walled tents of several designs, both modern and traditional. These designs include the Scott tent, a pyramid shaped tent similar to the design used by Robert F. Scott early in this century. These tents are stable in high winds and can be erected quickly. Cold-weather sleeping bags are used on ground cushions, and cooking is by portable stoves. Tent camps usually are placed or moved by helicopter or motor toboggan. Extended backpacking trips generally are not practical in Antarctica owing to the weight of the equipment and the fuel required to melt ice for water, to

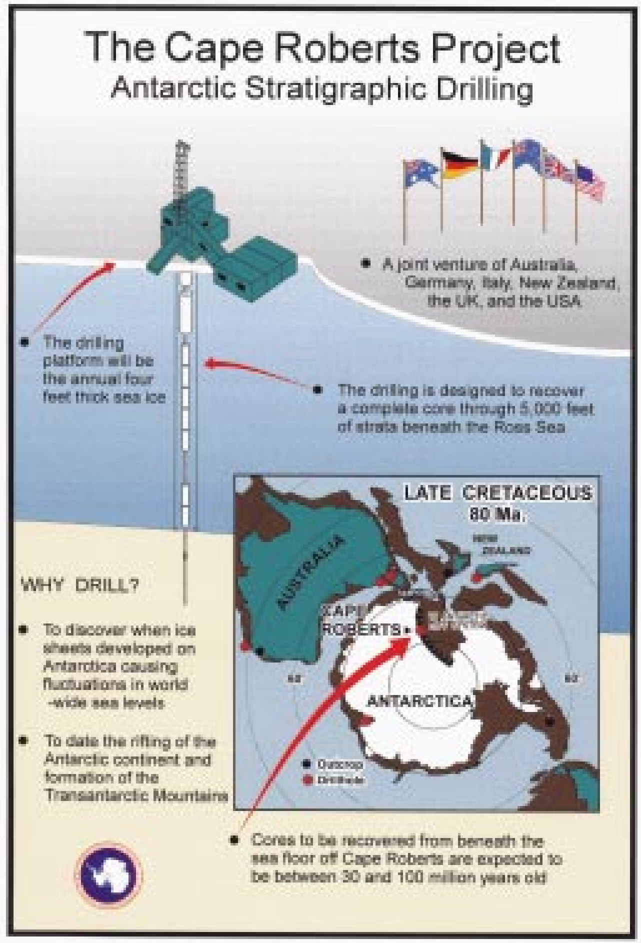


Exhibit 31

International cooperation in Antarctic research can be as simple as a scientist working at another nation's station or as complex a project as the Antarctic Stratigraphic Drilling Project at Cape Roberts. Field work is to begin in the 1997-1998 austral summer. Illustration courtesy of Peter N. Webb, Byrd Polar Research Center, The Ohio State University.

cook, and to combat the cold. All tent camps and huts are required to have radios, and all parties maintain daily contact with the nearest station.

4.2.14 Antarctic Activities of Other Federal Agencies Presidential Memorandum 6646 (1982) states that, "Other agencies (than NSF) may, however, fund and undertake directed short-term programs of scientific activity . . . . Such activities shall be coordinated within the framework of the National Science Foundation logistics support."

The National Aeronautics and Space Administration's (NASA) Antarctic activity includes suborbital studies of cosmic radiation and the Sun, study and archiving of meteorites, microbial studies with extraterrestrial applications, sea ice and ice sheet studies, stratospheric measurements related to ozone, a synthetic-aperture radar ground station, technology development (e.g., a food growth and waste recycling system for South Pole Station), and human factors including isolation and confinement and other analog studies. Using 1995 as an indicator, NASA funding was about $6M, in addition to expenditures for staff. The National Oceanic and Atmospheric Administration (NOAA) funds Antarctic climate monitoring, ozone studies, remote sensing (e.g., sea surface temperature, atmospheric temperature, cloud imagery), sea ice and iceberg analyses, and marine living resources research at about $4M per year. The U.S. Geological Survey (USGS) performs Antarctic mapping, geology, geophysics, glaciology, and long-term ecological monitoring at about $2M per year. The Department of Energy and the Smithsonian Center for Astrophysics fund astrophysics in the Antarctic at $140,000 and $115,000 per year, respectively.

Other agencies dealing with Antarctic matters include the U. S. Coast Guard, the Marine Mammal Commission, the Department of State (international representation, the U. S. role under the Antarctic Treaty, and chairing the interagency policy mechanism), the Environmental Protection Agency (environmental advice and oversight), and the Council on Environmental Quality (environmental protection policy).

Through NSF reimbursement, the Department of the Interior provides leasing services for non-DOD aircraft; the Naval Electronics Command, satellite communications expertise; the Department of Transportation, variable costs of icebreaker operations; and the Department of Defense, as discussed throughout the report, the backbone of Antarctic heavy-lift air and sea logistics.

4.3 Recent History of U. S. Science in Antarctica

U. S. researchers working in Antarctica have seen many changes in science support in the last two decades. The primary changes have been in the shift from predominantly military to predominantly contractor support and in the greater emphasis placed on research as the primary expression of the U. S. presence in Antarctica.

In the 1970s, there were approximately six support personnel (military and civilian) on the Ice for every scientist. The scientific facilities onshore at Palmer, McMurdo, and South Pole stations were generally unsuitable for conducting "cutting-edge" research. Scientific instrumentation in the laboratories was minimal and often outdated. Communication with fellow scientists back in the U. S. was poor to non-existent, and there was no efficient way to transmit data back to the U. S. Aside from a decade of research in the 1970s supported capably by the ice-strengthened USNS *Eltanin*, the primary oceanographic effort in Antarctica was based on U. S. Coast Guard icebreakers. Two icebreakers sailed to the Ice each year, one Polar-class ship whose mission was to break the passage to McMurdo Station, and another ship, the *Glacier*, whose mission was intended to be science. From 1968 to 1984 the program had a 125-ft. ice-capable wood ship, *Hero*, that complemented Palmer Station; in 1985 the ice-strengthened, 219-ft. research vessel *Polar Duke* was acquired on a long-term lease to replace *Hero*. The *Polar Duke* was a substantial improvement over the *Hero* and the *Glacier*, but could not compare to research vessels in the U. S. academic fleet, all but one of which are not ice-capable.

Considerable improvement in the infrastructure for support of Antarctic research has occurred in the past two decades, particularly since 1990 (Exhibit 32). Improved facilities and new instrumentation at South Pole Station have provided atmospheric scientists and astronomers with the first real opportunity to conduct cutting edge science on the Ice, demonstrated by projects such as the Center for Astrophysical Research in Antarctica (CARA), which began in 1991. In 1991-92 the new research laboratory, the Albert P. Crary Science and Engineering Center, opened at McMurdo Station. This facility provides scientists with state of the art instrumentation, particularly for biology and biochemistry. Also, a new research vessel, *R/V Nathaniel B. Palmer,* was launched in 1992. The *Palmer* is the first U. S. icebreaking research vessel with scientific capabilities equal to those of other research vessels in the U.S. scientific fleet. It is also the first U.S. Antarctic research icebreaker capable of accommodating more scientists and science support staff than crew.

Because the improved scientific infrastructure in Antarctica enables better science, a greater number of scientists have turned their attention to Antarctica and the level of sophistication of experiments being conducted there has increased.

The portion of the USAP budget spent in research grants to scientists has risen from 10 percent in 1984-85 to nearly 16 percent in 1996-97 (Exhibit 33) and the portion of the budget directly attributable to field support of research has kept pace with this change. In FY95, total research grants and research support was 36 percent of the USAP budget, with the balance (64 percent) providing operations and logistics (station operations, etc.) not directly attributable to specific research projects.

Since FY89, the number of research projects and scientific personnel working in the Antarctic has increased more-or-less steadily so that the USAP dollars per project has decreased (Exhibit 34 and Exhibit 35).

Within the research enterprise itself, modern science has tended to become more complex, demanding research teams composed of individuals with differing expertise and talents, and placing a greater demand on the science support infrastructure. Even with computers, more advanced communications and automated data gathering, as the science becomes more "high tech," the pressure for support personnel tends to increase.

Increased U. S. Antarctic scientific productivity since FY89 can be attributed to better utilization of the infrastructure during a period when the overall USAP budget (in 1997 constant dollars) was both rising (FY89-FY93) and falling (FY93-FY97). Based on the admittedly broad measures shown in the exhibits, productivity during the later years of the FY89-FY97 period compares very favorably with 1981-1985, when the number of science personnel was half today's number. The number of scientists in the 1981-1985 period exceeds the number in the years 1967-1971 by about 50 percent — although in both these periods the USAP annual budget (in 1997 constant dollars) was about the same (Exhibit 15).

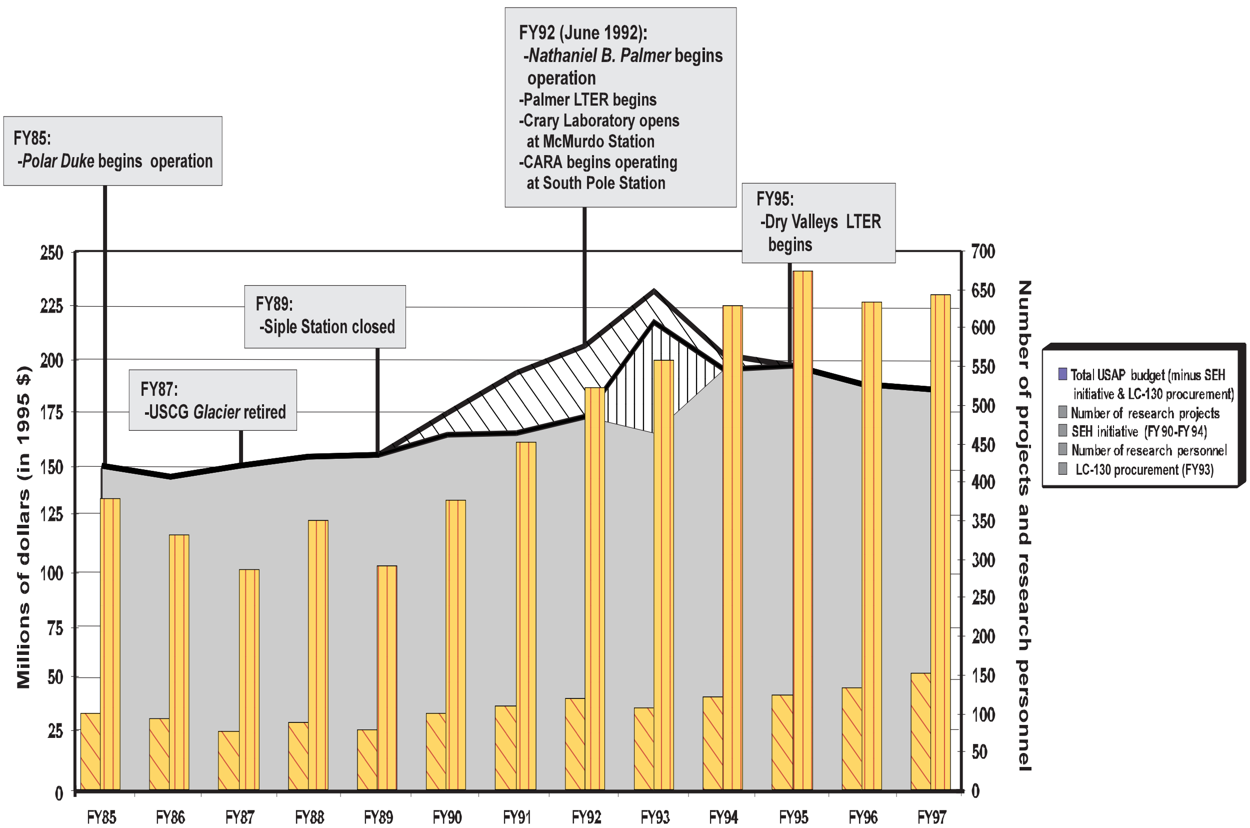
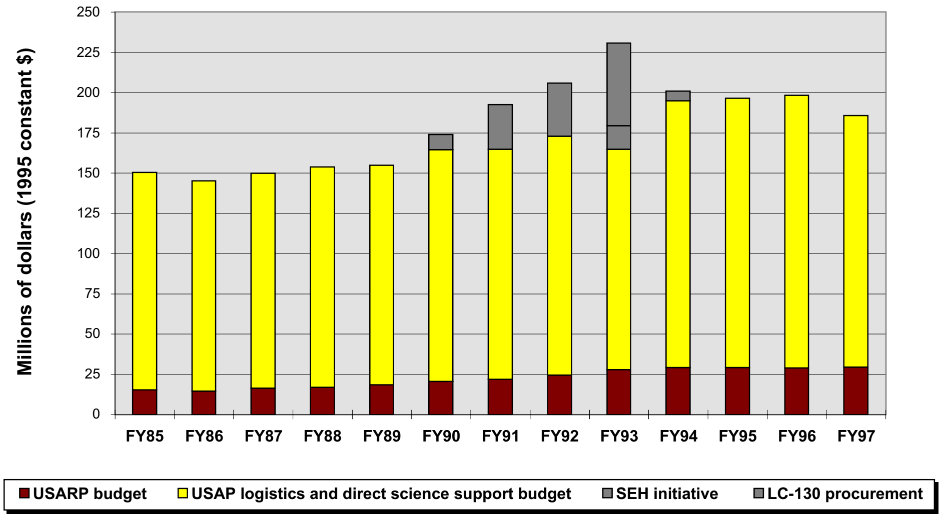


Exhibit 32

Number of projects and research personnel compared to budget. Research-support capability has changed significantly in the USAP from 1985 to 1997, with more added than deleted. Exploiting these new capabilities, the number of research projects and research personnel (rough measures of science productivity) has grown, and at a rate faster than that of the USAP budget. Two budget initiatives during this time were for SEH (safety, environmental protection and health upgrades) in FY90-FY94 and LC-130 aircraft procurement in FY93. Most cited facilities and activities are described in the text. Glacier *was an icebreaker configured to support onboard research. Siple Station, near the base of the Antarctic Peninsula, supported upper atmosphere research. LTER: Long term ecological research.*

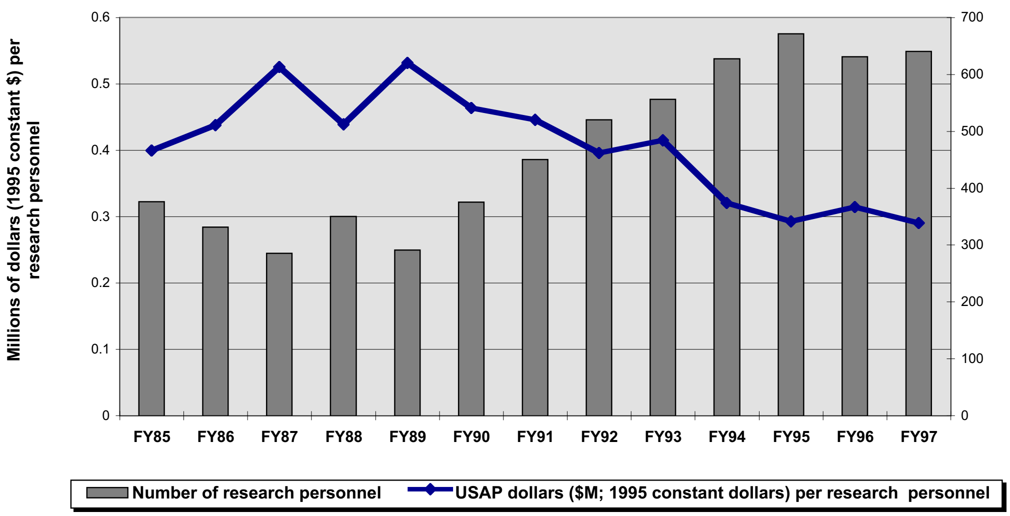
Exhibit 33

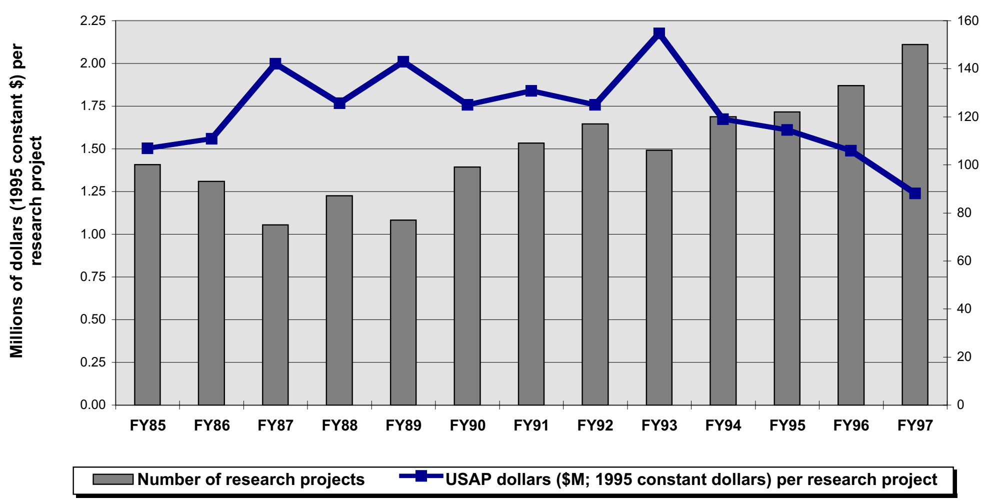
USARP (U. S. Antarctic Research Program) and Operational Support Budgets, FY85-FY97. The USARP budget — that part of the USAP budget that consists of direct award of funds to scientists at institutions for research projects — rose from 10 percent of the USAP in FY85 to 16 percent in FY97. In FY95 the USARP portion was 14.8 percent of the USAP budget of $196M; funds expended in direct operational support of each of these research projects equaled 21.5 percent, and funds expended for logistics and operations not attributable to specific research projects equaled 63.7 percent.



Exhibits 34 and 35

These graphs compare (upper) the number of research projects (which vary significantly in size within any year) and (lower) the number of research personnel to the total USAP budget for the years FY85-FY97, showing a downward trend in the cost per project and per researcher.





5.0 Antarctica - Significance Today

Antarctica is of considerable importance to humanity today. The present section of this report addresses the more significant of these aspects.

5.1 Importance of U. S. Presence in Antarctica

In support of its finding that "maintaining an active and influential presence in Antarctica, including year-round operation of South Pole Station, is essential to U. S. interests," the National Science and Technology Council in its April 1996 report on the U. S. Antarctic Program cites the criticality of the U. S. maintaining a decisive role in the maintenance and operation of the Antarctic Treaty. Indeed, it is clear in reviewing the historic record that it is in substantial part due to the proactive leadership role played by the U. S. in the Antarctic that this vital experiment in the governance of a non-sovereign territory has been so successful.

This commitment to an active, permanent presence in Antarctica has long been understood and supported by the U. S. Government:

- Considering U. S. interests in Antarctica, the President has decided that the Antarctic program should be continued at a level which maintains an active and influential U. S. presence in Antarctica and which is responsive to U. S. scientific, economic and political objectives. (*National Security Decision Memorandum 71 (Appendix 2)*, July 10, 1970)
- The President reaffirms the importance of maintaining an active and influential U. S. presence in the Antarctic. (*National Security Decision Memorandum 318 (Appendix 3)*, February 26, 1976)
- The USAP shall be maintained at a level providing an active and influential presence in Antarctica designed to support the range of U. S. Antarctic interests. This presence shall include the conduct of scientific activities in major disciplines; year-round occupation of the South Pole and two coastal stations; and availability of related necessary logistics support. (*Presidential Memorandum 6646 (Appendix 4)*, February 5, 1982)

In response to a request from the Panel, the U. S. Department of State on January 27, 1997, provided a statement which includes the following passage [complete text in Appendix III]:

"...We have coordinated further with DOD and wish to reiterate the basic point that maintaining an active and influential U. S. presence in Antarctica serves important strategic and foreign policy objectives. This presence in Antarctica, anchored at the South Pole, gives us a decisive voice in the Antarctic Treaty system, which is the basis for the peace and stability of the area." (Timothy E. Wirth, Under Secretary of State for Global Affairs)

The basis for U. S. historic policy toward Antarctica (Section 5.2) has in no way been diminished by global events over the intervening years since the Treaty was ratified. To the contrary, it has become increasingly clear to the global scientific and policy-making establishments, as well as to the general public, that the polar regions serve as the global environmental "barometer" with respect to the depletion of ozone in the upper atmosphere, global warming, and the impact of these phenomena on living systems. Antarctic research complements related activities in the rest of the world, including the Arctic.

The U. S. presence and its central role in bolstering the Antarctic Treaty are symbolically and physically manifested in the operation of the Amundsen-Scott South Pole Station. The site lies on the Earth's axis of rotation, the geographic apex of territorial claims. The station, and the U. S. commitment to research there, are a keystone to the maintenance of the Antarctic Treaty as well as a testament to the U. S. commitment to understand the global environment. Intermittent U. S. presence in Antarctica, and particularly at the Pole, would preclude the conduct of much of the research now underway and would undermine the U. S. policy of non-sovereignty.

The Antarctic "barometer" is also relevant to U. S. national security policy and interests since climatic effects are recognized as having a direct connection to the political stability of nations. Increased drought, for example, can, through agricultural impacts, have profound economic and political implications in developing nations. Understanding trends in climate can assist in identifying possible corrective actions and anticipating future global security issues.

5.2 Development of U. S. Policy

United States policy for Antarctica has evolved over a period of years. It is based on four principles: the U. S. recognizes no foreign territorial claims; it reserves the right to participate in any future uses of the region; Antarctica shall be used for peaceful purposes only; and there shall be free access for scientific investigation and other peaceful pursuits.

As early as 1948, drawing on its leadership in Antarctic and world affairs, the U. S. proposed an international trusteeship. Under this plan the seven claimant nations and the U. S. (and other nations, if they wished) would have agreed "not to seek a division of the territory in the area, but to join with the others." The eight nations would make joint explorations and would have free access over the area.

For a decade the idea did not gain necessary support. Then the International Geophysical Year renewed ties among nations involved in Antarctica, and in May 1958 President Dwight D. Eisenhower invited the 11 other Antarctic IGY nations to Washington to draft an Antarctic Treaty. He wrote: "The U. S. is dedicated to the principle that the vast uninhabited wastes of Antarctica shall be used only for peaceful purposes...We propose that Antarctica shall be open to all nations to conduct scientific and other peaceful activities there." Referring to the IGY, the President wrote: "Our proposal is directed at insuring that this same kind of cooperation for the benefit of all mankind shall be perpetuated."

Secretary of State John Foster Dulles referred to the extensive activities of U. S. expeditions to the Antarctic and set forth the basic position and proposal of the U. S. in the following words:

> *"In view of the activities of the U. S. and its nationals referred to above, my Government reserves all of the rights of the U. S. with respect to the Antarctic region, including the right to assert a territorial claim or claims.*
>
> *"It is the opinion of my Government, however, that the interests of mankind would best be served, in consonance with the high ideals of the Charter of the United Nations, if the countries which have a direct interest in Antarctica were to join together in the conclusion of a treaty which would have the following peaceful purposes:*

1) Freedom of scientific investigation throughout Antarctica by citizens, organizations, and governments of all countries...
2) International agreement to ensure that Antarctica be used for peaceful purposes only.
3) Any other peaceful purposes not inconsistent with the Charter of the United Nations. It is believed that such a treaty can be concluded without requiring any participating nation to renounce whatever basic historic rights it may have in Antarctica, or whatever claims of sovereignty it may have asserted. It could be specifically provided that such basic rights and such claims would remain unaffected while the treaty is in force, and that no new rights would be acquired and no new claims made by any country during the duration of the treaty."

The nations met, the Antarctic Treaty was written, and all the proposed provisions were incorporated into it. The Antarctic Treaty entered into force in 1961 and became the keystone of U. S. Antarctic policy.

In October 1970 President Richard M. Nixon stated U. S. policy for Antarctica to be "to maintain the Antarctic Treaty and ensure that this continent will continue to be used only for peaceful purposes and shall not become an area or object of international discord; to foster cooperative scientific research for the solution of worldwide and regional problems, including environmental monitoring and prediction and assessment of resources; and to protect the Antarctic environment and develop appropriate measures to ensure the equitable and wise use of living and non-living resources." The President added: "Science has provided a successful basis for international accord, and the Antarctic is the only continent where science serves as the principal expression of national policy and interest."

In 1970 and again in 1976 National Security Decision Memoranda (71 and 318) reaffirmed the "importance of maintaining an active and influential U. S. presence in the Antarctic that is 'responsive to U. S. scientific, economic, and political objectives.'"

In February 1982 President Ronald Reagan in White House Memorandum 6646 reaffirmed the prior policy and noted that the presence in Antarctica shall include "the conduct of scientific activities in major disciplines" and "year-round occupation of the South Pole and two coastal stations."

On 9 June 1994 Presidential Decision Directive NSC 26 ("United States Policy on the Arctic and Antarctic Regions") stated that U. S. policy toward Antarctica has four fundamental objectives: (1) protecting the relatively unspoiled environment of Antarctica and its associated ecosystems, (2) preserving and pursuing unique opportunities for scientific research to understand Antarctica and global physical and environmental systems, (3) maintaining Antarctica as an area of international cooperation reserved exclusively for peaceful purposes, and (4) assuring the conservation and sustainable management of the living resources in the oceans surrounding Antarctica.

An April 1996 report, *U. S. Antarctic Program*, by the President's National Science and Technology Council, directed the establishment of the present Panel and reaffirmed that essential elements of U. S. national and scientific interests are well served by continued involvement in scientific activity in the Antarctic as carried out by the U. S. Antarctic Program. The report states that policies in the 1982 memorandum continue to be appropriate at the current funding level and that present U. S. policy and practice with respect to the U. S. Antarctic Program are well justified (Exhibit 36).

5.3 Antarctic Research

The Antarctic research program comprises the following areas of endeavor: aeronomy and astrophysics, biology and medicine, geology and geophysics, glaciology, and ocean and climate systems. The science benefits from Antarctica's uniqueness as a natural laboratory where certain types of research can best or only be undertaken. The program includes fundamental research designed to provide an understanding of the Earth and its systems, such as the role of the Antarctic in Earth's climate and geological history. Antarctic

Date	Document	Title/Subject	Content
8/3/60	Bureau of the Budget Circular A-51	Planning and Conduct of the United States Program for Antarctica	Establishes Executive Branch responsibilities for implementing the continuing U. S. Antarctic Program following the International Geophysical Year
7/10/70	National Security Decision Memorandum 71	U. S. Antarctic Policy and Program	Transfers management of the U. S. Antarctic Program from DOD to NSF; affirms importance of "active and influential U. S. presence"
8/4/71	Office of Management and Budget Circular A-51 (revised)	Planning and Conduct of the U. S. Program in Antarctica	Establishes responsibilities of Antarctic Policy Group, NSF, and Department of Defense
3/6/73	Office of Polar Programs Memorandum	Statement of U. S. Policy Objectives for OPP's Long-Range Objectives Plan	OPP internal draft planning document; background of and reasons for U. S. policies
2/25/76	National Security Decision Memorandum 318	U. S. Policy for Antarctica	Reaffirms importance of "active and influential U. S. presence" in Antarctica. Reaffirms NSF's management responsibilities; funding for USAP should not be at expense of other NSF programs
10/21/81	Department of State Memorandum	Revised Decade Study	Assessment of future U. S. interests in Antarctica by the Antarctic Policy Group
2/5/82	White House Memorandum 6646	U. S. Antarctic Policy and Programs	Reaffirms importance of "active and influential presence;" presence to include year-round occupation of South Pole and two coastal stations
6/9/94	Presidential Decision Directive NSC-26	U. S. Policy in the Arctic and Antarctic Regions	States four objectives of U. S. policy in Antarctica: protecting environment; protecting opportunities for scientific research; maintaining Antarctica as area of international cooperation for peaceful purposes; conservation of living resources in the oceans surrounding Antarctica
11/13/95	Development of U. S. Antarctic Policy	Summary of Policy History	OPP internal document summarizes Antarctic policy history
4/26/96	National Science and Technology Council review of USAP	"United States Antarctic Program"	Evaluation of U. S. policy objectives and USAP

Exhibit 36

U. S. Government Executive Branch policy statements regarding Antarctica.

research addresses specific adaptations of polar organisms; e.g., ice algae and Antarctic fish living in 28°F. The Antarctic also provides a window for study of near-Earth and deep space, including study of the origins of the universe.

"Space weather," driven by solar flares, compresses the Earth's magnetic field and affects electrical power grids and communications around the planet. These phenomena are strongly manifested at the poles, where they are usefully studied. Such interactions may even affect Earth's weather.

The USAP has pioneered the use of Automated Geophysical Observatories that monitor these processes year-round at remote sites on the polar plateau, greatly increasing our understanding of Earth-space interactions, and perhaps leading to improved predictions of space-based disturbance of human-built technical systems.

The Antarctic ozone hole. Monitoring of Antarctic ozone began at the British Antarctic Survey station at Halley Bay, Antarctica, during the International Geophysical Year in 1957. By 1984, observations at Halley Bay revealed ozone values 30 percent below those observed in the previous decades of measurement, and the researchers announced their remarkable discovery of an ozone "hole." Their findings were quickly verified by other measurements, including those from South Pole Station (Exhibit 37).

In 1986 and 1987, USAP undertook the National Ozone Expedition to probe the cause of this remarkable thinning of the ozone layer. USAP's facilities in the Antarctic (particularly the unique ability to operate ski-equipped LC-130 aircraft) allowed a group of researchers to attack the problem quickly and, most importantly, to arrive at McMurdo Station in August. Ozone amounts were close to normal in late August, but dropped rapidly during September. The region of 'missing ozone' was shown to extend from about 7 to 12 miles altitude; near 10 miles most of the ozone was removed (Exhibit 38).

Observations of stratospheric ozone and many of the molecules involved in ozone chemistry (including chlorine monoxide, chlorine dioxide and nitrogen dioxide) were made at McMurdo in 1986 and 1987. These observations pointed towards human activities as the likely cause of the ozone hole. It is now established that the Antarctic ozone hole is caused mainly by perturbed chemistry due to human use of chlorofluorocarbons (CFCs). Ozone depletion is most pronounced in the Antarctic because extremely low stratospheric temperatures lead to polar stratospheric clouds, the particles of which provide surfaces upon which chemical reactions occur to free the chlorine from stable compounds and make it available to destroy ozone in a catalytic cycle. The ozone depletion occurs in the Antarctic spring because the process requires a combination of low temperatures and sunlight. In winter the Antarctic is too dark for much ozone loss, while in summer it is too warm.

International agreements are in place to eliminate global use of chlorofluorocarbons. Because of the long lifetime of CFCs, their impact on the atmosphere will decay slowly, and the Antarctic ozone hole will persist for decades. Exhibit 37 illustrates work at the South Pole Station to monitor the recovery of Antarctic ozone, documenting the atmospheric response to the unprecedented policy decision to phase out the ozone-depleting compounds. Exhibit 37 shows that observations of changes in the the detailed shape of the vertical profile of ozone (particularly in the key 7-12 mile altitude range where most of the ozone loss occurs) should allow the first detection of recovery near the year 2010.

U. S. researchers are studying the biological impact of the ozone hole. Recent studies have shown that phytoplankton that form the base of the food chain in the waters surrounding Antarctica can be affected by changes in ultraviolet radiation due to ozone depletion. Ongoing research is aimed at documenting this sensitivity and its implications for the Antarctic ecosystem. In March 1997 researchers presented the first direct evidence that increased ultraviolet light damages the DNA of animals — the eggs and larvae of icefish, an Antarctic fish lacking hemoglobin. The eggs accumulate DNA lesions called cyclobutane pyrimidine dimers.

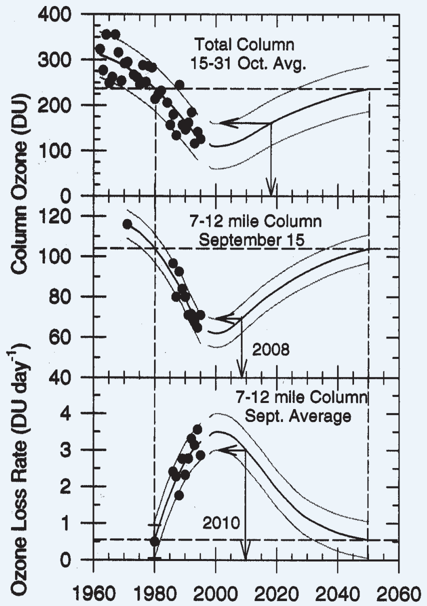


Exhibit 37

The top box shows the amount of total ozone measured from the surface in the air column over the South Pole, in Dobson units (DU), for the last half of October following the austral springtime ozone depletion process. The middle box shows the ozone amount present in the 7 to 12 mile altitude region on September 15, midway through the depletion process, obtained from balloon-borne ozonesonde measurements. The bottom box shows the ozone loss rate (DU per day) in the 7 to 12 mile altitude region during September. Each dot gives the value for one year. The triple curves in each box are average smooth curves with upper and lower bounds for the 1960 to 1995 data (the most recent data used here) and extend into the future to predict recovery based on stratospheric chlorine, which is projected to peak around 2000 and reach the 1980 level around 2050. Unambiguous confirmation that ozone recovery is underway will probably not be possible in the total ozone measurements until about 2018, while the indicators obtained at 7 to 12 miles from the ozonesonde data should allow detection in the 2008-2010 time period.

The polar ozone depletion work being conducted in Antarctica (Exhibits 37 through 40) has been critical in answering questions concerning conditions in the upper atmosphere that exacerbate the loss of ozone. Antarctica also provides the site of the world's cleanest air and as such is a baseline for studies of atmospheric chemistry at ground level.

New types of instruments are now being utilized at the Pole to explore deep space. These experiments are providing answers to questions about the origins of galaxies and the history of the universe.

The Antarctic Muon and Neutrino Detector Array (AMANDA) uses the deep ice at the South Pole as the largest neutrino telescope on Earth. The clean air and low atmospheric water-vapor content on the polar plateau make it very likely the best instrumented site on Earth for studying the radiation left from the origin of the universe as well as other radiation of similar wavelengths (Exhibit 41).

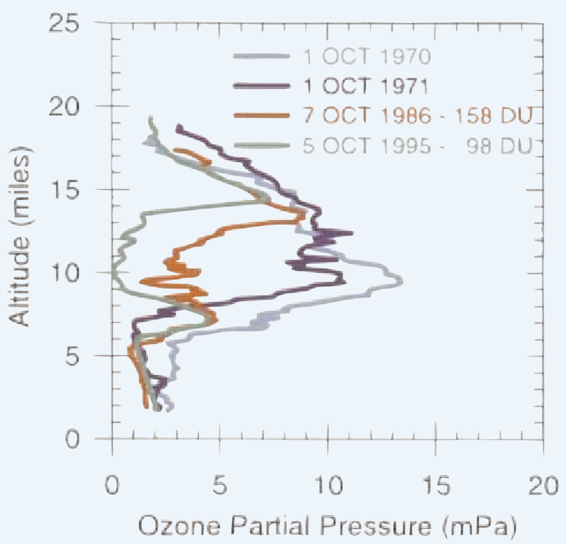


Exhibit 38

Balloon-borne ozone observations at the South Pole in four selected years showing the worsening of the ozone hole over time. The total ozone values for the 1970 and 1971 soundings were about 300 Dobson units (DU). mPa = millipascals. Graphs in exhibits 37 and 38 provided by Dr. David Hofmann, Climate Monitoring and Diagnostics Laboratory, NOAA.

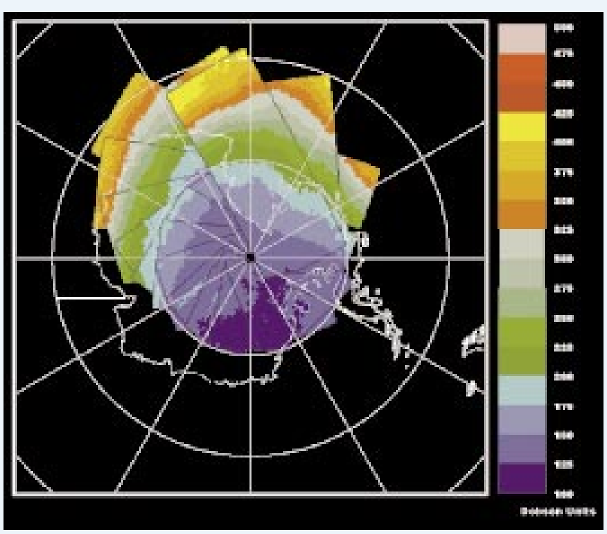


Exhibit 39

Total ozone over Antarctica on October 6, 1996, collected at McMurdo from a satellite as it passed overhead every 95 minutes. University of Wyoming researchers at McMurdo used the real-time images to schedule the release of balloon-borne instruments to collect data on polar stratospheric clouds and ozone. The ozone sensors collect data similar to those in Exhibit 38. Because some balloons carried expensive sensors designed to measure polar stratospheric clouds, which are more common well within the ozone hole, the real-time satellite measurements of the ozone hole formed an integral component in guiding the research. The lowest ozone levels for the year lie in the deep blue area in East Antarctica. Satellite data are from NASA's Total Ozone Mapping Spectrometer (TOMS) on its Earth Probe satellite.

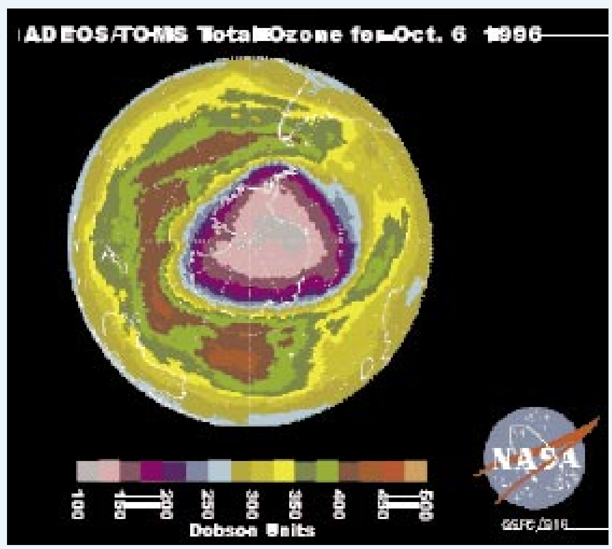


Exhibit 40

Total ozone over the southern hemisphere on October 6, 1996, from a NASA TOMS instrument on the Japanese ADEOS satellite. The lowest values for the year are in the gray areas over East Antarctica.

Conditions in the summer months in Antarctica, ice covered, continuously sun-lit, and surrounded by ocean, are also ideal to undertake Long-Duration Ballooning for scientific data gathering. Stratospheric circulation in Antarctica allows long-term experiments not otherwise possible on Earth, because the balloons literally circumnavigate the continent. The balloons carry payloads on a routine basis weighing a ton or more. In many experiments, the balloon flights are a less expensive alternative to space flights. NSF and NASA have cooperated to develop this capability in support of several scientific disciplines.

Solution of two linked problems lies in the ice of the Antarctic: understanding past climate change to help predict climate, and understanding ice-sheet evolution to help predict sea-level change. Antarctica contains ice hundreds of thousands to millions of years old. Sealed within that ice are indicators of past temperature, snowfall, ocean productivity, atmospheric composition, and much more.

Analyses of Antarctic ice cores have already revealed that natural variations in carbon dioxide and temperature have been closely linked, and that the ongoing human-caused rise in carbon dioxide has resulted in record atmospheric concentrations. When combined with results from Greenland ice cores, the Ice has shown that the Earth's climate has undergone larger, faster, and more-widespread changes than once believed possible, or than have previously been experienced by agricultural or industrial humans. Recent efforts to acquire deep cores through the West Antarctic Ice Sheet (Exhibit 42) seek to use exceptionally high-resolution cores for comparison with Greenland records to learn where climate changes start and how rapidly they spread — important information in learning to predict them.

Recent studies of large ice streams flowing into the Ross Sea provide some indications that the West Antarctic Ice Sheet presently is unstable and may experience rapid retreat some time in the next few millennia. The reasons for the apparent instability in the ice sheet are poorly understood, but the consequences of ice-sheet decay are well documented. One of these consequences is that sea level has risen approximately 300 feet in the past 18,000 years due to ice sheet retreat in both hemispheres. Due to this rise, the sea coasts of the world have been in a constant state of change.

Simulations lend support to the idea that the West Antarctic Ice Sheet may have a history of sporadic, and possibly very rapid, collapse. Given the delayed response of the ice sheet to changes in the bed on which it rests,

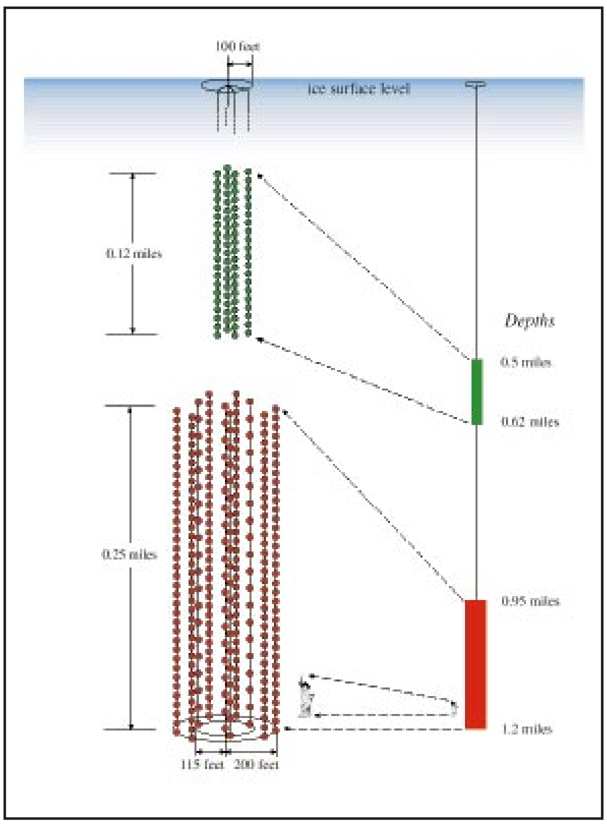


Exhibit 41

AMANDA (Antarctic Muon and Neutrino Detector Array). There are many ways to study the universe. Our early ancestors used their eyes, Galileo a telescope. Modern astronomers use the infrared and gamma-ray portions of the electromagnetic spectrum, among other portions, to look at the universe, just as physicians use x-rays to see inside living tissue. Recent technology has made possible "telescopes" that image the sky in high-energy neutrinos. Neutrinos are common subatomic particles, but they interact only weakly, and enormous numbers pass through Earth without interacting. They do collide from time to time with nuclei of water molecules, whether liquid or frozen, and detectors are being built in the Mediterranean, Lake Baikal in Russia, and the Antarctic ice sheet.

AMANDA at the South Pole exploits the advantages of ice over water as a detector. Photo detectors are lowered into holes in the ice made using hot water, then they freeze in place. The detectors look downward, so the entire Earth shields them from interactions caused by particles other than neutrinos. The diagram, provided by Dr. Robert Morse, University of Wisconsin, shows the array of 14 strings as it was in early February 1997. Each ball is a glass sphere about 16 inches in diameter inside of which is a photomultiplier tube that registers the neutrino interactions. Ice is more effective than water because it has no radioactivity or bioluminescence; the low temperature also reduces detector noise. The wires run just to the surface, rather than long distances to shore. A disadvantage of ice is that the detectors are permanently frozen in place and can't be changed when they malfunction. Also, the ice sheet at the South Pole (9,300 ft.) is not as thick as the Mediterranean is deep, so the non-neutrino background at South Pole is higher.

For image see *Science Magazine*, 21 February, 1997, p.1077.

Exhibit 42

WAIS and Glacier. The West Antarctic Ice Sheet (WAIS) project focuses on environmental research and education. Because the WAIS rests on a bed that is far below sea level in most places, it is prone to flowing rapidly into the ocean and raising sea level. Geological evidence shows that the WAIS has expanded and contracted many times since its formation 20 million years ago. The present WAIS has revealed a complex dynamic setting. Some regions are changing rapidly, while others appear dormant. Attention is focused on fast-moving rivers of ice called ice streams, where changes are especially rapid. Some models of the ice sheet suggest that a rapid collapse is possible, but others suggest stability. Part of the uncertainty comes from our lack of knowledge of how climate and sea level influence the WAIS. These studies have further shown that the WAIS is responding to past changes in climate and sea level.

Ice cores through the WAIS are expected to yield an unprecedented history of Antarctica's weather with annual resolution dating back thousands of years. Further, the ice cores contain bubbles of old air, including greenhouse gases, yielding important information about the influence of greenhouse gases on climate in the Southern Hemisphere.

Predicting the future of the WAIS requires understanding how the atmosphere delivers snow, how the ocean melts the underside of floating ice-sheet extensions called ice shelves, and other processes — as well as how these might change naturally or with greenhouse warming. Thus, to predict the future of the ice sheet and sea level change, and to help understand global climate change, scientists from a host of disciplines have come together in the WAIS project.

The WAIS interdisciplinary approach to a globally important problem offers opportunity for education and outreach. Some of this is being done through Glacier (http://www.glacier.rice.edu), a web-based, multi-media presentation of new WAIS results that targets middle school students but has audiences of all ages.

The map shows ice sheet surface elevations (black contour lines; heights in kilometers; 3 kilometers = 4.8 miles), divides between ice-drainage systems (red lines), mountainous regions (brown), sections of the ice sheet where the bed is above (tan) and below (blue) sea level, and the grounding lines (dotted lines) bounding the Ross and Ronne ice shelves. Image © Science Magazine 1997 after Charles R. Bentley, University of Wisconsin.

rapid retreat of the West Antarctic Ice Sheet may already have been set in motion. While the magnitude of sea-level changes caused by potential future collapse of the West Antarctic Ice Sheet may be small (perhaps only a foot or two, up to 10 ft. to 20 ft., depending on how much of the ice remains) the impact that such changes will have on some coasts would be profound. The West Antarctic Ice Sheet Study is a multidisciplinary investigation aimed at gaining a better understanding of those factors that influence the dynamic behavior of the ice sheet and, in so doing, establishing better models to predict future ice sheet behavior.

The great productivity of the Antarctic oceans feeds virtually all native life in the Antarctic and animals that range far beyond the Antarctic. The southern ocean area has large seasonal change (Exhibits 43, 44, and 45) and an important role in moderating global carbon dioxide (Exhibit 46). Biological studies show that this productivity is sensitive to human-caused environmental change, as shown by the decrease in productivity caused by ultraviolet radiation passing through the ozone hole.

In another area of Antarctic research, over the last 20 years research teams have collected about 16,000 meteorites representing many different meteorite classes. On the otherwise light-colored background of the ice sheet, meteorites are easy to observe, making collection relatively easy. Also, dynamic processes of the ice sheet, especially near the Transantarctic Mountains and other obstructions, cause meteorites which fell over the last several million years to accumulate at a relatively high density in slow-flowing ablation zones on the ice sheet. Further, the cold, dry environment preserves meteoriteswhich have in fact impacted the Earth's surface.

Meteorites offer important clues to the origin of the solar system and to active solar system processes. For example, scientists determined the ages of Earth and of the early condensation of the solar system from meteorite studies. Also, an emerging area of meteorite research focuses on minute particles of diamonds and other minerals, formed at high temperatures and pressure that are found in ordinary chondritic meteorites and may represent products of stellar processes that predate our solar system.

In 1984, the Antarctic Search for Meteorites program discovered an unusual meteorite in a region of

Exhibits 43-45

Sea Ice. The annual freezing and melting of Antarctic sea ice is one of the Earth's major climatic events. In its winter maximum, the sea ice is typically two- to three-feet thick, and covers nearly eight million square miles, an area greater than the continent itself. In summer it is reduced to 1.5 million square miles in a narrow fringe around the continent. It has profound effects on the physics, chemistry, and biology of the southern ocean.

In autumn when the ice cover is expanding, the ice acts as a distillation system, separating sea water into low salinity ice and high salinity brine, which sinks and increases the density of Antarctic Bottom Water, a globally distributed water mass. In winter, during its maximum extent, the ice shuts down the exchange of heat between the ocean and the atmosphere, lowering the surface air temperature by as much as 30°F and increasing the reflectivity (albedo) of the surface. In spring, melting releases microbes and plankton that had been growing in the ice and seeds of phytoplankton bloom. In summer it provides a breeding place for seals. For most of the year the transition zone from ice to open water is one of enhanced biological activity, where birds, seals, and whales congregate to feed. The schematic (© Scientific American 1988, after Gordon and Comiso, 1988) illustrates these actions.

The extent of the Antarctic sea ice has been closely tracked since 1973 from satellite-based sensors that measure the microwave energy emitted by the surface. Open water and sea ice appear very different in the microwave band, and therefore the ice edge can be established very precisely. There has been a slight decrease in the maximum extent of sea ice during the period of record, consistent with a slight climatic warming over the past 25 years. These microwave observations are our only source of information about the Weddell polynya, a large (over 100,000 square miles) area of open water surrounded by sea ice that maintained itself from 1974 to 1976 within the Weddell Sea. It has not been observed since, although evidence has been accumulated about the conditions that probably produced the polynya. Exhibits 44 and 45, prepared by NASA's Goddard Space Flight Center, show the annual minimum and maximum extent of the sea ice in February and September 1974.

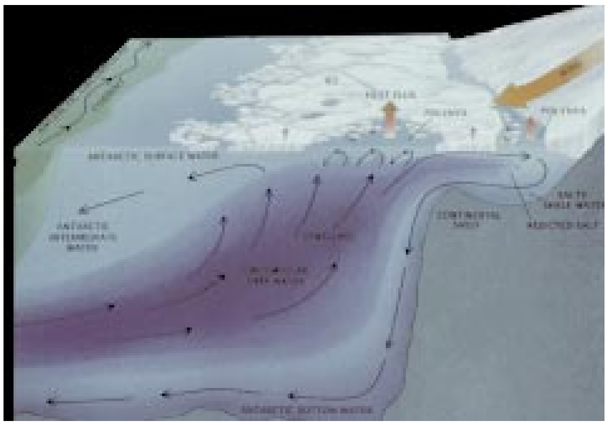


Exhibit 43

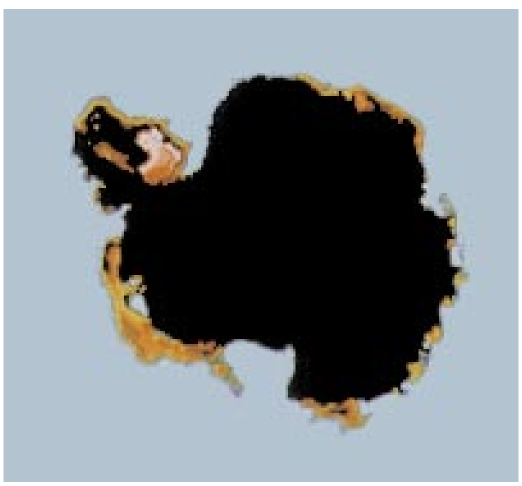


Exhibit 44

February (Summer) 1974

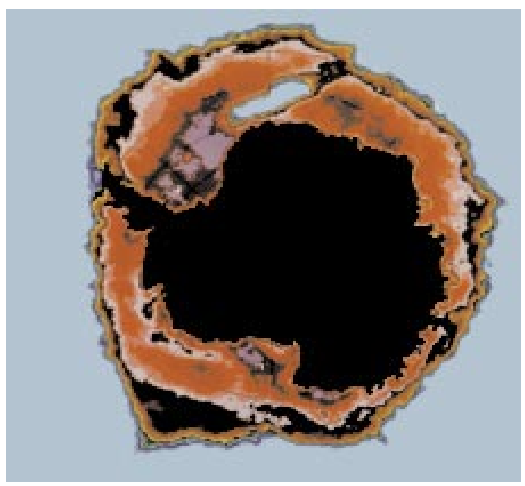


Exhibit 45

September (Winter) 1974

Exhibit 46

Satellite image of ocean color showing phytoplankton blooms, likely sites of biologically mediated flux of carbon dioxide between the atmosphere and the ocean. Carbon dioxide is the most important human-produced greenhouse gas contributing to global warming. To understand or predict global change, the amounts and the rates of carbon dioxide entering and leaving the atmosphere must be determined. The ocean is one of two major sinks, or removers, of atmospheric carbon dioxide (the terrestrial biosphere is the other one). Most oceanic carbon dioxide uptake occurs between 30°S latitude and Antarctica — the southern ocean. But the magnitude of this downward flux, or flow, is difficult to quantify with present knowledge.

The southern ocean is the fourth regional experiment of a U.S. contribution to an international program — the Joint Global Ocean Flux Study (JGOFS) — that is tracing the flow of carbon through the ocean's intertwined chemical, biological, and geological pathways. This work follows other regional experiments in the North Atlantic, the equatorial Pacific, and the Arabian Sea. While each region was chosen for its distinctive oceanic and climatic setting, the southern ocean is unique because its very cold surface allows very high values of dissolved carbon dioxide and because it facilitates vertical convection to the ocean bottom. Climate change models not only show that most of the global oceanic uptake of carbon dioxide occurs in the southern ocean; they also show that the southern ocean flux has the greatest sensitivity to biological variations.

The U.S. Antarctic Program research icebreaker Nathaniel B. Palmer is supporting the southern ocean research. By the end of March 1998, Palmer will have made seven cruises in less than 2 years in support of the Antarctic Environment and Southern Ocean Process Study (AESOPS), a major JGOFS experiment. More than 40 principal investigators will have studied processes including the exchange of gaseous carbon dioxide between the atmosphere and the ocean, the uptake of carbon by phytoplankton blooms, the sinking of organic and inorganic carbon-based matter to the ocean bottom, and the sequestering of carbon within the bottom sediment. Image © Science 1993 after C.W. Sullivan et al.

blue ice in the Allan Hills. After several years of research, planetary scientists recognized that this meteorite had originated on the planet Mars and been ejected to the Earth during a Martian collision with some other object. The presence in this meteorite of carbonate minerals, often associated with fluids, offers clues to past environmental conditions on Mars. Recently, an interdisciplinary team of scientists suggested that the presence of these carbonate minerals, along with complex hydrocarbon molecules also found in the meteorite, may be evidence of life on Mars some 3.6 billion years ago, although other researchers indicate that the carbonates formed at 1150°F in the absence of water, conditions not amenable to life as we know it.

Biological studies in the Antarctic also show how living things adapt to one of the harshest climates on Earth. Understanding the genetic and physical basis for the great adaptations of Antarctic life is revealing fundamental insights to biological processes, and is likely to prove useful to humans (Exhibits 47, 48, and 49).

A very exciting opportunity that can be developed is an application of molecular biology techniques to determine the biological history of the Earth, at the microbiological level, that is embedded in ice and sediment cores. With the ability to extract any nucleic acids that may be present, followed by sequencing, fingerprinting, etc., it should be possible to learn how life has changed with the Antarctic environment.

In an entirely different area of research, biomedical studies in Antarctica, and especially at the South Pole, usually in collaboration with NASA, have helped understand the physiology and psychology of living in the isolated environment of the Antarctic.

Antarctica has not always been glaciated. Indeed, 80 million years ago the coastal regions of Antarctica supported lush, temperate forests that were inhabited by a wide diversity of animals. At that time the continent was situated at a latitude similar to that of southern South America today. As the continent drifted toward the south away from the other Gondwana continents, insolation diminished and Antarctica's climate cooled. The evolutionary changes of plants and animals living on the continent and trying to adapt to these more harsh conditions are among the most spectacular and poorly understood paleontological events in Earth's recorded history. There is still much to learn about the evolution of the Antarctic continent, the ice sheet, and the organisms that have lived or continue to live there.

With the rich history of the discoveries emanating from Antarctic research over the past 50 years, as well as their frequent relevance to human well-being on Earth through improved understanding of weather, climate, ocean circulation, etc., Antarctica truly affords a unique laboratory for the conduct of science.

Exhibits 47-49

Life in the Extreme. Knowledge about extreme and unusual environments that are home to microbial life has expanded rapidly in the last decade. These environments, ranging from icy polar seas and dry polar deserts to hot deep-sea hydrothermal vents, may be analogs to ancient environments on Earth and on other planets. Only a fraction of these systems has been studied; knowledge of them will help us understand the diversity of microbial life, its biochemical adaptations enabling survival, and the range of physical and chemical conditions in which life can survive and even flourish.

The Antarctic offers unique opportunities for study of life in environments that are at the limits of the planet's cold, darkness, and dryness. In them, the energy available to support life is among the lowest levels on Earth. Here are three examples, chosen from many:

Exhibit 48

The perennially ice-covered lakes of the McMurdo Dry Valleys harbor communities of cyanobacteria that appear to thrive in stratified, saline water well below 32°F and sometimes in brine pockets in the ice cover.

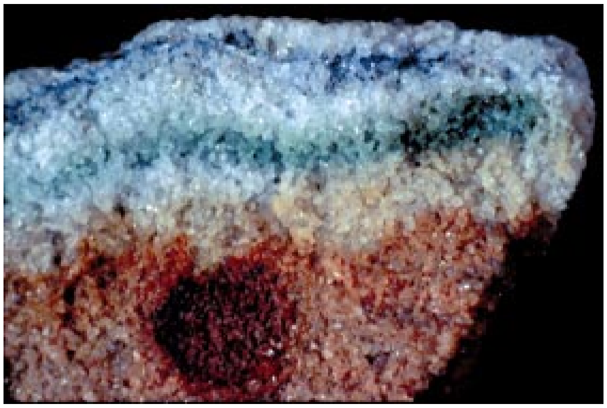


Exhibit 47

The outer few sixteenths of an inch of some rocks in the cold desert of the McMurdo Dry Valleys creates microclimates with just enough above-freezing days per year and just enough moisture that minute spaces between grains are home to organisms. These organisms are active enough to contribute to weathering of the rock surface, but they appear to be on the limit of their capability and are dormant most of the year. Here, an opened section of Beacon Sandstone from Linnaeus Terrace (Dry Valleys) shows layers of algae, fungi, and bacteria (photo courtesy of E. Imre Friedman, Florida State University).

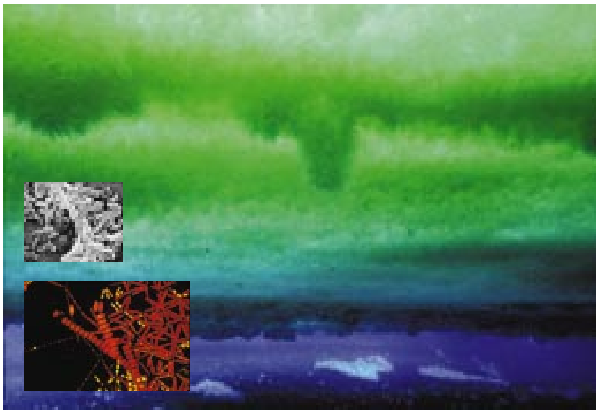


Exhibit 49

The undersurface of sea ice has rich algal blooms. The color inset is a photomicrograph of chains of sea ice algae with fluorescent stain to reveal protein (red) and lipid (yellow) content of living cells. The other inset shows bacteria from sea ice at greater magnification in a scanning electron microscope image (photos courtesy of C. W. Sullivan, National Science Foundation).

5.4 Environmental Considerations

Human activity in the Antarctic began as a quest for exploration, for economic gain, and for scientific knowledge. These goals were reflected in the early Antarctic exploration in the 19th century and the entry into force of the Antarctic Treaty in 1961. Interest in Antarctica now also reflects humankind's expanding influence upon and awareness of the environment.

Antarctica is one of the few remaining nearly pristine sites in the world, and is certainly by far the largest such site. Antarctica is particularly vulnerable to some types of environmental change, notably those that would require biological activity for reversal or amelioration. Pollutants that would be readily biodegradable elsewhere can have very long lifetimes in the Antarctic environment, increasing the possibility of long-term alteration through human activities.

Two treaties have already been put in place to extend the original Antarctic Treaty to include preservation concerns. The Convention for the Conservation of Antarctic Seals took effect in 1978, and the Convention on the Conservation of Antarctic Marine Living Resources took effect in 1982. The Antarctic Treaty together with the recommendations and measures adopted under it and the Seals and Marine Living Resources Conventions have collectively become known as the Antarctic Treaty System.

To enhance protection of the Antarctic environment, the Antarctic Treaty parties in 1991 adopted the Protocol on Environmental Protection to the Antarctic Treaty, designating Antarctica as a natural reserve and setting forth environmental protection principles to be applied to all human activities in Antarctica, including the conduct of science, tourism, and fishing. The Protocol has been signed by all of the 26 Consultative Party nations to the Antarctic Treaty, and will enter into force after the 26 nations have deposited their instruments of ratification, acceptance, approval, or accession.

The U. S. has taken a number of steps to implement the Protocol. Aggressive environmental measures have been introduced into the USAP under the Safety, Environment, and Health Initiative, including removal of all solid wastes and institution of an extensive recycling program at U. S. stations. The USAP has taken a science-based approach to environmental assessment in which careful measurements of environmental parameters are used to monitor changes and evaluate the need for additional protection measures. Thus, U. S. policy currently reflects not only geopolitical and scientific concerns, but also a position of leadership in the international stewardship of the Antarctic environment.

6.0 Findings

The Panel's review of existing policy regarding Antarctica and of ongoing activities in Antarctica has led to 22 findings which are presented in this section of the report.

6.1 Geopolitical Significance

The Panel examined the fundamental question of the value to the nation of the U. S. presence in Antarctica. In so doing, the Panel reviewed the historic basis of U. S. activity in the region, tracing in particular the evolution of U. S. involvement in Antarctica from the International Geophysical Year to the present.

The Antarctic Treaty, which entered into force in 1961, forms the basis of national policy for activity in the region. The Treaty reserves the region for peaceful purposes only; it neither recognizes nor disputes territorial claims and prohibits the assertion of new claims; and it protects the region's environment and ecology. These goals are in the national interest as stated in official documents and studies since the 1920s. The Treaty is the legal underpinning for governance of this non-sovereign territory.

Nevertheless, pre-existing claims of sovereignty still stand. But for the active presence of national research programs and commitment to the spirit of the Treaty, sovereignty claims could threaten peace on the continent and elsewhere. The leadership role of the U. S. in manifesting its presence in Antarctica in accord with the full spirit of the Treaty is instrumental in sustaining this instrument of responsible governance. The U. S. presence is powerfully expressed in the year-round operation of three research stations, and especially the station at the Earth's South Pole and the continent's geopolitical center. The U. S.'s scientific and environmental research in Antarctica give substance and relevance to the national presence.

6.2 Scientific Activity

The Panel concurs with the President's National Science and Technology Council's conclusions that the U. S. scientific effort in Antarctica is equivalent in quality to that conducted in the U. S. and elsewhere in the world, and that the science conducted in Antarctica either cannot be performed elsewhere or is best done in Antarctica. Much of this scientific research has potential significance for human health and welfare globally; e.g., studies evaluating the potential collapse of the West Antarctic Ice Sheet, an event which could result in an increased rate of sea-level rise; programs to monitor the ozone hole and its potential impact on organisms; and programs aimed at examining the impact of global warming on Antarctica's atmosphere, hydrosphere, cryosphere, and biosphere.

6.3 International Cooperation

The scope of international scientific research in Antarctica has expanded greatly since the field programs of the 1957-1958 International Geophysical Year which involved 12 nations. Twenty-eight nations now operate field programs in Antarctica. Seventeen of them in 1995 operated 37 year-round stations; these 17 and other nations also operated summer programs employing ships, aircraft, land facilities, and camps. The nongovernmental Scientific Committee on Antarctic Research of the International Council of Scientific Unions has grown to include 25 full-member nations and seven associate member nations. The Antarctic Treaty has grown from 12 signatories in 1959 to 43 in 1997 of which, in addition to the original 12 signatories, 14 have achieved consultative (voting) status because they pursue significant scientific activity in Antarctica.

Close scientific and logistics cooperation is maintained between the U. S., New Zealand and Italian programs, including shared space in New Zealand, shared transport to the Antarctic, and other cooperation, including that between McMurdo and neighboring New Zealand Scott Base.

A noteworthy example of international cooperation is an ice core project at Russia's Vostok Station in East Antarctica, where about 30 researchers from the U. S., France, and Russia are studying the ice record, expecting to trace back possibly 500,000 years. Studies of ice cores at Vostok already have shown a close link between climate and changing greenhouse gases in the atmosphere over the past 200,000 years. The drilling will penetrate to 12,000 ft. depth, just above Lake Vostok, a subglacial lake beneath Vostok Station. Lake Vostok and any life forms it may contain are hypothesized to have been sealed off from the atmosphere for hundreds of thousands of years. This program is a shared effort, both logistically and scientifically, among the three nations.

A very large international program underway at South Pole station is AMANDA, the Antarctic Muon and Neutrino Detector Array, which utilizes the Antarctic ice sheet as the detector for a neutrino telescope. AMANDA is a collaborative project involving scientists from the University of Wisconsin, Madison; the University of California, both the Berkeley and Irvine campuses; the University of Stockholm and the University of Uppsala, both in Sweden; the DESY (German Electron Synchrotron) Laboratory; individual scientists at NASA's Jet Propulsion Laboratory; and the U. S. Department of Energy's Lawrence Berkeley Laboratory.

It is evident that substantial effort has been devoted to integrating as closely as possible the operational planning and development of U. S. science programs with those of other nations. The trend is toward increased international collaboration in science.

While international cooperation at the individual and project level has existed for many years and is strongly supported by the Panel, international cooperation in logistics has only recently been regularized among the national programs. This latter form of cooperation is also strongly encouraged by the Panel. The mechanism for increased logistics cooperation is the Standing Committee on Antarctic Logistics and Operations, a sub-committee of the Council of Managers of National Antarctic Programs formed in 1990. Logistics managers from approximately 26 national programs come together annually to coordinate their operations and have increasingly begun to share resources where mutually beneficial. The Panel finds that this increasing cooperation, while perhaps not greatly reducing the cost of national programs, has nonetheless mutually increased the effectiveness of the programs, and should be encouraged.

International funding of basic infrastructure and facilities, however, appears to the Panel to go beyond the authority of the Council of Managers of National Antarctic Programs and into unknown and potentially hazardous legal terrain. The Panel found, considering the geopolitical history of Antarctica outside the reach of the Antarctic Treaty system, that joint funding and/or ownership of infrastructure and facilities may lead to substantial international legal issues while producing little or no fiscal benefit. The Panel is mindful of the experience of the space program in international cooperation, but draws a strong distinction between joint ownership of a space station — where there are no territorial issues in contention — and the joint ownership of a facility at, say, the South Pole.

6.4 Facilities

As has been noted, Antarctica represents a harsh environment. The U. S. presence on the continent and the science conducted there depend on the specialized infrastructure and logistics capabilities that enable the U. S. Antarctic Program. Indeed, many of the U. S. assets and programs in Antarctica are unparalleled in scope or capability. Key support facilities cannot, however, be viewed as having the same degree of merit, particularly when compared to the relative investments and modern character of facilities supported by other prominent Antarctic nations.

New Zealand's Scott Base, for example, has an infrastructure roughly equivalent to the U. S. South Pole Station. Its coastal location admittedly poses fewer logistical challenges than those confronted at the South Pole, and the scope of New Zealand's scientific research is less broad than that of the U. S. program. Nonetheless, Scott Base is a far more modern and comfortable facility — as well as being a safer facility — yet is supported by a country with a population roughly one-third that of Los Angeles.

Even recognizing the pioneering nature of Antarctic research and those who pursue it, U. S. facilities in Antarctica, especially at the South Pole, are, in the judgment of the Panel, far below the standards that we demand in our most basic working and living environments within the U. S., including Alaska. Not only are these facilities in Antarctica extremely costly to maintain, but many fail to meet fundamental safety criteria and construction codes and are becoming a growing impediment to the continued conduct of world-class research. Review of maintenance plans and examination of cost data as well as on-site inspections have caused the Panel to conclude that it is impracticable simply to further stretch the life of the current infrastructure at the South Pole.

Many of the facilities at McMurdo Station show serious signs of deterioration. While McMurdo especially, and the U. S. Antarctic Program generally, have made exemplary progress in such areas as waste management, major systems need systematic upgrading to maximize efficiency, minimize operating cost, protect the environment and assure safety. An example is the station's 17 above-ground, steel, bulk fuel storage tanks that were installed between 1955 and 1968. Two additional tanks were built in 1993. The tanks have a combined capacity of 8.7 million gallons. Inspection of the older tanks during the 1992-1993 summer season revealed a large number of fabrication defects and subsequent areas of damage (Exhibit 50). As a result of the inspection, one tank was

Exhibit 50

Most of McMurdo's tank farm is old, and many tanks require repair or replacement to safeguard the fuel supply (delivered once per year by ship) and the local environment.

taken out of service and has not been used since. The inspection report recommended replacing all of the tanks as soon as is practical. Bulk fuel storage needs secondary containment to protect the environment from fuel spills. Complete secondary containment would be difficult and expensive to apply to the tanks currently located on hillsides above the station, yet effective secondary containment should be incorporated.

The kitchen and dining hall in building 155, which feeds everyone on the station, has health-related deficiencies. Building 58, the mechanical equipment center, presents a fire- and life-safety risk. Warehousing is in 15 dedicated buildings and 10 other buildings with some warehouse space; none has sanitary facilities, and the disparate locations require extra vehicle use and employee time. The energy efficiency of many facilities is low; maintenance of numerous poorly insulated, small structures consumes additional fuel.

6.5 Provisions for Capital Asset Replenishment

The Panel concludes that the lack of a clear process to systematically identify and budget for capital renewal of Antarctic facility components has led, and will continue to lead, to erosion of the USAP physical infrastructure. A major issue is the inability within the NSF budgeting process to make provisions for out-year funding that can be dedicated to systematic infrastructure modernization. These costs cannot be accommodated on a year-to-year *ad hoc* basis by merely curtailing research activity during the years when major failures occur or investment demands become otherwise acute. Most major infrastructure modernization projects will by their very nature be multi-year and represent significant costs, the burden of which should be spread over time or otherwise funded.

6.6 Life-Extension of Existing South Pole Facilities

The fundamental infrastructure of the current South Pole facility was constructed in the 1970s. It replaced the original South Pole Station which was built in the era of the International Geophysical Year; that is, the late 1950s. The original station had a useful life of approximately 20 years. It was built on-grade, was plagued with drifting snow, became buried, eventually failed structurally and has now been buried completely by snow — nonetheless having served as the first permanent research platform and habitat at the Pole. The current station was also built on grade but uses metal arches and a geodesic dome as its fundamental structural components. The dome provides a relatively large, covered area protected from winds and drifting snow (Exhibit 51). The adjacent arches provide strong structures able to better withstand snow burial for major support components such as power generators, fuel storage and maintenance.

As the research activity at the Pole expanded, three modern elevated structures (Exhibit 52) were constructed, one for berthing and the others for science, and a water well system (Exhibit 53) was added that In

Exhibit 51

Snowfall at the South Pole is less than a foot a year (which compacts to four inches of ice), but drifting is continuous and any surface object accumulates drift. The geodesic dome was built on the surface in the early 1970s; the footings now are some 20 feet below the adjacent drift. The upper picture shows upwind drift, with typical wind scour. The weight of downwind drift (which does not scour) in 1989 snapped the steel foundation ring, since repaired. It is becoming increasingly difficult to control the drift with dozers. As has happened with earlier Antarctic facilities built on snow, the surrounding terrain of gradually rising snow (lower photo, made February 1997) will eventually collapse against the dome and other structures and will impose unacceptable loads.

Exhibit 52

Elevated structures at South Pole Station. Modeling and analysis provide convincing evidence that structures on stilts will minimize snow accumulation. This astronomy research facility with two telescope platforms, the Martin A. Pomerantz Observatory, was dedicated in 1994. Closed-cell-foam insulation and solar panels dramatically reduce fuel requirements. The observatory is across the skiway from the dome and its associated central station facilities.

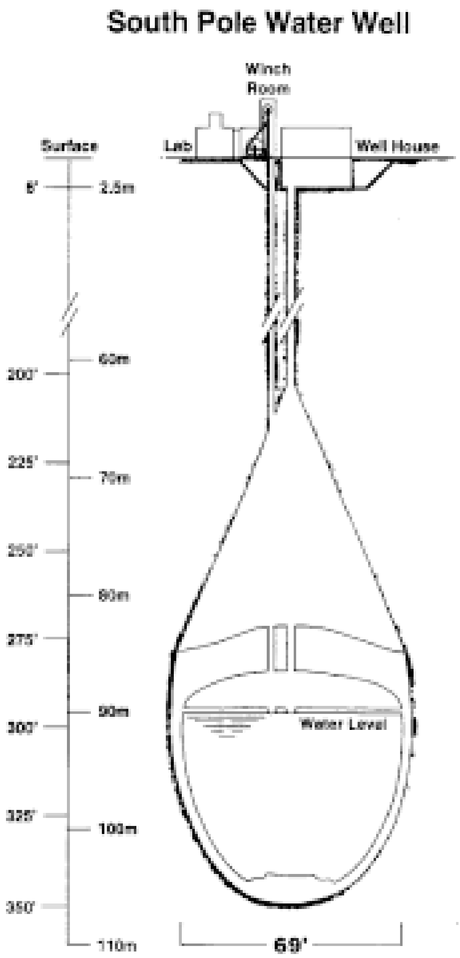


Exhibit 53

South Pole water well. South Pole Station sits on an unlimited supply of clean, fresh water— all of it frozen. Until 1994, traditional surface snowmelter technology was employed. This approach was labor intensive, cumbersome, and created a safety issue during daily trips to the "snow mine" in the austral winter. It only minimally met station needs.

Subsurface water reservoirs were first built in the 1960s for camps in Greenland. A similar design for South Pole was installed in 1992-93. The concept involves melting firn/ice at depth, creating a reservoir that can be pumped to the surface as needed. The impermeable firn/ice is both a container and an insulator. Being isolated, such a water well is less prone to contamination than is surface snow.

The well was made using a hot water drill to bore a one-ft. diameter hole to a depth of 230 ft. At this depth, the hot water jet melted an initial "bulb" of water. The drill was then replaced with a pump and a heating element consisting of an isolated circuit of fluid whose temperature is raised by heat exchangers on the exhaust stacks of the station's power plant. A numerical thermal model was developed to describe the relationships among water temperature and mass, reservoir size and depth and rate of change, and energy requirements as a function of time. The model shows that reservoir characteristics are strongly influenced by the rate and timing of potable water removal during the lifetime of the reservoir.

In early 1997 the reservoir was stable with an 80 ft. diameter and a 50 ft. height; the base of the bulb was 325 ft. below the snow surface. The reservoir contained about 180,000 cu. ft. of water compared to 70,000 cu. ft. of annual consumption. Waste heat from the power plant was more than adequate to maintain or grow the reservoir. Records from the first two years indicate that the well can be sustained for at least ten years. The well has reduced the cost per gallon of water from 75 cents to 10 cents and the annual cost from $422,000 to $57,000. Micrometeorites recovered from the well are being used in research.

Exhibit 54

These insulated canvas and wood structures, called Jamesways, were developed by the Army in the 1950s for use in the Korean War. Although heated, they lack plumbing and other amenities, but they can be assembled and taken down quickly and are air-transportable. The USAP still uses them for temporary camps at remote locations and for summer and emergency housing at South Pole Station.

dramatically increased the water available for use under the dome. Expansion of the summer population was handled through the use of Jamesway (Quonset-hut-like) structures for berthing (Exhibit 54).

There has been a continual evolution of the major utility and life support systems as the demands placed upon them grew with the increased level of activity at the station. These changes have been in the form of add-ons as opposed to replacements of major components. Simply stated, many of the major components of the current South Pole Station are at the end of their operational life.

The South Pole Station core facility, now in place for nearly 25 years, would take at least eight years to replace due to the short construction season and complex logistics train. The structural characteristics of geodesic domes have many advantages over standard post and beam construction, but are subject to structural failure if differential foundation settlement occurs. Several structural members did in fact fail in the late 1980s due to differential settling. In 1989, a major project was undertaken to repair and re-level the dome. Since that time, the snow elevation on the dome has been carefully controlled and annual surveys are performed to monitor the structural integrity of the facility. Currently, the elevations of the dome footings are within acceptable tolerances, but with each passing year the snow management effort grows and the probability of large differential settling increases. Consideration has been given to raising the dome, but that would only delay the structural failure of the dome and not correct the other basic deficiencies in the station.

The major structures at the pole in most cases do not meet current construction codes that serve as minimum standards in the U. S. Although some of the substandard conditions in the existing facilities are attributable to the trend toward more stringent codes and some can be eliminated through upgrading, to do so requires further investment in aging structures that have limited additional life expectancy and entail high maintenance costs. The already planned and funded upgrade of the vehicle maintenance facility, power generation plant, and fuel storage facility are critical to the continued use of the station, but they too do not address the underlying issue of the overall deterioration of the facilities in an unforgiving environment.

6.6.1 Cost Assessment Working with Decision Support Associates, Inc., the Office of Polar Programs developed an analytical model to conduct cost/benefit comparisons for various options for either rehabilitating the existing South Pole Station or building a new station. These studies combine conventional cost/benefit analysis and Monte Carlo computer simulation. Using standard failure probability distributions for each significant component of the station, 1,000 simulations were run for each option to determine the median expected cost and the 20 percent and 80 percent confidence intervals. All of the options considered assume the replacement of the garage (Exhibit 55), fuel storage (Exhibit 56) and power plant, as already approved in the FY97 budget for the South Pole Safety and Environment Upgrade Project, and therefore do not include the costs of these upgrades.

Exhibit 55

The South Pole Station garage (shown) is crowded, poorly ventilated and seriously contaminated with grease. Administrative measures, such as limiting mechanics' hours, have been taken to preserve worker safety and health. The Congress provided funds to the NSF in FY97 to replace this structure with a more suitable facility that will add to the efficiency and safety of station operations.

Exhibit 56

Nine 25,000-gallon rubber bladders were installed during construction of the 1970s Existing Station to hold more than a year's supply of diesel fuel. Funding for replacement of the bladders with steel tanks was provided in FY97.

the cost analysis of options involving construction of a new station, a total of $5 M for temporary quick fixes of random failures in the existing station has been included. Normal maintenance has not been included in any of the initial costs used to compare various options. However, for comparison of total life cycle costs (FY98- FY25), operating and maintenance costs were included throughout the period.

Four principal options for preserving a viable South Pole presence have been considered by the Panel, and appropriate cost data have been developed in conjunction with each option.

Option 1 - Rehabilitate the Existing Station
Option 2 - Rehabilitate the Existing Station and Incorporate Safety Features
Option 3 - Construct an Enhanced New Station (Option defined prior to this review)
Option 4 - Construct an Optimized New Station (Reduced cost relative to above Enhanced Station)

For the purposes of comparing the four options, all costs are expressed in FY97 dollars ... that is, no provision is made for future inflation.

The costs and benefits of each of these four alternatives are discussed in the following four sections of this report. Unless otherwise noted, all costs in Section 6.6.1 are in FY97 dollars to simplify the comparison of the various options. Thereafter, in addressing the matter of actually programming funds, then-year dollars will be displayed.

6.6.1.1 Rehabilitated Existing Station In this option, the life of the Existing Station (Exhibit 57) is extended by replacing systems as they fail or, where possible, as they approach failure. The features and

Exhibit 57

Existing Station (1989 photograph). The geodesic dome and the arches shelter mechanical systems and insulated structures within. This core facility has been in use since 1975. The arches had not yet been completely covered by drift when this photograph was made. Photo © 1989 Neelon Crawford.

capabilities of the replacement systems would be similar to existing systems, except that the new items would, where practicable, be upgraded to comply with current safety codes and standards. Most noteworthy, however, is that under this option certain aspects of the station — fire suppression systems, confined space in the utilidor, and emergency egress from the dome and arches — would remain unchanged due to the impracticality of upgrades. Under this option, the installation of replacement systems is constrained to fit within the existing dome and arches. The electrical systems would be replaced insofar as practicable to meet current industrial standards but no new capabilities or capacity would be provided.

The cost model for the Rehabilitated Existing Station was based on statistical predictions of the useful life of 20 individual systems. As already noted, the three most urgent system replacements (power, fuel storage, and garage) funded under the FY97 appropriations are not included in the cost model, although the implementation work remains to be accomplished. Of the remaining 17 systems, 10 have "most likely" failure dates prior to 2003 (Exhibit 58).

Since many of the existing systems are nearing the end of their useful life, it is likely that some will fail before their scheduled replacement. If a temporary fix can be made to allow a malfunctioning system to operate until a replacement system is available by sea transport, as is assumed herein, the median expected total cost of this option (FY97 dollars) is $79M through 2002. The corresponding cost through 2025 is $135M. Were this life extension option to be chosen, the most economical and effective strategy would be to begin

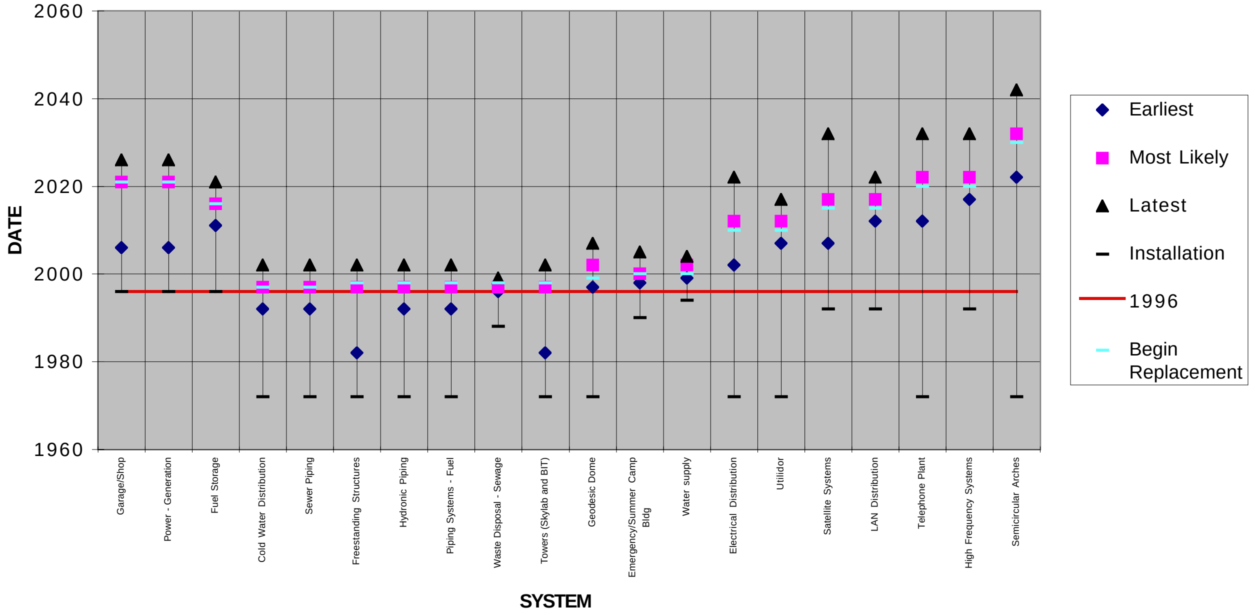


Exhibit 58

This graph predicts the earliest, latest, and most likely year of failure of 20 existing South Pole Station systems. It is part of a study performed by Decision Support Associates for the National Science Foundation.

replacing systems before their most-probable failure dates. This approach was used in developing the costs that form the basis for comparing the various options.

6.6.1.2 Safety Upgraded Station This option is identical to the Rehabilitated Existing Station option except that station-wide fire suppression is provided, exit stairways are added to the dome and arches, and, because of extremely confined space, the undersnow utility corridor (utilidor) (Exhibit 59) is replaced. The median total expected cost (FY97 dollars) is $88M through 2002 and $144M through 2025.

6.6.1.3 Enhanced Station The Enhanced Station option resulted from a long-term planning effort over the past several years to provide a facility that would offer the most potential for science productivity at the South Pole (Exhibit 60). It provides for living accommodations, science laboratories, communications, and administrative areas to be relocated to an elevated three-building complex adjacent to the existing facilities. Industrial functions such as the garage, power plant, fuel storage, sewage treatment, and warehouses variously remain in the existing arches or new arches. All current open storage is relocated so as to reside within the arches, and all existing buildings and utilities within the dome and arches are removed from the continent. Electrical and electronic systems are replaced with state-of-the-art equipment. The dome is dismantled and removed from Antarctica in

Exhibit 59

The utilidor, or utilities tunnel, through the ice beneath Amundsen-Scott South Pole Station is -50˚F. Plumbing leaks in this aging system must be stopped quickly to minimize the buildup of additional ice on the floor. Because of the confined space, tools and parts must be brought into the utilidor by hand.

keeping with established environmental practices. Exhibits 61 and 62 compare the design parameters and capabilities of this option with those of the current station.

The proposed concept utilizes two forms of modularity. First, the structural system will be modular and panelized to facilitate standardization of components. Because of size limits of the LC-130 transport aircraft, modular “room size” building blocks cannot be

Exhibit 60

Enhanced Station option (artist's conception). Dashed lines indicate the arches of the Existing Station (by then to have been buried by drift); the arches are used in the Enhanced Station for storage and other functions. The Existing Station's dome is removed from Antarctica.

used, but the floor and roof panels will conform to a standard module size of approximately 7-1/2 ft. wide and up to 34 ft. long. The second level of modularity will be on a much larger scale. Each wing of the two main elevated buildings will be modular in nature to allow phased construction and ease of modification should that be desired in the future.

The cost model for the Enhanced Station is based on a rather detailed estimate generated in 1995, modified to exclude the aforementioned $25M cost of the new power plant, garage, and fuel tanks that have already been funded in FY97. The median expected cost for the Enhanced Station is $150M through 2002 and $189M through 2025.

6.6.1.4 Optimized Station The Optimized Station option is similar to the Enhanced Station option except that as a cost saving measure the elevated complex is reconfigured to two buildings rather than three and various systems are reduced in scope or deleted to reduce costs (Exhibit 63). The below-grade elements are unchanged from the Enhanced Station

Service Provided	1996 Conditions	Enhanced Station	Optimized Sta.
Population			
Science Personnel - Summer	43 scientists	46 scientists	Same
Support Personnel - Summer	67 persons	64 people	Same
Construction Personnel -Summer	65 persons	None	Same
Winter Population	26 total with 7 scientists and 19 support	50 total with 19 support. Additional mix of population will depend on science tasking	Same
Fuel storage capacity			
Diesel Fuel	225,000 gallons (bladders), being replaced with 300,000 gallons (steel)	400,000 gallons (steel)	Same
Area Comparisons (sq.ft.)			
SPSE			
Heated Space	N/A	15,274	15,274
Unheated Space	N/A	11,117	11,117
SPRP			
Heated Space	N/A	79,688	74,554
Unheated	N/A	30,104	28,324
Totals			
Heated Space			
Science	11,500	16,126	15,754
Support	32,894	78.836	74,074
Unheated Space	57,753	41,221	39,411
Combined Total	***102,147***	***136,183***	***129,269***
Satellite Communications			
ATS -3	6 hrs @ 1.2 kb/s, no internet capabilities	6 hrs @ 1.2 kb/s, no internet capabilities	Same
LES-9	7 hrs @ 28-36kb/s, internet capabilities	7 hrs @ reduced rates	Same
GOES -2		5 hrs @ 64 - 128 kb/s	Same
GOES 3	5 hrs @ 512-1,544kb/s, internet capabilities	5 hrs @ 128 kb/s, internet capabilities	Same
LAN access	Limited science and support areas	All science and support facilities as well as access being available in bedrooms	Same
LAN Distribution	Simple IEEE 802.3 Ethernet, limited subnetting; mixed coaxial/fiber backbone, non redundant	High bandwidth, high reliability backbone with fully managed components, state of the market design	Same
Telephone	Ham and satellite patch capable	Direct public network telephone via satellite, duplex	Same

Exhibit 61

Capabilities of Existing, Enhanced, and Optimized South Pole Stations. In area comparisons, SPSE (South Pole Safety and Environment Enhancement) is work funded in FY97. SPRP (South Pole Redevelopment Project) is the work considered for funding in FY98-FY02.

Service Provided	1996 Conditions	Enhanced Station	Optimized Station
Water Distribution	Dome and arches. Summer camp has individual systems in bathroom modules	Habitat and science areas in the elevated facility	Same
Electrical Distribution	Upgrades have corrected code deficiencies. Limited EMI suppression. Limited flexibility	Improved distribution with enclosed cable trays, designed EMI mitigation system, efficient, clean electrical distribution	Same
Emergency /Summer Facilities	Upgrades ongoing to emergency power and berthing facilities but they remain marginal. Snow drifting maintenance concerns. Substandard exiting from sleeping rooms and no fire suppression	Emergency facilities will be provided within the elevated facility with the emergency power plant and berthing with in a single wing. All berthing facilities within the elevated facilities will have fire suppression	Same
Main Station Facilities	Below grade habitat needs replacing due to aging, thermal efficiencies and non-compliance with current codes	All habitat facilities will be above grade maximizing the use of renewable energies, minimizing drifting, thermally efficient, and in compliance with current building codes	Same except delete fuel cell and wind turbine. Photovoltaic and other renewable projects remain
Geodesic Dome	Existing structure is a snow drift concern, a fire /smoke concern and has limited usable space within the facility	The enclosed heated space existing within the dome would be provided in the elevated structures	Same
High Frequency systems	Manual HF radio operations, aging infrastructure, SSB PTT voice	Automatic HF radio system, new infrastructure	Same
Arches	Current arches are effective enclosed cold facilities	New concept maximizes the efficient utilization of the existing structures	Same
Sewer Collection	Sewer is undergoing constant maintenance of four isolated systems	New distribution systems will be incorporated in the elevated facilities and connected to subsurface utilidors reducing the number of systems	Same
Sewage Disposal	Discharge into four sewer sumps in the snowfield	Based on results of environmental studies and technological advancements, sewage disposal systems may be incorporated into the station. One sewage sump will service the entire station	Continue with current procedures
Utilidors (sub-grade utility ducts	Space limited; violates OSHA standards for confined space	Maximize use of enclosed passageway in elevated station and arches. Utilidors where required will meet confined space requirements	Same
Water Supply	Current facilities require three water supply systems to accommodate summer camp and the one in the main station	The water supply for this facility will come from a single treatment source. The supply will be the sub-snow-surface water well	Same
Precision Approach Radar	None, removed in the 95/96 season	Replace system that was identified in the 1994 programming documentation	Deleted
Hydroponics	80 sq.ft.	480 sq. ft	300 sq.ft.

Exhibit 62

Design parameters of Existing, Enhanced, and Optimized South Pole Stations. EMI = electromagnetic interference. SSB = single sideband. PTT = push to talk.

option except for the sewage treatment and alternate energy arch, which are deleted.

Exhibit 64 summarizes the $30M reduction in cost relative to the Enhanced Station due to reduced requirements, lower cost of implementation, and deletion or deferral of energy technology and environmental technology development.

6.6.2 Comparison of Costs Exhibit 65 compares the costs of the various options considered by the Panel.

Sensitivity analyses were conducted to determine confidence levels for the cost estimate associated with each option. It was found that these variances are essentially the same for each case considered, with the 80 percent confidence level adding approximately $6M in each instance. The Panel has not included any contingency provision, although it notes that this represents a departure from commercial practices.

The Panel concluded, as will be discussed in Section 7, that the most cost effective alternative, in terms of function and total cost to the government, is

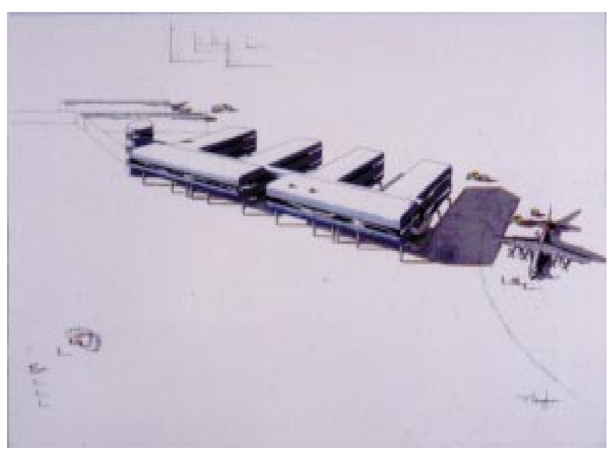


Exhibit 63

Optimized Station option (artist's conception). Dashed lines indicate the arches of the Existing Station (by then to have been buried by drift); the arches are used in the Optimized Station for storage and other functions. The Existing Station's dome is removed from Antarctica.

$M	Items Reduced or Eliminated
Reduced requirements	
1.5	**McMurdo aircraft fuel storage.** With the reduction in fuel usage at McMurdo during the past four years due to better energy efficiency, additional projected storage requirements have been eliminated.
5.6	**Precision radar.** Extensive review of the requirement for precision radar landing assistance at South Pole has been ongoing for two years. The Navy and Air National Guard concluded in 1995 that the precision radar may not be beneficial, and have been operating without precision radar for the past season without adverse impacts on safety or operations.
0.7	**Mobile laboratories.** Two mobile laboratories, one for chemistry and one for snow and ice research, were identified as a requirement by the science community in 1989, but current funding will not allow expansion in these fields at present.
1.9	**Tunnel to dark sector.** A personnel tunnel between the main station and the dark sector was determined in the early 1990s to be desirable for safety reasons. The tunnel would also function as a utilidor for power and communications. Experience during the past 3 winters has shown that personnel can commute to the dark sector on foot without a tunnel, and utility cabling can be buried. The tunnel is desirable, but is not an absolute requirement.
Value engineering	
10.6	**Number of buildings in station.** Floor plans were revised to consolidate functions, improve space utilization, and reduce utilities/mechanical requirements relative to the earlier three-building design. The greenhouse was reduced in area. The 1,200-line-item schedule and estimate were revised for the two-building concept. The ability to expand the station at a future time still exists, but expansion will be slightly more difficult.
0.7	**Marisat.** Marisat, to a considerable extent, duplicates capabilities that will be provided by the GOES satellite system which is included.
0.4	**Aviation computing.** This requirement can be met with the proposed new station computing system.
Energy/environmental technology deferral	
2.0	**Fuel cells.** The technology of fuel cells that operate on JP8 has not yet advanced sufficiently to allow their deployment as part of a new station. The Office of Polar Programs will continue to monitor their development and use them when cost effective.
1.8	**Wind power.** Recent analysis indicates that wind turbines at South Pole are probably not cost effective. Photovoltaic and solar heating appear to be cost effective and remain in the plan.
4.6	**Sewage treatment.** NASA is developing a prototypical sewage treatment system for South Pole Station. The system is in a preliminary development stage and its performance is unverified at this time. The cleaner effluent produced by wastewater treatment would still be discharged into the ice sheet. Wastewater treatment would increase operations and maintenance cost for relatively modest environmental gain. The Office of Polar Programs environmental officer agrees that sewage treatment can be deferred and incorporated at a later time using proven technology. The Memorandum of Agreement with NASA needs to be reviewed to clarify NSF obligations on this development project.
$29.8M	**Total cost reduction**

Exhibit 64

Reductions (in FY97 dollars) from the Enhanced Station option to achieve the Optimized Station.

	Through 2002 (construction and quick fixes)	Through 2025 (construction, quick fixes, operation and maintenance)
Rehabilitated Existing Station	$79M	$135M
Safety Upgraded Station	88M	144M
Optimized Station	120M	159M
Enhanced Station	150M	189M

Exhibit 65

South Pole Station median expected cumulative costs (FY97 dollars). Costs through 2002 include construction and quick fixes of systems that fail in the existing station while it is still in use. Life-cycle costs through 2025 include construction, quick fixes, operation and maintenance. Note that the life-cycle cost difference between the Safety Upgraded Station and the Optimized Station is approximately 10 percent.

the Optimized Station option. This case will therefore be used in the following Section as the baseline for determining budgetary requirements.

6.7 Level Funding

All costs pertaining to budgeting for a new station will be presented in "then-year" dollars since these are the measure to be used in Government budgetary decisions.* The Panel used the FY97 budget as the baseline for evaluating a so-called "level funded" U. S. Antarctic Program. The purpose of this assessment was to seek ways to fit the needed improvements to the U. S. facilities in Antarctica under a "flat budget" constraint. This assumption results in the funding availability shown in Exhibit 66.

		Actual FY97		FY98-FY02 (5X)
Science Grants	$30.5M		$152.5M	
Science Support	41.0M		205.0M	
Total Science		$71.5M		$358M
Operations		$59.4M		$297M
Logistics (DoD)		$62.6M		$313M
Total USAP		**$193.5M**		**$968M**

Exhibit 66

Available funding (level profile). Assumed USAP "level" budget, FY98-FY02, in then-year dollars. Total five-year estimates are simply five times the FY97 figure, thus it is implicit that inflation has somehow been offset.

The level funding scenario in Exhibit 66 assumes that inflationary effects will be offset by improved efficiencies, a reduced level of effort, a compensating increase in budget, or a combination of the three. The Panel considers such actions to be part of the baseline program under a level funding scenario and has made no explicit provision for their consequences in the discussion which follows. However, it is noted that in the absence of either budgetary increments to offset inflation or a corresponding improvement in efficiency, the level of effort in FY02 would have to be reduced by some $20M relative to FY97, with a cumulative reduction of $61M for the period FY98-FY02. This would have a serious negative impact on the level of activity and productivity of the USAP. *Further, the Panel notes that many non-governmental sources of future inflation rates provide estimates which significantly exceed the government's values used herein.*

6.7.1 Additional Program Costs (FY98-FY02)

The principal additional cost during the five-year period FY98-FY02 is the construction of a new South Pole Station. The estimated fiscal year cost profile for the Optimized Station (the Panel's recommendation - see Section 7) is shown in Exhibit 67 both in FY97 dollars and in then-year (TY) dollars, assuming that costs will on average be incurred one year after obligation. Included in the numbers are the median estimated costs for quick-fixes for system failures in the existing station prior to its replacement.

	FY97 Dollars	Then-Year Dollars
FY98	26.2M	27.3M
FY99	30.9M	33.0M
FY00	26.3M	28.7M
FY01	25.4M	28.3M
FY02	11.3M	12.9M
Total	**120.1M**	**130.3M**

Exhibit 67

Funding schedule for the South Pole Optimized Station. Each entry includes $5M for quick-fixes to keep the existing station viable until the Optimized Station is ready. Then-year dollars (TY$) assume annual inflation of 2.2 percent, the rate used when these costs were estimated, and assume outlays occur one or more years later than budgeted.

As discussed in section 6.13, the Panel has identified a limited number of near-term infrastructure needs at McMurdo and Palmer Stations. Estimated cost augmentations for the eight systems potentially needing attention at these locations total $32.3M (Exhibit 68).

Although the Panel concludes that the construction of the new South Pole Station should be afforded highest priority, the Panel nonetheless believes that a minimum of $15M must be invested at Palmer and McMurdo Stations during the forthcoming five-year period. Failure to do so will simply place these installations on the same path that has led to the operational and budgetary problems now being encountered at South Pole Station.

6.7.2 Potential Cost Offsets (FY98-FY02) The transition of activities of the Naval Support Force Antarctica to the NSF and NSF contractors, and those of the Naval Antarctic Support Unit in Christchurch to

* Estimated costs in "then-year" dollars assume inflation of 2.2 percent each year from FY97 forward, which was the rate being used by the Government for estimating future inflation at the time cost estimates were made. If the Government's estimated inflation rate is revised, the numbers shown herein should be adjusted accordingly.

	Cost, $M
FACILITIES	
Fuel Tank Replacement	6.0
Galley Upgrade	1.5
Mech. Equip. Center Replacement	1.4
Fire Suppression (Dorms)	1.9
Sewage System	2.5
Total	13.3
EQUIPMENT/COMM	
Air Traffic Control (Ops)	4.0
Power Plant	3.0
Vehicle Fleet Replacement	6.0
Communications Modernization	6.0
Total	19.0
TOTAL, Candidate Items	**32.3**
Minimum Recommended, FY98-FY02	15.0

Exhibit 68

Estimated cost of McMurdo and Palmer infrastructure improvements, then-year dollars.

an NSF contractor, are expected to yield cumulative savings of approximately $19M in FY98-FY02. In addition, the transition of LC-130 operations from the Navy to the Air National Guard (ANG) has been estimated to yield savings of approximately $25M. Thus, these savings, given aggressive management, can be expected to total $44M during the next five-year period. Nonetheless, because of the uncertainty of the estimates and the expectation that certain unbudgeted safety upgrades of the LC-130 aircraft will be required, the Panel has discounted the savings from the transition to a total of $30M.

Cost savings in addition to those just cited can be achieved through temporary reductions in the level of science activity during the five-year period when South Pole Station is being redeveloped. For example, temporarily reducing five percent of the science grant funding and six percent of the science support funding over five years can provide $20M to partially offset the cost of constructing the replacement South Pole Station. Some reduction in the level of scientific activity during this period would very likely be necessary in any event as logistics resources are partially reassigned to support the construction effort. It is noted that because of the large fixed cost component of science support activities in Antarctica, a six percent reduction in *total* science support funds would require a much higher percentage reduction in terms of science support field capability. It is recommended that this reduction in activity in Antarctica be partially offset by increased analysis and preparation at the investigators' home institutions so as to reduce the impact on the research and graduate training program.

The Panel notes that since South Pole science will be the principal beneficiary of the new station, a temporary reduction in science and science support at that location during the construction period is appropriate. Exhibit 69 shows science and support costs by location.

	Science Grants	**Science Support**
Palmer Station	$ 25.0M	$ 6M
South Pole Station	35.0M	21M
McMurdo Station	17.5M	10M
Field camps	52.5M	83M
Research vessels	22.5M	85M
Total USAP	**152.5M**	**205M**

Exhibit 69

Estimated USAP science grants and science support costs, FY98-FY02, in then-year dollars. A total reduction of $20M in science and science support during funding of construction of the new station at the South Pole is considered reasonable and appropriate by the Panel.

6.7.3 Summary (FY98-FY02) The additional costs required to construct an Optmized Station (relative to the FY97 level of spending), and potential offsetting cost reductions, are summarized in Exhibit 70, with all figures shown in then-year dollars.

As shown in Exhibit 70, a net five-year augmentation of $95M is required beyond that available in a level funded USAP budget. Exhibit 71 presents the profile of the additional funding needs in then-year dollars using the prescribed inflation rate and making no provision of a reserve for contingencies. (A reasonable contingency, based on commercial practices, would be $6M.)

Cost Requirements		
South Pole Station (Optimized)	$130M	
McMurdo/Palmer Infrastructure	$15M	
Total Additional Costs		**$145M**
Cost Reductions		
Transition from Navy Operations	$30M	
Science Grants and Support	$20M	
Total Cost Reductions		**$50M**
Net Cost Augmentation Required		**$95M**

Exhibit 70

USAP level cost five-year (FY98-FY02, then-year dollars) budget assessment using Optimized Station option for South Pole. (Quick-fix costs to repair failures in existing station prior to replacement are included.)

This $95M shortfall represents an $81M reduction relative to previously proposed options, made possible by a temporary reduction in science and science support ($20M), reduced operating costs ($30M) and adoption of a more austere station design ($31M).

Year	Incremental Funding needed	Offsetting Reductions	Shortfall
FY98	28.30	1.60	26.70
FY99	34.90	2.44	32.46
FY00	33.35	13.73	19.63
FY01	31.95	13.73	18.22
FY02	16.70	18.50	-1.80
Total	145.20	50.00	95.20

Exhibit 71

U. S. Antarctic Program funding shortfall, FY98-FY02, in millions of then-year dollars. This is one possible profile intended to approximate the USAP requirement. It assumes otherwise level USAP funding (Exhibit 66). Incremental funding needs include the South Pole Optimized Station (Exhibit 67) and improvement of McMurdo and Palmer stations (Exhibit 68). Offsets include reallocations or decreased costs from reducing science and science support, consolidating LC-130 operations in the New York Air National Guard, transferring functions from the Navy to an NSF contractor, and improving managerial approaches.

6.8 Safety and Health

Based on its review of relevant health and safety documentation, the testimony and written reports provided by both internal NSF and external experts, and its site visit to the South Pole Station, the Panel finds that the living and working conditions of U. S. personnel at South Pole Station are increasingly unsafe and that the point of unacceptability has been, or soon will be, exceeded.

The Panel also finds that the NSF has made significant improvements in the overall health and safety of operations in the U. S. Antarctic Program since the Safety in Antarctica report of 1988. These improvements include major changes made at the South Pole Station such as the construction of several modern buildings for both housing and scientific research, and the provision of additional emergency exits from certain buildings. Indeed, during the time the Panel conducted its investigations, several of the most critical health and safety hazards were being eliminated through the commitment of funds to construct a new garage and to replace the existing fuel bladders with stainless steel tanks. Additional interim measures, both physical and procedural, are being implemented in the garage area to improve the health and safety of the staff prior to the availability of the new construction, albeit at a loss of efficiency to the operation.

Nevertheless, the continuing gradual degradation of most of the working and living spaces, particularly those under the dome, and the aging infrastructure as a whole have inexorably increased the threat to life, property and program to the point where further delay in the decision to either replace the station or immediately initiate major safety retrofits to the existing station would be inadvisable. While many code violations in the existing structures can be documented (not altogether unusual for 23-year-old structures), the cost of refurbishing the existing station to bring it into compliance with current Uniform Building Code and National Fire Protection Association safety criteria would be excessive, if indeed it could be done at all.

Mr. Jon Kumin, a registered architect with 20 years of experience designing facilities for use in extreme cold climates (principally the Alaska North Slope), personally inspected the South Pole Station in 1995. In a report to the Panel, he expressed his belief that certain of the structures under the dome, including the berthing facilities, would not be allowed to be occupied were they located in Alaska. Mr. Kumin concluded his report to the Panel as follows: “A final point — it will take about six years to design, construct and occupy a new facility. Continued delay in addressing the issues discussed above requires a continuation of the good fortune enjoyed to date.” The Panel does not believe that the safety of U. S. personnel living and working at the South Pole Station should be left to “continued good fortune,” but rather to an immediate decision to replace the current station with a new station consistent with current design standards and safety codes enjoyed by U. S. citizens elsewhere — even in highly challenging environments.

While the Panel addressed much of its attention to the particular health and safety issues at the South Pole Station, it also encountered several matters at McMurdo Station which also need attention. Of particular note, the Panel found that the cold food storage operations at McMurdo are unsafe and that improvements in this operation should be given high priority. Frozen food is currently managed in a large freezer warehouse, from which retrieval is precariously performed by hand from stacked heavy boxes, many feet above the floor. The hazard should be eliminated through implementation of modern rack retrieval equipment.

6.9 Management Effectiveness

The Panel finds that the NSF has met the challenging management tasks of the USAP with professionalism and diligence. The Office of Polar Programs of NSF deals with an exceptionally broad range of scientific subjects (truly from the “a” of astronomy to the “z” of zoology) and has done an excellent job of fostering quality science across this spectrum of topics. Further, the USAP involves not only administration, design, and implementation of scientific programs but also the management of extensive logistics and extremely complex infrastructure functions. Indeed, the scope of the Antarctic Program management task is comparable in many ways to that of operating three small towns — but in an extraordinarily unforgiving environment that places a premium on sound planning — using a mix of governmental and contractor personnel working in a manner unlike that of any mayor/manager/council. Examples of recent management successes include the safe clean-up of accumulated hazardous wastes, community compliance with both the spirit and letter of waste procedures, construction of modern living quarters at McMurdo Station, and the establishment of new research directions. The opportunity to further reinvent the U. S. approach to activities in Antarctica will be presented in the near-term, particularly those associated with changes in military to civilian support, clarifications of authority and responsibility, identification of needs via a dynamic planning process, and implementation of cross-discipline versus functional budgetary control.

6.10 Ongoing Facility Improvements

The Panel examined the approach to cost reduction carried out by the NSF to date. The Panel concludes that the NSF has done an excellent job of achieving efficiencies within the USAP. In particular, NSF has systematically examined and capitalized on opportunities for savings through investment, redesign, and transfer of functions from military to civilian support. For example, investment in updated weather equipment has reduced the number of turn-around flights, substantially cutting the cost of air operations. Design and implementation of the mobile runway support facility has improved the Williams Field operations and generated significant savings in fuel and capital investment (Exhibit 72). The transfer of galley operations to civilian contractors has resulted in cost savings, and transfer of air ticketing for civilian employees to a civilian contractor has reduced the cost of air travel. Cargo handling has been greatly modernized, with a new tracking system in place that enhances the ability to accurately monitor cargo movements. Improvements have been achieved in inventory control, and cost savings have been realized through long-range planning to maximize the use of relatively low-cost cargo ship transport rather than airlift. Helicopter operations have been privatized with considerable attendant savings while maintaining a high degree of safety and customer responsiveness. Exhibit 73 provides another example of a recent USAP cost avoidance measure.

Exhibit 72

Mobile runway support facility. As the U. S. Antarctic Program transitions from military to contract support for all functions except LC-130 operations, efficiencies, improved performance and cost changes are being achieved sometimes by reduced personnel levels, but often through managerial or technological changes in the way the work is performed.

Williams Field is McMurdo's skiway complex on the Ross Ice Shelf that is used by ski-equipped Hercules (LC-130) airplanes during the months that wheeled takeoffs and landing at McMurdo's two hard ice runways (one on sea ice and one on glacier ice) are not possible. Formerly, the 150 or so people who operate Williams Field lived in berthing at the site. Now they commute daily the six miles from McMurdo. The change has reduced the labor to operate the facility from 800 to 150 person-weeks per year, has reduced fuel consumption from 180,000 to 136,000 gallons per year, and has reduced the installation cost for facilities (required every 7 to 10 years for the older facility because the Ross Ice Shelf is in motion) from $8.2M to $5.1M.

Additional cost savings are expected to be achieved as the transition of air transport operations to the ANG is finalized. Still further, efficiencies can be achieved through modernized approaches to coordination of the personnel, cargo and inventory tracking systems. Overall, the Panel concludes that the most obvious sources of cost reductions are already being pursued by the NSF, although, as will be discussed in Section 6.15, additional opportunities remain.

6.11 Cost Visibility

As noted in Section 5, the continuing presence of the U. S. in Antarctica is motivated by several factors. While science is a prime and enduring objective, it is not the sole force behind the U. S. Antarctic Program. Hence, it is difficult to evaluate the true total cost of individual scientific projects, since the facilities and infrastructure in which science is carried out exist not only for scientific reasons but also because of geopolitical and stewardship considerations.

Exhibit 73

Reverse osmosis water production at McMurdo Station. Sea water is desalinated to make McMurdo's supply of domestic fresh water. In 1994 a reverse-osmosis system was installed to replace aging flash evaporators. The shift increased the amount of water available, permitting daily showers for the first time for all residents, and it cut the per-gallon cost in half, from 14 cents to 7 cents. The annual cost to operate and maintain the new system dropped to $52,000 (from $187,000 for the old one). Installation cost for the new unit was $1,018,000, substantially less than the flash evaporator installation cost of $1,650,000.

Within the current USAP, scientific proposals are peer reviewed on a merit basis as are all other proposals to the National Science Foundation. The budgets used in evaluating proposed projects in general include only the university-based and "off-Ice" costs, such as graduate student support, investigator salaries, research equipment unique to the project, and institutional overhead. While funding for the operational infrastructure needed "on-Ice" for the program as a whole may be considered separately, the direct science support cost attributable to individual projects including such items as helicopter support, personnel per diem while in the Antarctic, etc., are not currently included in the direct proposal evaluation process. Consideration of such science support costs — along with scientific merit — in the proposal assessment by peer reviewers could help to achieve cost reductions and motivate researchers to better contain their own science support costs. This would aid the NSF in constructing a balanced program that optimizes science within the overall available budget, including that for infrastructure and support. It is the conclusion of the Panel that insufficient visibility of overall project costs hinders the most efficient use of available resources by both the NSF and its researchers.

6.12 Personnel Issues

The Panel held (voluntary) town meetings at McMurdo and at South Pole Stations, which were attended in total by over 300 individuals. It also met with individual scientists and support staff at both locations as well as at field sites in the Dry Valleys. The scientists, support staff and construction personnel were in general found to be highly motivated individuals willing to work long hours under extremely difficult conditions. It was noted that some individuals are attracted to work in Antarctica in part because of the adventure, danger and hardship that are an inevitable part of working at the bottom of the Earth. In fact, some individuals at South Pole Station were concerned that any redevelopment project might diminish the excitement of being at the Pole — where a generally healthy "can-do" ethos has been generated over the years. Most individuals were very interested in improved communications, especially since the one air drop to South Pole and McMurdo conducted during the winter has been discontinued as an economy measure. The town meeting at McMurdo revealed an interest in having professional counseling available to help work out personal problems which arise from time-to-time.

Also, concerns were expressed which suggested that a review of the management approach by the current food service operator might be in order. Much as Napoleon observed that "an Army travels on its stomach," food takes on extraordinary significance in remote locations with few human outlets beyond working, sleeping, eating and surviving. The Panel has subsequently learned that the food service problem has been corrected and that the NSF is planning for counseling as part of the transition from Navy to contractor medical services. The longer term goal is to reduce or eliminate factors that contribute to stress.

6.13 Support Capacity

The Panel concluded that support elements in Antarctica are fully taxed with the shape and pace of today's operations, causing deferral of projects that would significantly contribute to a modernized, efficient Antarctic presence and scientific capability.

Capital improvements and renewal projects are generally funded from within the operating budget and are vulnerable to the vagaries of what funds might be available in any given year. The resulting understatement of capital requirements jeopardizes an orderly modernization program. Deterioration of the plant then generates greater maintenance costs, which in turn further reduce the ability to properly remedy a growing capital backlog.

The Panel noted a number of conditions extant in the logistics structure located at the principal Antarctic support base, McMurdo Station, which are inconsistent with efficient, effective operations. These concerns include:

- **Heavy Equipment/Vehicle Fleet** The task of maintaining a totally nonstandard fleet (some components from the IGY-era) (Exhibit 74) makes operations very difficult, including the need to keep runways operational — the key to Antarctic operability.

Exhibit 74

Vintage equipment in the heavy vehicle fleet. One of several remaining low ground pressure D8 bulldozers. Caterpillar built about 10 of these units in the 1950s for the International Geophysical Year. Their primary role was to tow heavy sled trains across the ice shelf and parts of the plateau during early exploration and station development (Little America, Byrd). By the 1960s, the U. S. Antarctic Program was concentrated at Palmer, McMurdo and South Pole and no longer conducted long traverses. Modified only by removing the huge fuel tanks, the D8s became station workhorses for tasks for which they are still used (e.g., towing fuel tanks, moving portable buildings, snow grooming; pushing snow to keep Williams Field level, winching equipment from the sea bottom that has fallen through the ice). Despite their dwindling reliability, poor operator comfort and long-ceased parts support, dedicated mechanics have kept these uniquely capable machines operating over the years. Photo courtesy of G.L. Blaisdell, CRREL.

- **Electrical Generation Plant** Although all five generators are of the same age and are nearing the end of their predicted life, there is not a funded plan for phased replacement of these items.
- **HF Transmitters** Transmitters providing for vital aircraft and other communications are obsolete, no longer supported by the original vendor or the Navy. Equipment configurations do not lend themselves to automation, and maintenance is intensified.
- **Warehouses** The lack of a modern inventory system in a number of locations causes shortages, overages, excessive demands of operator-time, and losses due to shelf life expiration.
- **Local Area Network (LAN)** An insufficient number of modern workstations, exacerbated by the incompatibility of operating systems, produces significant inefficiencies. For example, a modern, integrated information infrastructure could potentially obviate the need for costly warehouse centralization.
- **Fuel Tanks** The present condition and capacity of fuel storage threatens continuing environmental compliance and precludes the achievement of economies.
- **GPS Navigation System** Modernization of the aviation navigation system with a system based on GPS (Global Positioning System) would provide both enhanced capability and a reduction in ground personnel required for operations.
- **Galley** Basic structural problems threaten the long-term viability of the facility and jeopardize human services.
- **Dormitories** Significant energy losses and configuration layout constrain creature comfort and efficiency in those buildings not yet modernized.
- **Recreation** Productivity and a spirit of community is adversely affected due to the lack of adequate wellness facilities.

6.14 Management Structure

The current management structure has evolved over a period of years since the Navy first began providing support for U. S. Antarctic activities. During the 1957-1958 International Geophysical Year, the NSF expanded its traditional role of funding U. S. science activity to include Antarctic science. With the 1959 Antarctic Treaty guaranteeing freedom of access for scientific and other peaceful purposes, the U. S. began a long transition to decrease military involvement in Antarctica. Later reductions in defense spending, coupled with the desire to obtain increased operating efficiency, resulted in further reductions in military involvement. As the Navy's role decreased, the NSF moved further into the role of providing support functions. With the cooperation of all involved, the support structure has been made to work remarkably well during the still-ongoing transition period.

The existing organization evolved over three decades of gradual transfer of functions and control from the Navy to the NSF and to support contractors and other government agencies. In 1968, the first civilian prime contractor, Holmes and Narver, was selected to complete the construction of the South Pole Station and to assume operational control of the Pole, Palmer Station, parts of McMurdo and all research vessels. ITT Antarctic Services held the support contract during the 1980s, and in 1990, Antarctic Support Associates (ASA, a joint venture of EG&G, and Holmes and Narver) was selected as the prime support contractor and fills that role today.

As the Navy transition began, the NSF moved additional functions under the prime support contractor. But today, ASA contracts directly with Ken Borek Air for Twin Otter aircraft support, Edison Chouest for the *R/V Palmer* and *R/V Gould* research vessels, and Rieber Corporation for the *Polar Duke* vessel. NSF contracts directly with PHI for the operation of Antarctic helicopter aircraft. The Department of Interior, Office of Aircraft Services, assists NSF in the administration and oversight of the helicopter contract — as it does for a variety of other U. S. Government agencies. It is unclear why ASA, which provides all tasking for helicopter operations, does not contract directly with PHI — as it does for other contractor aircraft.

The Naval Command, Control, and Ocean Surveillance Center in Service Engineering, East Coast Division (NISE-East) located at Charleston, SC, is the Navy's executive agent for Air Traffic Control (ATC) and meteorology and will provide civilian contractor personnel and manage the ATC and weather forecasting functions in Antarctica. The Panel believes that it is in the USAP's best interest that these functions be performed by U. S. Government agencies (military services or the Federal Aviation Administration) due to the legal peculiarities of air operations in Antarctica. Appropriately, the NSF will execute agreements with NISE-East. NSF, believing a contractor should not control a Federal agency, in this particular situation plans for ASA to have direct dealings with NISE-East only at the technical interface level and not at the supervisory level, since the latter could potentially lead to coordination and accountability issues.

6.15 Cost Reduction Opportunities

The Panel identified five general areas for achieving cost reductions: (1) the transition from military to civilian support, (2) reinvention of and reduction in science support, (3) reinvention of and reduction in the cost of science grants, (4) reinvention and reduction in other support/infrastructure systems, and (5) continuing reliance on cost advantages of USCG icebreaker services and DOD bulk fuel and transportation rates.

The Navy will complete the phase-out of its historic support role in 1999. Some cost savings and efficiencies will result from this process, and the USAP command and control structure will be rendered more efficient through consolidation into a more streamlined operation/support train. The completion of the transition from Navy to ANG LC-130 support is estimated to result in savings of up to $25M between 1998 and 2002. The transfer of meteorological, medical/dental, communications, air traffic control, and other services is expected to yield an additional $19M between 1998 and 2002.

The completion of the transition from Navy to civilian and ANG support is estimated to yield a net reduction of some 268 Full-Time-Equivalent (FTE) employees. In order to fully realize the potential long-term gain in efficiency from the transition and contain growth, the Panel believes that population caps at all U. S. Antarctic stations commensurate with at least this reduction will have to be implemented.

Several opportunities for cost savings in general infrastructure and support were identified (although important safety and modernization needs imply *added* costs in other areas, discussed elsewhere). One important function to be evaluated in this regard is fire protection — an extraordinarily important function, particularly in the dryness of Antarctica — but one which at McMurdo now utilizes 44 fully-dedicated personnel. Special needs for fire protection in conjunction with flight operations and fuel handling must, of course, be considered in addressing any potential change, but it is possible that the formal fire department at McMurdo could be downsized and augmented with designated volunteers, much as is done at South Pole and Palmer Stations and New Zealand's nearby Scott Base.

Helicopter fuel and support is another area of potential savings. By moving more of the helicopter support to the Marble Point location, which is closer to the majority of destinations, further economies in fuel consumption would result.

As McMurdo's buildings and other support functions age and are replaced, careful attention should be given to added thermal insulation for energy efficiency.

Science support also deserves further analysis and continued streamlining as it responds to the evolving science requirements. For example, science activities at Palmer Station have changed markedly in recent years: ozone research once demanded year-round operation, but those research efforts have shifted to the South Pole. Other research once carried out at Palmer has moved aboard research vessels. While the Panel finds continuation of Palmer Station to be essential for scientific, stewardship, and geopolitical interests, the possibility that the station not be operated in winters during one or more years of South Pole reconstruction should be examined.

Cost savings in the grants and in the direct science support areas are derived from several sources and largely require changes in both the evaluation and implementation of science projects in a manner which enhances cost visibility. The Panel finds that increased incentives for the investigators themselves (as well as support personnel) to reduce costs would benefit program efficiency. Such an approach is needed to optimize science while achieving the critical infrastructure objectives enumerated throughout this report. Program management can aid this process through avenues such as continuing to discourage multiple trips within a field season and increasing incentives for researchers to fully test and prepare equipment before deployment. Investigators can in some cases be encouraged to conduct further scientific analysis at home rather than collecting additional field data. Some reductions could also be achieved by encouraging researchers to minimize the size of field teams. The proposal evaluation process offers a powerful lever to achieve these objectives.

The Panel finds that some savings can also be realized through more explicit "on-Ice" cost accounting for services and consumables such as sample analysis and materials and supplies. The use of an accounting system that more fully tracks such expenditures and makes investigators responsible for choosing their support requirements within a given budget could be a mechanism to foster cost savings. Such a system, in this age of computerized accounting, should be capable of implementation without creating an unacceptable administrative burden.

Finally, agreements with DOD and USCG on costs of strategically important transportation, material, and icebreaking services need to continue if the Antarctic program is to realize cost advantages as the NSF maintains this nationally significant presence.

6.16 Transition of Aviation Responsibilities

As has been noted, the principal enabler of U. S. activities in the interior of the Antarctic continent is the existence of a small fleet of ski-equipped cargo aircraft (LC-130s) which possess considerable lifting capability and range. In response to the direction of the 1976 National Security Decision Memorandum 318, which instructed the NSF to seek more cost effective support, and by agreement of a March 1993 interagency working group, the Navy announced a five-year withdrawal plan from Antarctica in 1993. The New York ANG currently provides all U. S. LC-130 support in the Arctic and has in the past augmented the Navy in the Antarctic. The ANG is a sound choice to provide LC-130 support because of its broad polar experience and the potential efficiencies of year-round operations as activity shifts between the Arctic summer and the Antarctic summer.

Consolidation of the NSF and ANG LC-130 aircraft assets provides 10 LC-130s in the national fleet to service both the Arctic and Antarctic areas. NSF has research interests in the Arctic, particularly Greenland, that can utilize LC-130 support, and the ANG also has responsibility for certain military missions in the Arctic.

During the next three seasons (1996/7, 1997/8, and 1998/9), the LC-130 roles and activities of the Navy and the ANG will reverse. The Navy will no longer have a role in LC-130 operations (or base operations) after the 1998/9 season. During the current 1996/7 season, the ANG will augment the Navy; during the 1997/8 season the Navy and ANG strengths should be approximately equal; and during the 1998/9 season responsibilities will transfer to the ANG with a small residual Navy augmentation.

The transition from the Navy to ANG and the assumption of other functions by organizations such as ASA results in a decrease from 780 Full Time Equivalents to a projected 256. After offsetting the additional slots that will be required to fulfill certain other functions traditionally provided by the Navy, which will not be assumed by the Air National Guard, a total savings of some 268 Full Time Equivalent personnel will result.

As important as the savings derived from civilianization are for U. S. activities in Antarctica, the Panel believes that it is important to retain the currently planned degree of Department of Defense (DOD) partnership in Antarctica. The DOD has unmatched capabilities to meet unforeseen — and potentially catastrophic — events, such as the need for search and rescue. The U. S. presence and roles are undoubtedly enhanced by a continued, modest involvement of DOD personnel, especially in contingency planning regarding Antarctica. As well, NSF enjoys the benefits of the price advantages of DOD rates and quantity purchases of commodities. These must be continued to assure maximum economy of Antarctic operations despite DOD's reduced involvement in other Antarctic affairs. The U. S. Coast Guard's operating budget within the Transportation appropriation will need to continue to absorb the level of overall fixed icebreaker costs. Changes in either of these practices would produce significant negative impacts on the NSF operating budget. The presumption is that, for example, the U. S. would wish to maintain the existing modest icebreaker capability whether or not it had an Antarctic program.

6.17 Telecommunications

Modern telecommunications with Antarctica enable technologically advanced research by connecting researchers and their data with colleagues in real time; enhance operational support with real time flow of management information; and improve morale by providing contact with family and other associates.

Dependable telephone and Internet service is now provided at all three year-round stations and the two research vessels. A technology partnership with NASA Goddard Space Flight Center has produced the first very high speed (300 million bits per second) data link from Antarctica (McMurdo) via the NASA Tracking and Data Relay Satellite System.

Antarctica challenges the delivery of communications. McMurdo (78°S) lies at the high-altitude fringe of commercial satellite service. Palmer Station (64°S) has a good view of the geosynchronous communications satellite belt (12° elevation view), but the economics of commercial communications for this small station have precluded NSF from providing service beyond occasional use of a commercial maritime satellite telephone (INMARSAT), opting instead for shared access with Government satellites which have exceeded their useful lifetime in normal service.

South Pole (90°S) is inaccessible from geostationary satellites. Contact with South Pole Station can at present be accomplished by two means of communications. High frequency radio (HF) provides primarily voice. HF signals reflect on the ionosphere to reach over the horizon to McMurdo or the United States. The high latitude of South Pole Station results in HF radio being susceptible to disturbances in the ionosphere caused by solar activity (solar flares) and the Earth's magnetic field. Blackouts in HF radio occur for days at a time during the peak of the 11-year sunspot cycle. HF radio is not suited to digital communications at the quality, reliability, and data-rate needed for science at South Pole Station, and the systems in place are old and labor intensive. However, HF radio continues as the best means for on-demand contact between McMurdo and South Pole operations and for communicating with aircraft supporting the station.

Internet and connection to the U.S. telephone system are provided by aging geosynchronous satellites that have drifted out of their original equatorial (geostationary) orbits into a tilted (inclined) orbit that allows South Pole Station periodically to "see" them. These satellites typically have outlived their original missions but have been kept active and can provide a daily link for the 5-7 hours per day, wherein they are in line-of-sight (Exhibit 75).

South Pole Station uses the satellites ATS-3 (simple voice), LES-9 (modest data-rate Internet), and GOES-3 (higher data-rate Internet). Each is an old Government satellite (NASA, USAF, and NOAA, respectively), nonetheless capable of providing useful communications for South Pole Station. These satellites are well beyond their original design lives. Ready alternatives to these satellites are limited (GOES-2, GOES-7). Reliance upon serendipity for future similar Government or commercial satellites does not provide the certainty needed to sustain a science program. Current national and international policy regarding the management of space debris, in the absence of deliberate attention drawn to the unique requirements for South Pole, will further diminish the possibility for the serendipity now being enjoyed.

Commercial low Earth orbit satellite communications systems now being implemented or planned may provide solutions for South Pole Station and other Antarctic locations. The 66-satellite Iridium system (Motorola, Inc., principal investor; a $3.2B system) is to provide total global coverage for satellite-delivered cellular telephone, fax, and low-rate dial-up data. Started in 1990, Iridium may be fully operational by 1998 with the first launches now scheduled for mid-1997. The proposed 840-satellite Teledesic system (Gates, McCaw venture; possible $9B system) also provides full global coverage, but with high speed data links suited for Internet and bulk telephone service. Teledesic may become operational in the latter half of the next decade.

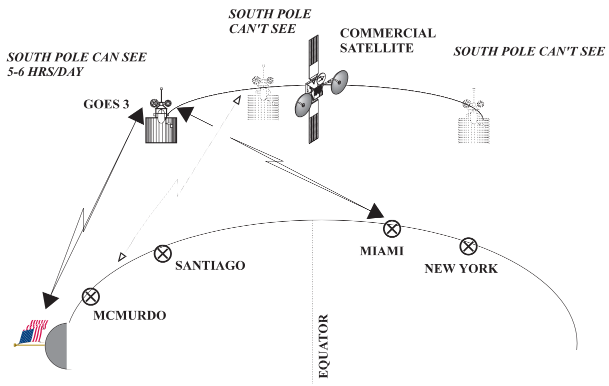


Exhibit 75

Communication with the South Pole. Most communications satellites are launched into orbits that serve the needs of the vast human populations in the mid-latitudes. A satellite 24,000 miles over the Equator is geostationary: it appears to park over a particular location on Earth because its speed to offset gravity equals Earth's speed of rotation. From there it has a line of sight to Earth locations as high as 80° latitude (which includes McMurdo). Small onboard rockets are fired periodically to keep the satellite in place. Without these boosts the satellite tends to drift north and south of the Equator, becoming less able to provide its original prime role.

But these north-south swings place the South Pole in view of the satellite several hours a day. The USAP, rather than trying to budget for a family of dedicated polar communications satellites, uses NASA's ATS-3, Air Force's LES-9, and NOAA's GOES-3, which, out of fuel (solar panels power their communications), move in a fashion where they have line-of-sight to South Pole Station five to six hours a day.

6.18 Robotics

An issue of substantial interest to the Panel is the potential for robotics and telescience to generate program cost reductions while maintaining a high level of quality of scientific work. Within the U. S. space program, robotics result in significant savings as compared to manned spacecraft for many missions. Some robotics applications are evident in the USAP today, particularly the deployment of six Automated Geophysical Observatories on the High Plateau. These relatively simple automated stations collect critical geophysical data from remote locations and report back through the Argos satellites which periodically pass overhead.

The state of the art in robotics, however, is not sufficient to displace economically the bulk of the sophisticated science and support operations now conducted in Antarctica. In contrast to the space program, where robotics can often allow unmanned operations, such technology can only result in partial reductions in personnel in Antarctica and hence far smaller savings — since substantial fixed costs are associated with maintenance of any personnel on site. In addition, a serious impediment to such operations at the South Pole today is the lack of a high-speed digital communications capability which would be necessary to perform substantial telescience. Finally, in many respects the Antarctic environment is more hostile to electronics and mechanical devices than that of space. Nevertheless, the Panel believes that as communications capabilities improve in the future, the USAP can realize benefits from the increased use of robotics, provided the focus of such developments is directed to the displacement of existing operations rather than to enhancements in capability — the latter having often been the case in applying new technology.

6.19 Technology Opportunities

As has been discussed, the focus of U. S. Antarctic activity has traditionally been basic scientific research. This emphasis has been productive, resulting in advances in knowledge in a variety of disciplines including several of global importance. At the other end of the science/technology spectrum, innovative technologies have been incorporated into the operations of the USAP to reduce costs and enhance science support. The disciplines of applied research and technology development that are bounded by the end-members of basic research and technology insertion have to date been a relatively minor part of the USAP. The Panel believes that the USAP offers significant attendant technological opportunities which could be realized at modest incremental cost.

To this end, there have already been a few quite effective partnerships with USAP in the field of technology, such as the demonstration of advanced satellite communications with NASA and development of a heavy over-snow transport capability with Caterpillar, Inc. Broadening the number of technology partnerships and the applied research program base could provide additional funding while spreading the cost of operations across a larger funding/user base. The involvement of new organizations, to include other federal agencies as well as industry, brings the opportunity for leveraging resources and building or expanding cooperative programs that can have both applied research and basic science components.

As with the basic science conducted in Antarctica, the applied research and technology development conducted there should comprise only those activities that demand the unique environmental conditions or physical features present in Antarctica.

6.20 Education Opportunities

For centuries people have been fascinated by Antarctica. Much of the ongoing activity there involves exploration of the unknown, where the geology (lithosphere), climate (atmosphere), ice sheet (cryosphere), ocean (hydrosphere), and inhabitants (biosphere) are delicately linked. For this reason, Antarctica is an ideal natural laboratory upon which to base multidisciplinary science education curricula designed to capture the curiosity of students who might otherwise find science uninteresting.

Other aspects of Antarctica suit it well for education outside the immediate realm of science. For example, science in Antarctica requires the support of people with a wide span of backgrounds and skills ranging from heavy equipment operators to medical doctors; and from electricians to accountants — all of whom share pride and dedication in carrying out challenging tasks as part of a team. As such, they provide excellent role models for youth.

The advent of electronic media and, in particular, the "web," has paved the way for involving the public in science "on the Ice." NSF has taken the initiative to foster educational programs that reach out to all segments of the public — pre-school through senior citizen. These programs include live television (e.g., "Live from Antarctica" on PBS) and K-12 curricula involving experiments using current data from Antarctica, such as satellite images of the continent. Another NSF program sends teachers to Antarctica and allows them to share their experiences with students all around the country via the web. There is a new web site (http://www.glacier.rice.edu) which with the help of financial support from NSF contains a wealth of information about Antarctica, including updated weather reports from a number of research stations. “Glacier” provides a home page where scientists can describe their latest discoveries, thereby sharing the excitement of their work. NSF encourages the scientific community to contribute to existing educational programs and to develop new ways of involving the public in the science of Antarctica. This is an effort worthy of encouragement and expansion.

6.21 Tourism

An emerging aspect of human involvement in Antarctica is tourism. The past five years have seen rapid growth in the number of private visitors to Antarctica. Most arrive by ship in the Peninsular region, but the number of these visiting at McMurdo is increasing, and even South Pole Station receives a few tourists each year. Many of these visitors seek to tour U. S. research stations and, as such, can become important ambassadors for the scientific work being conducted. At the same time, there are limited resources available to support such visits and the threat to Antarctica’s slow-to-recover environment can be significant if not responsibly managed.

While the number of scientists in Antarctica has increased by about a factor of two in the past decade, and the number of national programs has increased somewhat less than that over the same period, the number of tourists visiting the continent has increased far more rapidly, from only about 1,000 in the early 1980s to over 6,000 in the early 1990s. Exhibit 76 depicts the total estimated number of tourists visiting Antarctica via ship and air from 1980/1 through 1995/6.

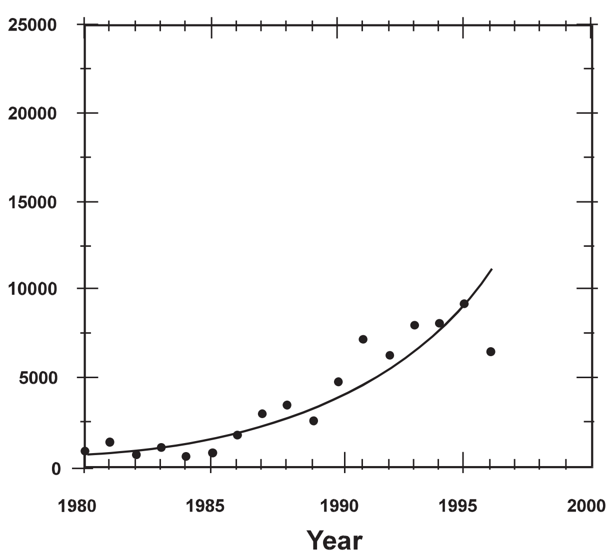


Exhibit 76

Number of tourists visiting Antarctica since 1980. Recent variability is related in part to a few large cruise ships that operate approximately every other year. [From Science and Stewardship in the Antarctic, National Academy Press, pre-1992, and from Nadene Kennedy of the NSF (personal communication), post-1992.]

A quadratic projection of this curve indicates that there will be a substantial number of tourists annually visiting Antarctica by the early part of the 21st century. The increased pressure from tourism must be considered in designing conservation measures and has been one of the major factors prompting the Protocol on Environmental Protection.

It has been the policy of the USAP to allow visitors to its Antarctic facilities while controlling their number. In addition to visitors arriving by ship, tourist sightseeing overflights by air have taken place from time to time — including the Air New Zealand DC-10, which, while flying around Mount Terror in 1979, crashed into Mount Erebus, located only some 20 miles from McMurdo Station, killing all 257 persons aboard. Such flights ceased until 1996, when Australia (Qantas) resumed regular “flightseeing” tours of Antarctica. In 1989, the Argentine government supply and tour ship *Bahia Paraiso* ran aground and sank. While no one was injured, the ship lost 170,000 gallons of fuel to the sea, severely damaging the area’s wildlife.

The International Association of Antarctica Tour Operators was established in 1991 to advocate and promote responsible private-sector travel to Antarctica. In a world of increasing affluence and mobility, tourism will become a growing factor on the Antarctic continent.

6.22 National Commitment to an Antarctic Policy

Since the Antarctic Treaty ratification of 1959, a series of memoranda, circulars and directives has established responsibilities, objectives and practices that, taken together, document U. S. Antarctic Policy. Section 4 contains a summary of these documents and more recent policy-oriented correspondence is presented in Appendix III. The Panel finds the Department of State letter of January 27, 1997 (Appendix III), most helpful in presenting a position that sustains the importance of presence addressed to the National Security Council by the previous State Department memo of 1996. It is noted by the Panel that overseeing U. S. presence in Antarctica far surpasses the normal responsibilities of the National Science Foundation. At the same time, the Panel strongly supports the designation of the NSF as the principal managing and coordinating agent for all U. S. activities in Antarctica.

7.0 Recommendations

The Panel offers 12 recommendations based on findings in Chapter 6 which, in the Panel's view, are in keeping with fundamental U. S. policy toward Antarctica and specifically address the charge given to the Panel.

7.1 Presence

Antarctica today is a continent generally characterized by peaceful, environmentally friendly, human activity. High among the reasons for this situation is the role played by the U. S. over many years in helping create a system of treaties and international agreements governing the nature of human conduct on the continent. The presence of the U. S. in Antarctica is a key element of the continued stability of the region.

> **Recommendation I: The U. S., as a matter of national policy, should maintain a continued year-round presence in Antarctica, including at the South Pole.**

7.2 Safety and Health

Various critical safety and health deficiencies exist at U. S. facilities in Antarctica, particularly at South Pole Station. The most urgent of these are currently being rectified using funds appropriated for this purpose in FY97. Additional concerns persist which, although not all of obvious imminent consequence, demand attention. Such concerns take on particular significance in an environment of extreme fire hazard due to dryness, remoteness and occasionally limited water supply.

> **Recommendation II: Promptly initiate steps to eliminate safety and health shortfalls at all U. S. facilities in Antarctica and, because of their magnitude, particularly at South Pole Station.**

7.3 Program Scope

The USAP operates three major field sites (Palmer, Amundsen-Scott and McMurdo), two research ships (*Polar Duke* and *Nathaniel B. Palmer*) and numerous remote data collection sites which are either uninhabited or inhabited only on a temporary basis.

The three major stations play very different roles in the fabric of the USAP. Palmer Station provides a base for the study of marine biology in a climatic zone that allows year-round access. Palmer Station also serves as a port for research vessels that undertake marine studies. McMurdo Station offers access for ships carrying supplies and serves as the logistics base for most inland operations, as well as offering excellent research facilities itself. McMurdo is critical in providing logistics for South Pole Station.

South Pole Station is strategically located from a geopolitical standpoint and provides a unique base for the conduct of certain types of science. It has a long and continuous observational record that is critical in such areas as documenting changes in atmospheric ozone, and is the base for astronomy projects that provide new insights into astrophysics. The existence of a continental-sized block of extraordinarily transparent ice provides an opportunity for the study of high-energy neutrinos.

Palmer is the least costly of the three stations to operate, is unique in the biology it supports, and is of geopolitical significance because of its location in a region of the continent characterized by overlapping claims. South Pole Station is in some respects the "crown jewel" of Antarctic presence — but cannot operate without logistics from McMurdo Station. The Panel thus concludes that facilities at all three locations should continue to be maintained. The level of activity at each is the subject of a later recommendation

> **Recommendation III: The U. S. should continue to maintain permanent, facilities in Antarctica at Palmer, McMurdo and the South Pole.**

7.4 International Cooperation

International research cooperation and shared support offer significant benefits to the U. S. in achieving its objectives in Antarctica and can help foster and advance Antarctic research and international understanding. Scientific results can be shared and redundancy reduced. However, the notion of reducing cost through international projects, although attractive in principle and realistic in some instances, particularly for larger projects, is in many cases obviated by the increased coordination and reduced efficiency associated with international endeavors.

The Panel also concludes that to internationalize the physical plant in Antarctica with foreign capital investment in fixed facilities at the U. S. stations raises ownership issues that, ultimately, work to the detriment of U. S. interests and, in the opinion of the Panel, worldwide interests. It is not, it would seem, illogical that a nation which shares the basic costs of the existence of a facility would seek a voice in the operation and governance of that facility — and ultimately in the title to that facility.

Recommendation IV: International cooperation in scientific research and logistics support should be encouraged, but permanent facilities and infrastructure at permanent U. S. sites in Antarctica should be provided by and maintained by the U. S.

7.5 South Pole Facilities

The estimated cumulative costs of the four options addressed by the Panel were summarized in Exhibit 65 (Section 6.6.2) for the construction funding period FY98 through FY02 and for the period FY98 through FY25.

Although the Rehabilitated Existing Station is the lowest cost option, it would be an imprudent choice because of the lack of fire suppression systems, the substandard space conditions in the utilidors, the need for improved exits from the dome and arches, and the disruption to operations caused as various systems fail due to aging.

The safety issues relating to the Rehabilitated Existing Station are addressed by the Safety Upgraded Station. However, compared with the Optimized Station, the cost tradeoff for this Upgraded Station is unattractive. The design, capability, reliability, maintainability, and building code compliance advantages of the Optimized Station are so compelling that it would be more cost effective to invest $120M (FY97 dollars) in the latter new station than to invest $88M (FY97 dollars) upgrading the existing 20-year old station. The life cycle cost tradeoff is even less attractive for the Safety Upgraded Station.

The Enhanced Station would provide additional capability and the opportunity for development of energy and environmental technologies. However, these additional capabilities are not mandatory and the additional cost is significant, making this option somewhat less attractive in a fiscally constrained budget environment.

The Optimized Station design, incorporating elevated modularity, provides the best foundation for dealing with future needs while reducing costs relative to the previously proposed Enhanced Station.

A sensitivity analysis with future costs and savings discounted was conducted and did not change the thrust of the above argument. Analyses also showed that delaying construction of a replacement station increased overall costs and raised the risk that components of the current facility would fail prior to replacement.

Recommendation V: The existing South Pole Station should be replaced with an Optimized Station. This construction can be accomplished by the year 2005 if the necessary budgetary steps are taken immediately (to initiate funding for the period FY98-FY02).

7.6. Funding

The USAP has over the years made the transformation from an expeditionary activity to the establishment of a presence to an operation dedicated to high-quality scientific research. Budget austerity and other changing conditions have necessitated the transition of management of the U. S. Antarctic interest from the Department of Defense to the NSF. The consequence of this change has been to place in a relatively small, research-oriented agency, normally dedicated to the support of science in an academic environment, the fiduciary responsibility for a major national undertaking in one of the world's most remote and demanding environments. Given the magnitude of this challenge, the Panel finds it remarkable that the NSF has been able to assume this responsibility with little or no apparent disruption to ongoing activities — and indeed with the realization of considerable efficiencies. Nonetheless, the USAP should be viewed as a national program, much like the space program, not merely as another NSF science project, and should therefore be scoped, funded, and judged as such. The NSF Antarctic budget is simply not adequate to fund in entirety the periodic major capital expenditures associated with maintaining an activity of the scale of the USAP. The consequence of seeking to function as if this were not the case is to suffer a continually eroding capital plant, as has indeed been the realization to date.

The Panel has devoted considerable attention to the issue of how much funding for construction of South Pole Station should come from reductions in Antarctic research. There is strong consensus that the quality of science should be maintained and, further, that the Panel should not seek to micromanage the detailed content of the science effort in Antarctica. Nonetheless, it is the Panel's position that the most equitable way to control the cost of science on the continent is to limit the number of scientists conducting research in Antarctica.

Traditionally, the Antarctic research program has been strongly field-oriented. This was to some extent a necessity because of the poor communications between Antarctica and the rest of the world; it was virtually impossible to transmit data to and from the Ice. Antarctic science is now entering a new era in which more science is being performed at university laboratories in the U. S. The NSF should continue to encourage these types of projects and limit the number of expeditions to the Ice — especially during the South Pole construction phase. This approach will lead to significant savings in the overall science budget, will have the least impact on Antarctic science, and will facilitate the development of remote operations and robotics. Obviously, however, some presence in the field is required for many types of Antarctic research.

Given the imperative to replace the existing facility at the South Pole and the lack of any current budget plan for doing so, the Panel concludes that five funding sources must be drawn upon (values shown are in then-year dollars):

1) A moderate cut-back in research activity during the period the new facility is being constructed ($20M cumulative over the period FY98-FY02).
2) Reduction in the capability initially planned for a new South Pole facility to the level of the Optimized Station (approximately $31M savings in then-year dollars).
3) Application of the $25M already appropriated in FY97 to resolve urgent safety, health and environmental concerns in a fashion which is compatible with the Optimized Station.
4) Generation of cost reductions associated with the transition from Navy functions of $30M.
5) Provision of additional funds to assist in the construction of the recommended facility — $95M then-year dollars over the five-year period FY98-FY02.

> **Recommendation VI: After having taken all prudent steps to reduce the cost of a new facility at South Pole Station and to seek other cost reductions to fund such a station, there remains a funding shortfall; therefore, additional funds in the amount of $95M (then-year dollars) over the five-year period FY98-FY02 should be added to the NSF budget to permit the phased replacement of the existing South Pole Station.**

7.7. Planning and Budgeting

As has been noted, the lack of a continuing long-range Antarctic integrated capital plan (and supporting budget) makes it virtually impossible to maintain an efficient and modern set of facilities. The draft Long Range Development Plan must integrate the science, support and capital facility needs, and become the model for budget justification.

> **Recommendation VII: The NSF should prepare, and annually update, a long-range plan that coordinates science, support and facility needs to carry out the U. S. Antarctic Program. Implementation funds should be provided to support the long range plan.**

7.8 Management

U. S. operations in Antarctica present an enormous management challenge because of their diversity (research, ground transportation, food supply, construction, air operations, ship activities, medical care, maintenance...) and because of the length of the "pipeline" involved in supporting Antarctic operations (7,100 miles from Los Angeles to Christchurch, 2,400 miles from Christchurch to McMurdo; 840 miles from McMurdo to the South Pole). Two management tenets which apply in such situations are to have a single overall manager for support activities and to establish an organization under this manager which minimizes the number of interfaces required. For various reasons, it has not been possible for these principles to be fully embraced in the design of the USAP management structure to date, but they should be a key goal of the evolving structure. In this regard, the Panel recognizes the value of competition in assuring a high level of performance by the operating contractor, but it also recognizes the value of continuity. These sometimes conflicting objectives can generally be satisfied by immediately competing the role of poorly-performing contractors and continuing the role of well-performing contractors. The existence of such a policy in itself forms a powerful incentive and is consistent with evolving practice in Japan, the U. S., and elsewhere.

> **Recommendation VIII: To the greatest extent possible, all support activities in Antarctica should be placed under a single prime contractor — with oversight by a single individual/ office designated by the NSF. Subsidiary organizational elements should be restructured to minimize overlap, duplication and interfaces.**

7.9 Program Integration

While the infrastructure required to support science in Antarctica may in an accounting sense be similar to that of other facilities (such as astronomical observatories, ships, accelerators, and aircraft) whose costs are not readily attributable to individual projects, many of the direct science support functions needed for Antarctic research (such as technical support, transportation, energy costs, etc.) can in fact be related to particular projects. Evaluation of such costs should constitute an important part of the research proposal review and approval process, particularly where activities with substantial support costs are concerned. Explicit allocation of these costs will also help motivate researchers to achieve efficiencies on their own.

The approval process for scientific proposals to all divisions in the NSF consists of a critical peer review by mail, by panels, or both. The cost of proposed research at many large facilities (such as astronomical observatories) is often reviewed by panels in order to help provide cost containment. The research program in Antarctica could benefit from a similar approach.

It is recognized that evaluation of total project costs as part of the mail review process (which today principally focuses on the merits of the proposed science) could add significant administrative cost and reduce efficiency since many proposals fail based upon scientific grounds alone. One mechanism that the NSF could consider adopting would be to have a panel review the overall Antarctic program in a fashion whereby scientific merit would be considered together with approximate total costs (including support) for projects receiving favorable preliminary mail reviews. Such an approach could help to better balance cost with scientific benefit in the selection criteria and could be expected to produce significant savings within the science program. Further, such a process would allow the scientific community to participate in the design of the overall program and the decision-making process that will be needed to undertake such pursuits as the modernization of the South Pole Station.

The administrative problem of allocating support costs to a specific end-project is, of course, not unique to the Antarctic research program. Nonetheless, the situation which exists today is one wherein a support contractor is specifically incentivized (in this case with an "award fee") to be highly responsive to the demands of researchers; yet those same researchers have little insight into the cost implications of their demands — or of alternatives that might be available. Such circumstances almost inevitably generate unnecessary costs. Examples of activities that could be adversely impacted through such a practice are the use of helicopters, manifesting of fixed-wing aircraft, use of air versus surface transportation, the number of persons visiting Antarctica (some for very short periods of time and for repeat visits), and the delivery to Antarctica of scientific equipment which is incomplete or inadequately tested.

Recommendation IX: The NSF should implement mechanisms to include science support costs as an explicit rather than implicit portion of the evaluation of proposed scientific projects that make up the USAP.

7.10 Transition

As has been noted, it is the Panel's view that all support functions should be integrated under the management of a single prime support contractor. By so doing, additional efficiencies are obtainable. This and certain ongoing transitions of management responsibilities offer particularly attractive opportunities to "reinvent" U. S. operations in Antarctica and to consolidate like-functions and eliminate unneeded functions.

Recommendation X: The NSF and its contractor, Antarctic Support Associates, should review those functions no longer to be performed by the DOD to ensure that those functions are transferred to the recipient organization in the most efficient possible manner...or, where possible, eliminated. Similarly, the U. S. Coast Guard's operating budget should continue to absorb the level of fixed icebreaker costs that exceed reimbursement.

7.11 Telecommunications

Telecommunications capabilities in Antarctica have been improved substantially in recent years but remain substandard. Further improvement is a means to lower operating expenses while maintaining the quality of the research program. Emerging technologies such as those based on large constellations of low Earth-orbiting satellites may become commercially operational and alleviate current communications shortcomings. Until that time, effort must be expended to ensure the continued gains made for South Pole Station utilizing inclined "geosynchronous" satellites which have exceeded their useful commercial life.

Recommendation XI: The NSF should seek advance arrangements with governmental and commercial geostationary satellite operators to make such satellites systematically available as they near the end of their economic commercial life.

7.12 Tourism

Tourism in Antarctica is increasing rapidly and is an inevitable facet of a more affluent, globally mobile world. There is no logic to argue that Antarctica should be reserved solely for a limited number of researchers; hence, visitations by the general public should in general be welcomed. On the other hand, a greater presence of humans in so brittle an environment will require development of mechanisms for visit management, just as our nation's parks require a management structure that depends upon the volume and nature of usage. Now is the time to work with other nations and agencies to proactively plan for the accommodation of increasing numbers of visitors in a manner which permits the magnificence of Antarctica to be widely enjoyed but is not harmful to the environment or disruptive to the research being performed there. Additionally, peripheral issues arise in connection with the growth of tourism that are best resolved prior to their occurrence, such as who is to fund the cost of search and rescue operations; what nations shall have directive air traffic management authority over non-sovereign territory; and so forth.

RECOMMENDATION XII: The U. S. Government, presumably the Department of State, should convene those U. S. Government organizations having interests in Antarctica and develop a policy regarding the increased tourism to be expected in Antarctica in the years ahead and, further, should work with other interested governments to address this issue in a proactive and cooperative manner.

*   *   *   *   *

"The efficiency of a polar expedition varies on the whole according to the adequacy of its preparations, the worth of its equipment and scientific gear, the services of its personnel and staff of scientists and the length of its stay in the field."

Richard E. Byrd, Little America, *1930*

Appendices

I. Biographies of Members

II. Terms of Reference

III. State Department Views

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Appendix I.

Biographies of Members

Chairman:

Norman R. Augustine Mr. Augustine, Chairman of the U.S. Antarctic Program External Panel, is Chairman and Chief Executive Officer of the Lockheed Martin Corporation. He has served as Chairman of the Defense Science Board, the National Academy of Engineering, the White House/NASA Advisory Committee on the Future of the U.S. Space Program, and the Aeronautics Panel of the Air Force Scientific Advisory Board, as well as President of the American Institute of Aeronautics and Astronautics. He holds a B.S.E. and M.S.E. from Princeton University, is the recipient of more than 10 honorary degrees and is a member of the American Academy of Arts and Sciences. He has served as a Trustee of Princeton University and Johns Hopkins University, and as a member of the Advisory Board of The Johns Hopkins School of Medicine. He is a former Assistant Director of Defense Research and Engineering in the Office of the Secretary of Defense and a former Under Secretary of the Army. Mr. Augustine has been to Antarctica twice and to the South Pole once.

Members:

Richard Alley Dr. Alley is a Professor of Geosciences and Associate of the Earth System Science Center at Pennsylvania State University, University Park, where he has worked since 1988. He graduated with a Ph.D. in 1987 from University of Wisconsin and earned M.S. (1983) and B.S. (1980) degrees from Ohio State University, all in Geology. Dr. Alley teaches and conducts research on the climatic records, flow behavior, and sedimentary deposits of large ice sheets to aid in prediction of future changes in climate and sea level. He is a Packard Fellow, a former Presidential Young Investigator, and the 1996 recipient of the Horton Award of the American Geophysical Union Hydrology Section. Dr. Alley has served on a variety of advisory panels and steering committees for the National Science Foundation, targeted research activities, and professional societies. His Polar experience includes three field seasons in Antarctica, one to the Pole and five in Greenland.

John B. Anderson Dr. Anderson is Professor and Chairman of the Department of Geology and Geophysics at Rice University. He earned his Ph.D. from Florida State University, an M.S. from University of New Mexico and a B.S. from University of South Alabama. He has published 160 articles and has written 150 abstracts, most dealing with Antarctic marine geology and coastal evolution. He has written or contributed to three books — *Glacial Marine Sedimentation*, *Paleo–climatic Significance of Glacial Marine Deposits*, and *Antarctic Marine Geology*. Dr. Anderson was the Associate Editor of *Geology* from 1991 to 1993. He currently serves on the editorial boards of the American Association of Petroleum Geologists and the American Geophysical Union-Antarctic Research Series. He is a member of the National Academy of Sciences Polar Research Board, and a member of the Steering Committee-West Antarctic Ice Sheet Study. He received the 1992 Gulf Coast Association of Geological Studies Outstanding Educator Award and the 1996 Rice University Graduate Teaching Award. Dr. Anderson has made 18 expeditions to Antarctica and the Southern Ocean region.

Rita R. Colwell Dr. Colwell is President of the University of Maryland Biotechnology Institute and Professor of Microbiology. She received her B.S. and M.S. degrees from Purdue University and her Ph.D. from the University of Washington, Seattle. Dr. Colwell has received several honorary degrees, including an honorary Doctor of Science from her Alma Mater, Purdue University. Dr. Colwell was named the 1996 Maryland Legislature Outstanding Woman of the Year. Her other awards include the Medal of Distinction from Barnard College, Columbia University; Andrew White Medal, Loyola College; Purkinje Gold Medal, Czechoslovakia Academy of Sciences; the Maryland State Civic Award (presented by Governor Schaefer); and the Fisher Award, American Society for Microbiology. Dr. Colwell is a past President and Board Chairman of the American Association for the Advancement of Science and has served as President of the International Union of Microbiological Societies, the American Society of Microbiology, and Sigma Xi. She is a Member of the Health and Environment Research Advisory Committee (HERAC), Department of Energy; Board of Trustees, International Centre for Diarrhoeal Disease Research, Bangladesh; and Science Board, Food and Drug Administration. Dr. Colwell chaired the Crary Science and Engineering Center Panel, Division (now Office) of Polar Programs, and the Polar Research Committee, National Science Board, and served as Vice-Chair, Polar Research Board, National Academy of Sciences. Dr. Colwell has traveled to Antarctica four times and has made four trips to the South Pole.

Charles E. Hess Dr. Hess is Director of International Programs at the University of California, Davis. He earned his Ph.D. in Physiology, Horticulture and Plant Pathology and an M.S. degree from Cornell University, and holds an B.S. degree from Rutgers University. He is a former Assistant Secretary for Science and Education at the Department of Agriculture. He served as a Member and Vice-Chair of the National Science Board, Member of the U.S. Antarctic Safety Review Panel, and Member of the NSB Committee on the National Science Foundation Role in Polar Regions, which recommended the construction of the Crary Science and Engineering Center. Dr. Hess has made five trips to Antarctica and four trips to the South Pole.

Hansford T. (H.T.) Johnson General Johnson, USAF (Ret), is Chairman of the Greater Kelly Development Corp. in San Antonio, Texas. He is responsible for leading the transformation of the $7.5 billion Air Force depot into an industrial center that will perform government and commercial work. He served as the President and CEO of USAA Capital Corp. and was a member of the 1993 Base Closure Commission. As Commander in Chief of the U.S. Transportation Command, he led the movement of the troops and equipment to Panama in 1989 and the Persian Gulf in 1990-91. His command was also responsible for the air and sea lift to Antarctica, and he landed a C-5 Galaxy on the ice at McMurdo Station in 1991. Gen. Johnson was the Deputy Commander of the U.S. Central Command during the escorting of the Kuwaiti tankers through the Persian Gulf and Head of Operations in the Strategic Air Command during the raid on Libya in 1986. Gen. Johnson's responsibilities have included balancing Air Force programs at successive lower levels during a period of "downsizing." He was a combat pilot in Vietnam and was a graduate of the first class — and later served as Assistant Professor — of the USAF Academy. He holds Masters Degrees from Stanford in Aeronautics and Colorado in Business. Gen. Johnson has been to Antarctica twice and the South Pole once.

Lewis E. Link, Jr. Dr. Link is the Director of Research and Development of the U. S. Army Corps of Engineers. Prior to this assignment, he served as the Director and Technical Director of the U. S. Army Cold Regions Research and Engineering Laboratory in Hanover, New Hampshire, and Fairbanks, Alaska, the principal federal center of expertise for cold regions engineering research serving both the Department of Defense (DoD) and civilian agencies. He has served as the Assistant Chief of the Corps at the Coastal Engineering Research Center and has been active in research, publishing over 90 technical papers and reports. He has served on or chaired advisory boards and technical committees for NASA, American Society of Civil Engineers, Society of American Military Engineers, American Society of Mechanical Engineers, NATO, the Department of Defense, and various universities. Dr. Link earned a Ph.D. in Civil Engineering from Pennsylvania State University, a M.S. in Civil Engineering from Mississippi State University and a B.S. in Geological Engineering from North Carolina State University. Dr. Link has been to Antarctica twice and to the South Pole twice.

Rudy K. Peschel Rear Admiral Peschel, recently retired from the U .S. Coast Guard as Chief, Office of Navigation, overseeing that agency's polar operations, among other responsibilities concerning international and domestic waterway safety. Early-career aviation and sea duty took him to Arctic regions during the North Slope oil discovery and transportation development. Headquarters and field command billets involved him in capital planning, resource justification to the Office of Management and Budget and Congress, and major base transitions from the Department of Defense to USCG management. He was Deputy Commander of the multi-agency/multi-nation Western Hemisphere Drug Traffic Task Force and Commander of the ice-intensive Great Lakes District. He spent part of the 1996 icebreaking season at McMurdo Station and aboard *USCGC Polar Star*. He graduated in 1963 with a B.S. in Engineering from the U.S. Coast Guard Academy, in 1966 from Navy Flight Training at Pensacola, and in 1972 from Naval Postgraduate School at Monterey with an M.S. in Management Science. Adm. Peschel has been to the Antarctic and the South Pole twice.

Russell L. (Rusty) Schweickart Mr. Schweickart is President and CEO of ALOHA Networks, Inc. (ANI). He received his B.S. and M. S. degrees from the Massachusetts Institute of Technology in 1956 and 1963. He served in the Air Force and the Massachusetts Air National Guard as a fighter pilot. Selected by NASA in the third group of astronauts in 1963, he flew as the Lunar Module Pilot on Apollo 9's flight to the Moon in March 1969. He served as Commander of the backup crew on the first Skylab mission and subsequently as a Program Manager at NASA Headquarters. In 1977, he joined the administration of Governor Jerry Brown of California as his Advisor for Science and Technology. Appointed by the Governor to the California Energy Commission in 1979, Mr. Schweickart served as its Chairman for five years. In 1985, he founded the Association of Space Explorers, the professional organization of astronauts and cosmonauts, and was later the founder and president of Courier Satellite Services, Inc., and Executive Vice President of CTA Commercial Systems, Inc. In 1987-88, Mr. Schweickart chaired the National Science Foundation's Antarctic Safety Review Panel producing the "Safety in Antarctica" report. Mr. Schweickart has been to Antarctica three times and to the South Pole twice.

Susan Solomon Dr. Solomon is a Senior Scientist at the National Oceanic and Atmospheric Administration's Aeronomy Laboratory. She served as Head Project Scientist for the National Ozone Expedition at McMurdo Station, Antarctica, in l986-7, and has been a leader in ozone research for more than a decade. Her theoretical and observational work was key to identifying the cause of the Antarctic ozone hole, and she has received numerous honors in recognition of those studies. She is a Member of the U. S. National Academy of Sciences and a foreign associate of the French Academie des Sciences. She has previously served as Chair of the Advisory Committee for the National Science Foundation's Division of Polar Programs and as a member of the Polar Research Board, National Research Council. She earned her M. S. and Ph.D. degrees in chemistry from the University of California, Berkeley, her B. S. degree from the Illinois Institute of Technology, and she has three honorary doctorate degrees. Dr. Solomon has been to Antarctica four times and to the South Pole once.

Edward C. Stone Dr. Stone has been Director of the Jet Propulsion Labotatory (JPL) since January 1991, and a Vice President and David Morrisroe Professor of Physics at California Institute of Technology. He earned his M.S. and Ph.D. degrees in Physics from the University of Chicago. He is Chairman of the California Association for Research in Astronomy, which is responsible for the W. M. Keck Observatory in Hawaii. Dr. Stone is a Member of the National Academy of Sciences, the American Philosophical Society and the International Acacemy of Astronautics, and received the National Medal of Science from President Bush. He has been an investigator on 14 NASA missions and served as the Chief Scientist for the Voyager Mission. He has been to Antarctica once and to the South Pole once.

* * * * * *

The Panel expresses its heartfelt appreciation to Laura Cooper Herrera who handled all the mechanics of preparing the text of this report.

NATIONAL SCIENCE FOUNDATION
4201 WILSON BOULEVARD
ARLINGTON, VIRGINIA 22230

OFFICE OF THE DIRECTOR

TERMS OF REFERENCE
United States Antarctic Program External Panel

BACKGROUND

In its April 1996 report on the United States Antarctic Program (USAP), the National Science and Technology Council (via its Committee on Fundamental Science), determined that:

> "The National Science Foundation has implemented U.S. policy in an effective manner"
>
> "the USAP research program is of very high quality"
>
> "at the current level of investment, the USAP is cost effective in advancing American scientific and geopolitical objectives; from a science perspective, the NSTC supports the continuation of three stations with year-round presence."
>
> "maintaining an active and influential presence in Antarctica, including year-round operation of South Pole Station, is essential to U.S. policy interests".

The NSTC also recognized, however, that budgetary uncertainties place a premium on detailed understanding of cost reduction options. Thus, the NSTC recommended that "an external panel be convened by NSF to explore options for sustaining the high level of USAP science activity under realistic constrained funding levels."

PANEL CHARGE

The report suggests that the panel should "examine a full range of infrastructure, management, and scientific options." In particular, I request that the panel examine and make recommendations concerning: the stations and logistics systems that support the science while maintaining appropriate environmental, safety, and health standards; the efficiency and appropriateness of the management of these support systems; and how and at what level the science programs are implemented. The panel's views and recommendations should include consideration of eventual replacement of South Pole Station and other infrastructure.

The panel's advice is sought on how the USAP can maintain the high quality of the research program and implement the U.S. policy in Antarctica under realistic budget scenarios.

The Administration's projections are that the overall National Science Foundation budget will decrease somewhat through fiscal year 2000 before increasing with inflation for the subsequent two years. Thus, one scenario that should receive particular attention is that corresponding to a budget freeze for the USAP science program and infrastructure, including South Pole Station. Purchasing power would decrease by approximately 15% between now and the year 2002 in this scenario. Supplemental funding from other federal agencies or other sources within NSF should not be assumed, but the panel is encouraged to consider best practices developed by these agencies and the private sector in operating remote facilities, as well as new technologies (e.g., robotics) and approaches that could yield further efficiencies and cost savings. NSF looks to the Panel to recommend promising approaches and investments that can produce significant long-term savings in the USAP.

In considering other scenarios, the panel is encouraged to identify areas in which substantial increases in program effectiveness would result from resource reallocations or short-term changes in budget profiles. Capital investments that lead to overall reductions in life-cycle costs should receive careful attention under all budget scenarios considered.

NSF will evaluate and seek to implement the recommendations of the panel to the extent practical within the context of overall budget constraints and competing requirements.

EXPECTED OUTPUT

Input to the FY 1998 budget process is highly desirable (October - December 1996 timeframe), and thus the panel is asked to report in two phases.

1) In the first phase, options for cost savings within the current program scope should be explored and recommendations developed for how these cost savings could best be applied to meet the science, foreign policy, and national security objectives of the USAP. A useful specific target might be seeking savings adequate to support South Pole Station replacement within the current budget envelope. These results, provided late in 1996, will furnish a useful benchmark for the budget process and for the Panel's further deliberations.

2) In the second phase, the Panel is asked to examine the full range of options available to optimize the Antarctic program at various funding levels.

In its deliberations the panel should consider:

- priority, scope, and scale of the various science programs
- options for use and levels of activity at research stations, field camps, and research vessels
- changes in logistics and supply operations to optimize delivery of science.
- increased use of robotic or other automated technologies and possible reductions in on-site presence of program personnel.
- cost sharing with international partners at a program and infrastructure level.
- investments that over the long term would improve the program and reduce life-cycle costs .

The report should include a summary of the panel's recommendations on maintaining an effective program in the various scenarios, with an explicit statement of the assumptions and tradeoffs made.

The panel charge is complex, but I ask that the panel provide its final report to me in early 1997. The recommendations will guide me in my planning and policy discussions within the NSF and NSB, as well as with OSTP, OMB, and the Congress as we seek to sustain the high quality USAP science programs and maintain an active and influential presence in Antarctica in the face of budget realities.

Neal Lane

Neal Lane
Director
National Science Foundation
August 2, 1996

Appendix III.

United States Department of State

Under Secretary of State for Global Affairs

Washington, D.C. 20520-7250

RETR. AUGUST

JAN 30 1997

January 27, 1997

Dear Norm:

I would like to underline our interest in seeing strategic and foreign policy considerations accorded due weight in examining options for the future United States Antarctic Program, including United States presence in Antarctica. The fact that you are chairing the external review panel examining these options, (already known as the Augustine Panel), in itself, is reassuring to us on this score.

When the Congress mandated a study of future United States presence in Antarctica in light of growing budget constraints, it was clear that United States strategic and foreign policy objectives, as well as science priorities, were at stake. The importance of our strategic and foreign policy interests in Antarctica is summarized in the Department of State's Memorandum of March 9, 1996 to the National Security Council. The Department of Defense cleared this memorandum. A copy is attached.

We have coordinated further with DOD and wish to reiterate the basic point that maintaining an active and influential United States presence in Antarctica serves important strategic and foreign policy objectives. This presence in Antarctica, anchored at the South Pole, gives us a decisive voice in the Antarctic Treaty system, which is the basis for the peace and stability of the area.

Mr. Norman Augustine,
Chairman of the Board,
and Chief Executive Officer,
Lockheed Martin Corporation,
6801 Rockledge Drive,
Bethesda, Maryland 20817.

The Treaty prohibits military and nuclear activities in Antarctica and guarantees freedom of scientific research there. It sets aside disputes over territorial claims which would otherwise put us at odds with important allies and guarantees our access to the entire continent for peaceful purposes. Moreover, it has proven a dynamic and resilient basis for dealing with new issues relating to resources and the environment.

It is essential that our strategic and foreign policy objectives be reflected in the important decisions that must be made about the future U.S. presence and program in Antarctica. In our judgment, when viewed from the perspective of overall national objectives, investment in this presence, including rebuilding and continued occupation of South Pole Station, will be seen as cost-effective as well as necessary.

I wish you every success in overseeing completion of the work of the Panel.

With best wishes,

Sincerely yours,

Tim

Timothy E. Wirth

Washington. D.C. 20520

'96 ... P 1:07 March 9, 1996

UNCLASSIFIED

MEMORANDUM FOR ANDREW D. SENS
EXECUTIVE SECRETARY
NATIONAL SECURITY COUNCIL

SUBJECT: Antarctica: Funding of the United States Antarctic Program, including South Pole Station

The United States has important foreign policy and national security interests in Antarctica. These interests are given concrete expression through the Antarctic Treaty of 1959. The Treaty guarantees freedom of scientific research in Antarctica and prohibits military and nuclear activities, with rights of on site inspection to assure compliance. It is the indispensable basis for successful pursuit by the United States of the unique opportunities Antarctica offers for scientific research, as well as associated goals of protecting the environment of Antarctica and conserving its resources.

The Treaty's framework for managing conflicts over territorial sovereignty in Antarctica has prevented regional conflicts such as the dispute over the Beagle Channel or the Falklands War from spreading to Antarctica. The international peace and political stability in the area resulting from the Treaty has greatly supported foreign and national policy objectives of the United States. Moreover, the importance of Antarctica for national security, environmental and scientific interests was reflected in PDD-26 signed by President Clinton.

The success of the Antarctic Treaty and the achievement of United States interests through it rest upon the year round presence in Antarctica maintained by the United States Antarctic Program (USAP), the program of scientific research and associated logistics funded and managed by the National Science Foundation. The most visible symbol of this presence is South Pole Station, in continuous operation since 1956.

UNCLASSIFIED

Budget constraints have raised important issues relating to United States presence in Antarctica. The Senate Appropriations Committee has expressed concern over the costs of the USAP and called for the National Science and Technology Council to review United States presence in Antarctica. U.S. facilities at the South Pole have reached the end of their design life and need replacement.

The Department believes that our foreign policy and national interests must be reflected in budgetary decisions affecting United States presence in Antarctica. This presence is particularly important when viewed in the light of the dispute over territorial sovereignty in Antarctica. Seven nations (Argentina, Australia, Chile, France, New Zealand, Norway and the U.K.) assert claims to territorial sovereignty over parts of Antarctica. The claims of Argentina, Chile and the U.K. overlap. The United States, along with Russia and others active in Antarctica, reject claims and assert the right of access to all areas of Antarctica for peaceful purposes. At the same time, the United States has a solid basis of claim in Antarctica, resulting from its activities there prior to 1959.

The Antarctic Treaty includes imaginative juridical and decisionmaking provisions that permit Parties to agree to disagree over sovereignty. It freezes previously asserted rights and claims to territorial sovereignty in Antarctica, including reservation of any prior basis of claim (e.g., the United States basis of claim). It prohibits new claims and provides that no acts or activities carried out while the Treaty is in force may constitute a basis for a claim. Decisionmaking authority in the Treaty system is linked to actual involvement in activities in Antarctica. The twelve nations that negotiated the Treaty were all active in scientific research on the continent. Participation in decisionmaking by nations that subsequently become Party requires demonstration of interest in Antarctica by the conduct of substantial scientific research there.

The Treaty has proven to be durable and dynamic, evolving to deal effectively with new scientific, environmental and resource management issues and to accommodate new participants. The number of Treaty Parties active in Antarctica has grown from the original twelve to twenty-six and includes all permanent members of the United Nations Security Council as well as Japan, India and Brazil. The regular meetings of the Treaty Parties provide a forum for peaceful cooperation among them even when bilateral relations are strained or hostile. For example, Argentina and the U.K. continued to interact peacefully within this forum during the Falklands War and the United States and Soviet Union were able to cooperate on Antarctic matters even when relations were at their worst.

More than any other nation, the United States benefits from the Antarctic Treaty. The potential for international discord and conflict over Antarctica that would exist absent the Treaty is, if anything, greater now than when it was negotiated. The United States has developed a world class program of scientific research in Antarctica and shaped the innovative resource management arrangements that have evolved under the Treaty. The effective operation of the Antarctic Treaty is a direct result of the active and influential United States presence in Antarctica maintained through the Antarctic Program. This presence accords the United States a decisive role in the Treaty's activities based decision system and in maintaining the political and legal balance that makes the Treaty work.

The Department of State believes it essential that the United States continue to maintain an active and influential presence in Antarctica, including year-round operation of South Pole Station. United States presence at the South Pole Station demonstrates United States commitment to assert its rights in Antarctica, its basis of claim, and its committment to conduct cutting edge scientific research there. Abandonment of the Station would create a vacuum and likely result in a scramble to occupy the site, to the detriment of our position as well as to the stability of the Treaty system.

Shrinking budgets raise issues of priority, particularly in respect of capital outlays such as are projected for necessary replacement of South Pole Station. However, funding decisions on the United States Antarctic Program must be based on the fact that it is a national program that serves important foreign policy and national objectives as well as basic scientific, environmental and economic interests. From this perspective, appropriation of the funds necessary to maintain an active and influential United States presence in Antarctica, including renovation of South Pole Station, represents both a priority and cost effective investment.

The Department of Defense has cleared this memorandum.

William J. Burns *for*
Executive Secretary

Appendix IV.

Summary of Recommendations

Recommendation I: The U. S., as a matter of national policy, should maintain a continued year-round presence in Antarctica, including at the South Pole.

Recommendation II: Promptly initiate steps to eliminate safety and health shortfalls at all U. S. facilities in Antarctica and, because of their magnitude, particularly at South Pole Station.

Recommendation III: The U. S. should continue to maintain permanent, facilities in Antarctica at Palmer, McMurdo and the South Pole.

Recommendation IV: International cooperation in scientific research and logistics support should be encouraged, but permanent facilities and infrastructure at permanent U. S. sites in Antarctica should be provided by and maintained by the U. S.

Recommendation V: The existing South Pole Station should be replaced with an Optimized Station. This construction can be accomplished by the year 2005 if the necessary budgetary steps are taken immediately (to initiate funding for the period FY98-FY02).

Recommendation VI: After having taken all prudent steps to reduce the cost of a new facility at South Pole Station and to seek other cost reductions to fund such a station, there remains a funding shortfall; therefore, additional funds in the amount of $95M (then-year dollars) over the five-year period FY98-FY02 should be added to the NSF budget to permit the phased replacement of the existing South Pole Station.

Recommendation VII: The NSF should prepare, and annually update, a long-range plan that coordinates science, support and facility needs to carry out the U. S. Antarctic Program. Implementation funds should be provided to support the long range plan.

Recommendation VIII: To the greatest extent possible, all support activities in Antarctica should be placed under a single prime contractor — with oversight by a single individual/ office designated by the NSF. Subsidiary organizational elements should be restructured to minimize overlap, duplication and interfaces.

Recommendation IX: The NSF should implement mechanisms to include science support costs as an explicit rather than implicit portion of the evaluation of proposed scientific projects that make up the USAP.

Recommendation X: The NSF and its contractor, Antarctic Support Associates, should review those functions no longer to be performed by the DOD to ensure that those functions are transferred to the recipient organization in the most efficient possible manner...or, where possible, eliminated. Similarly, the U. S. Coast Guard's operating budget should continue to absorb the level of fixed icebreaker costs that exceed reimbursement.

Recommendation XI: The NSF should seek advance arrangements with governmental and commercial geostationary satellite operators to make such satellites systematically available as they near the end of their economic commercial life.

Recommendation XII: The U. S. Government, presumably the Department of State, should convene those U. S. Government organizations having interests in Antarctica and develop a policy regarding the increased tourism to be expected in Antarctica in the years ahead and, further, should work with other interested governments to address this issue in a proactive and cooperative manner.

Appendix V.

Presentations and Interactions

The Panel, in its deliberations, was greatly assisted by presentations by, or conversations with, the following individuals:

NATIONAL SCIENCE FOUNDATION

Dr. Joseph Bordogna, Acting Deputy Director
Mr. Bill Bryant, Contracting Officer, Contracts Policy and Oversight
Dr. Karl Erb, Senior Science Advisor, Office of the Director, and Liaison to the Panel
Mr. Guy Guthridge, Executive Secretary to the Panel, Office of the Director
Mr. Joseph Kull, Director - Budget and Finance Division, and Chief Financial Officer
Dr. Neal Lane, Director
Mr. Larry Rudolph, General Counsel

From the Office of Polar Programs

Mr. David Bresnahan, Systems Manager, Operations and Logistics
Mr. Frank Brier, Facilities, Engineering and Construction Program Manager
Mr. Erick Chiang, Acting Deputy Director
Mr. Dwight D. Fisher, Acting Section Head, Polar Research Support Section
Ms. Joyce Jatko, Environmental Officer
Dr. Harry Mahar, Safety and Health Officer
Mr. Al Martin, NSF Station Manager, McMurdo Station, Antarctica
Ms. Altie Metcalf, Budget and Planning Officer
Dr. Dennis Peacock, Section Head, Antarctic Sciences Section
Mr. John Rand, South Pole Engineering Projects Manager
Mr. Patrick D. Smith, Technology Development Project Manager
Dr. Cornelius W. Sullivan, Director
Mr. Alexander Sutherland, Ocean Projects Manager

NSF SUPPORT

Colonel Archibald Berberian, Chief of Staff, New York Air National Guard
Dr. William Detrich, Chair, Palmer Station Users Committee
Dr. Jay Farmwald, Director of Health Facilities, Alaska Public Health Service
Dr. Hank Grant, Decision Support Associates
Dr. Dave Hofmann, Director, Climate Monitoring and Diagnostics Laboratory, NOAA
Mr. Jim Holik, Science Cruise Coordinator, Antarctic Support Associates
Ms. Kate Jensen, Former NOAA Field Team Leader at South Pole Station
Mr. Jon Kumin, Kumin and Associates
Dr. Donal Manahan, Chair, McMurdo Area Users Committee
Dr. Doug Martinson, Chair, Research Vessel Oversight Committee
Dr. Robert Morse, Chair, South Pole Users Committee
Dr. Samuel Mukasa, Chair, Office of Polar Programs Advisory Committee
Mr. Jerry Mullins, Polar Programs Manager, U.S. Geological Survey
Ms. Ann Peoples, Former ASA Station Manager for McMurdo and Palmer Stations
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Appendix VI.

International Agreements: Excerpts

THE ANTARCTIC TREATY, signed on 1 December 1959 and entered into force on 23 June 1961, establishes the legal framework for management of Antarctica. Administration is carried out through consultative member meetings - the 21st Antarctic Treaty Consultative Meeting was in the Hague, Netherlands, in May 1996.

Currently, there are 43 treaty member nations: 26 consultative and 17 acceding. Consultative (voting) members include the seven nations that claim portions of Antarctica as national territory (some claims overlap) and 19 nonclaimant nations. The U. S. and some other nations that have made no claims have reserved the right to do so. The U. S. does not recognize the claims of others.

The year in parentheses indicates when an acceding nation was voted to full consultative (voting) status, while no date indicates the country was an original 1959 treaty signatory. Nonclaimant consultative nations are - Belgium, Brazil (1983), China (1985), Ecuador (1990), Finland (1989), Germany (1981), India (1983), Italy (1987), Japan, South Korea (1989), Netherlands (1990), Peru (1989), Poland (1977), South Africa, Spain (1988), Sweden (1988), Uruguay (1985), the U. S., and Russia. Claimant nations are - Argentina, Australia, Chile, France, New Zealand, Norway, and the U. K.

Acceding (nonvoting) members, with year of accession in parentheses, are - Austria (1987), Bulgaria (1978), Canada (1988), Colombia (1988), Cuba (1984), Czech Republic (1993), Denmark (1965), Greece (1987), Guatemala (1991), Hungary (1984), North Korea (1987), Papua New Guinea (1981), Romania (1971), Slovakia (1993), Switzerland (1990), Turkey (1996), and Ukraine (1992).

Article 1: area to be used for peaceful purposes only; military activity, such as weapons testing, is prohibited, but military personnel and equipment may be used for scientific research or any other peaceful purpose

Article 2: freedom of scientific investigation and cooperation shall continue

Article 3: free exchange of information and personnel in cooperation with the UN and other international agencies

Article 4: does not recognize, dispute, or establish territorial claims, and no new claims shall be asserted while the treaty is in force. No activities while the Treaty is in force shall constitute a basis for asserting, supporting, or denying a claim

Article 5: prohibits nuclear explosions or disposal of radioactive wastes

Article 6: includes under the treaty all land and ice shelves south of 60 degrees south

Article 7: treaty-state observers have free access, including aerial observation, to any area and may inspect all stations, installations, and equipment; advance notice of all activities and of the introduction of military personnel must be given

Article 8: allows for jurisdiction over observers and scientists by their own states

Article 9: frequent consultative meetings take place among member nations

Article 10: treaty states will discourage activities by any country in Antarctica that are contrary to the treaty

Article 11: disputes to be settled peacefully by the parties concerned or, ultimately, by the ICJ

Articles 12, 13, 14: deal with upholding, interpreting, and amending the treaty among involved nations

Other significant international agreements under the Antarctic Treaty system:

Conservation of Seals

Under the Antarctic Treaty, the Convention for the Conservation of Antarctic Seals entered into force in 1978. This convention prohibits the taking of some species and limits the take of others.

Whale Sanctuary

In 1994 the International Whaling Commission designated the southern ocean south of 40°S (south of 60°S between 50°W and 130°W) as a whale sanctuary. Commercial whaling is not allowed in the sanctuary.

Marine Living Resources Convention

The Convention on the Conservation of Antarctic Marine Living Resources (CCAMLR) is an international agreement to assure that (1) any harvesting or associated activities in Antarctic waters will be done in such a way that the size of the harvested species will not fall below levels that will assure stable recruitment and (2) the ecological relationships among harvested, dependent, and related populations will be maintained. The USA is a ratifying nation. Title III of Public Law 98-623 (the Antarctic Marine Living Resources Convention Act of 1984—16 USC 2431 et seq.) provides the legislative authority necessary to implement the convention in the USA. The law makes it unlawful to harvest marine species in violation of the convention, and it provides for certain other activities. Marine biologists, other marine scientists, and ship operators should be familiar with this law.

Protocol on Environmental Protection

The Protocol on Environmental Protection to the Antarctic Treaty and its five annexes respond to the need for a comprehensive system to protect the Antarctic environment. The parties to the Antarctic Treaty held a special consultative meeting to discuss and explore proposals for protection of the Antarctic environment and its dependent and associated ecosystems. This meeting consisted of several sessions held over a year. At the final session in Madrid, Spain, in October 1991, representatives of the Antarctic Treaty nations signed the Protocol on Environmental Protection to the Antarctic Treaty, including annexes I-IV, which cover environmental impact assessment, conservation, waste disposal and management, and prevention of marine pollution. Annex V (special area protection and management) was adopted by the 16th Antarctic Treaty consultative meeting, also held in October 1991. In the Protocol, the representatives agree to means for providing comprehensive protection of Antarctica's environment and dependent and associated ecosystems in order to preserve the region as a natural reserve devoted to peace and science. The protocol bans mining (see section 5.2).

The protocol will enter into force when all the signatory nations deposit their instruments of ratification. U.S. PL-104-227, the "Antarctic Science, Tourism, and Conservation Act of 1996," signed 2 October 1996 by the President, implements the provisions of the Protocol. The Senate had already given its advice and consent to ratification of the Protocol. Deposit of the U.S. ratification with the Antarctic Treaty System awaits completion of regulations pursuant to PL-104-227.

To the extent possible, the U.S. complies with the Protocol. The U.S. legislation when enacted may contain provisions different from those in the Protocol.

Appendix VII.

Bibliography

Americans in Antarctica 1775-1948, by Kenneth J. Bertrand, American Geographical Society, 1971

Antarctica: Authentic Accounts of Life and Exploration in the World's Highest, Driest, Windiest, Coldest, and Most Remote Continent, edited by Charles Neider, Random House, 1972

Antarctic Conquest: The Great Explorers in Their Own Words, edited by Walker Chapman, Bobbs-Merrill Company, 1965

Antarctic Research: Program Announcement and Proposal Guide (NSF 96-93), National Science Foundation, April 1996

Cold. The Record of an Antarctic Sledge Journey, by L. M. Gould, Brewer, Warren, and Putnam, 1931

Endurance, Shackleton's Incredible Voyage, by Alfred Lansing, McGraw Hill, 1959

Facts About the U.S. Antarctic Program (NSF 92-134), National Science Foundation, October 1994

90 Degrees South: The Story of the American South Pole Conquest, by Paul A. Siple, G.P. Putnam's Sons, 1959

United States Antarctic Program, Committee on Fundamental Science, National Science and Technology Council, April 1996

Poles Apart: Parallel Visions of the Arctic and Antarctic, text and photographs by Galen Rowell, University of California Press, 1995

South Light: A Journey to the Last Continent, by Michael Parfit, Macmillan, 1985

The Ice: A Journey to Antarctica, by Stephen J. Pyne, University of Iowa Press, 1986

The Worst Journey in the World, by Apsley Cherry-Garrard, first published 1922

Glossary

AESOPS	Antarctic Environment and Southern Ocean Process Study
AMANDA	Antarctic Muon and Neutrino Detector Array
ANG	Air National Guard
ASA	Antarctic Support Associates, Inc.
ATC	Air traffic control
CARA	Center for Astrophysical Research in Antarctica
CCAMLR	Convention on the Conservation of Antarctic Marine Living Resources
CFCs	Chlorinated fluorocarbons
CRAMRA	Convention on the Regulation of Antarctic Mineral Resources Activities
DOD	Department of Defense
DU	Dobson units
FTE	Full-time-equivalent
FY	Fiscal year (begins 1 October in U.S. Government)
IGY	International Geophysical Year, 1957-1958
JGOFS	Joint Global Ocean Flux Study
LC-130	Ski-equipped C-130 (four-engine transport aircraft)
LEO	Low Earth orbit
LTER	Long term ecological research
M	Million
NASA	National Aeronautics and Space Administration
NOAA	National Oceanic and Atmospheric Administration
NSC	National Security Council
NSF	National Science Foundation
NSFA	Naval Support Force Antarctica
NSTC	National Science and Technology Council
NYANG	New York Air National Guard
OPP	Office of Polar Programs, NSF
PHI	Petroleum Helicopters Inc.
R/V	Research vessel
SEH	Safety, environmental protection, and health
TOMS	Total ozone mapping spectrometer
USAF	United States Air Force
USAP	U. S. Antarctic Program
USARP	U. S. Antarctic Research Program (Component of USAP)
USCG	United States Coast Guard
USGS	United States Geological Survey
USNS	United States Naval Ship
VXE-6	Antarctic Development Squadron 6, U.S. Navy
WAIS	West Antarctic Ice Sheet