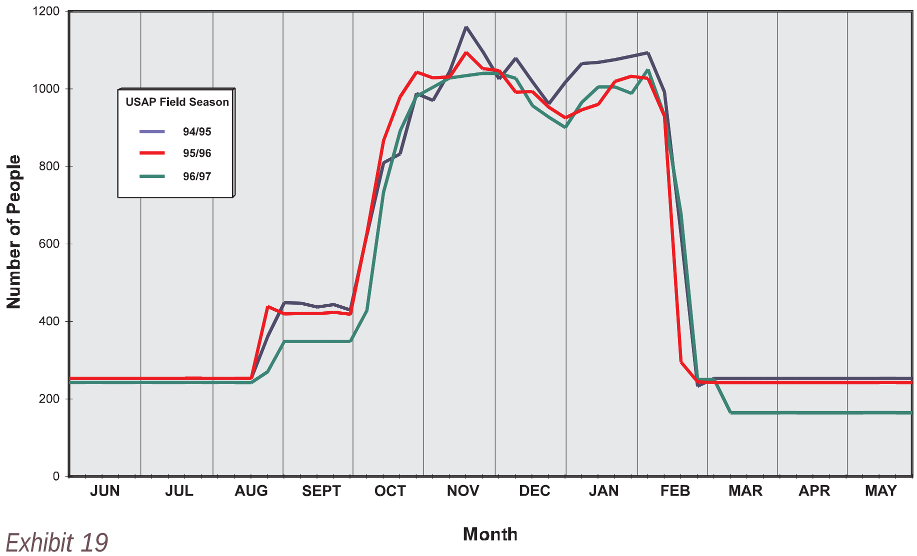


Exhibit 19

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

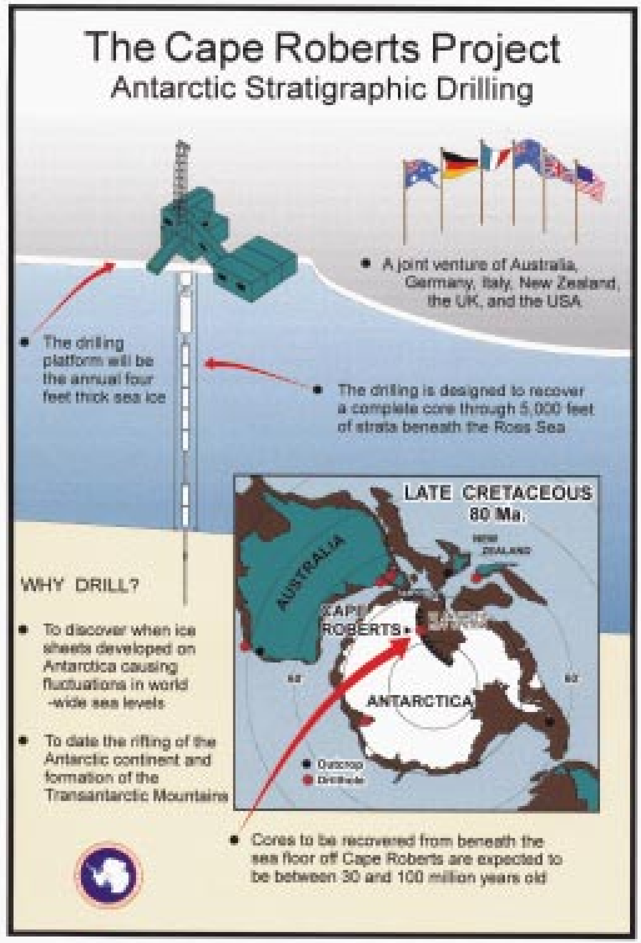


Exhibit 31

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).

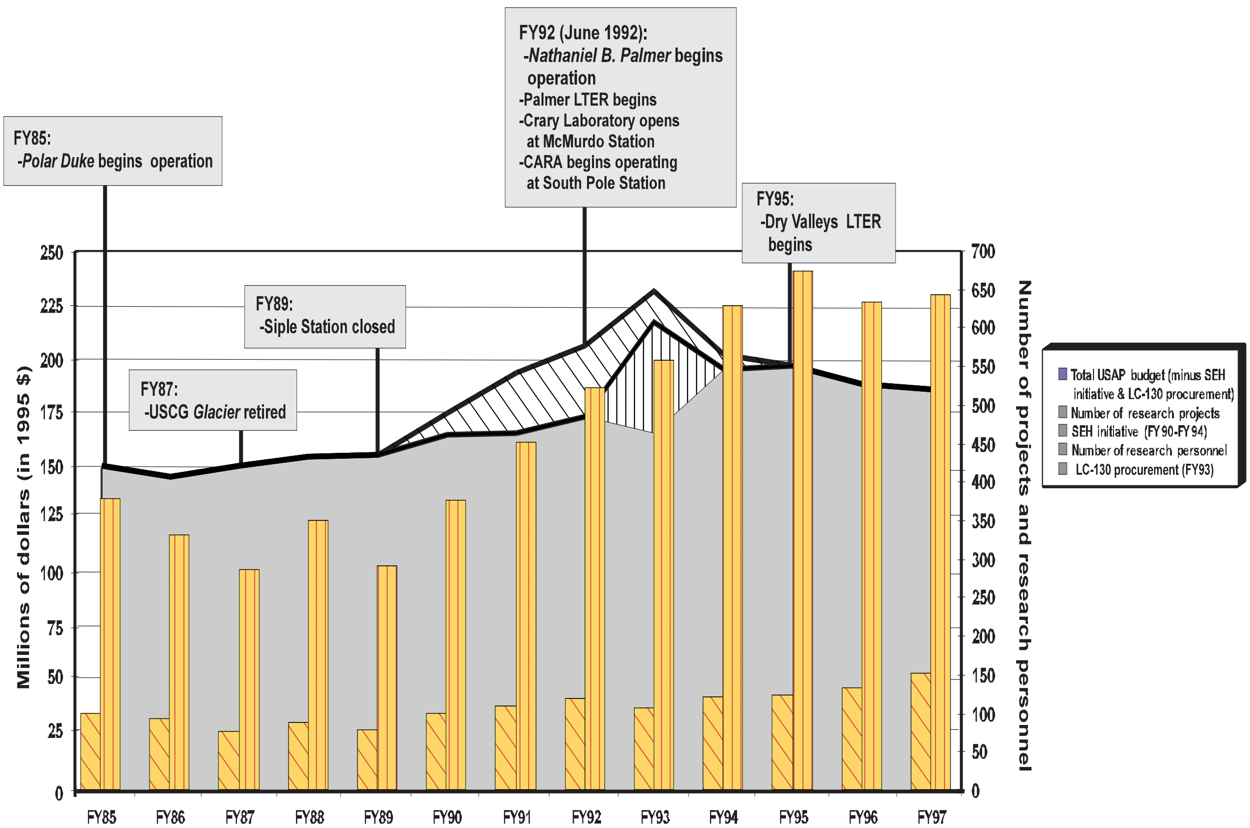
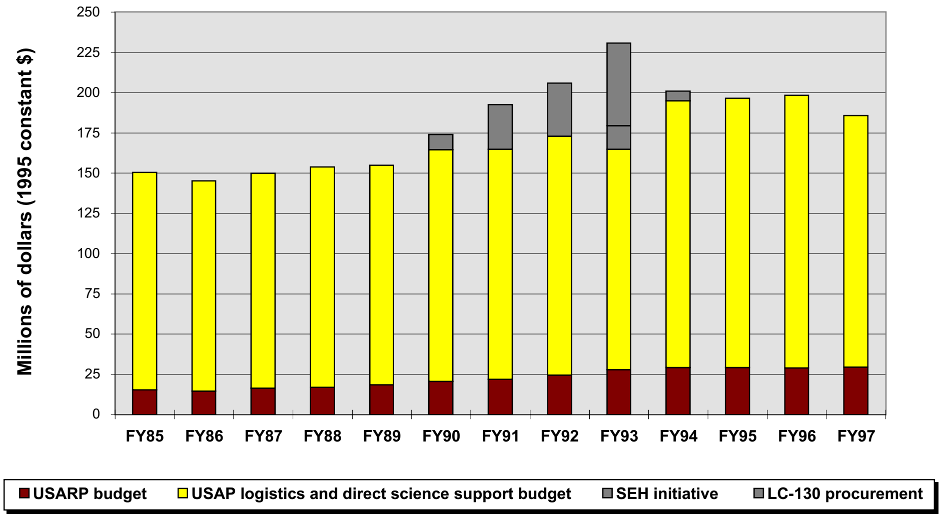


Exhibit 32

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.