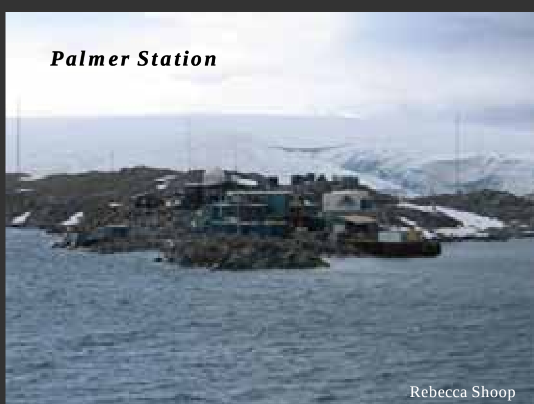
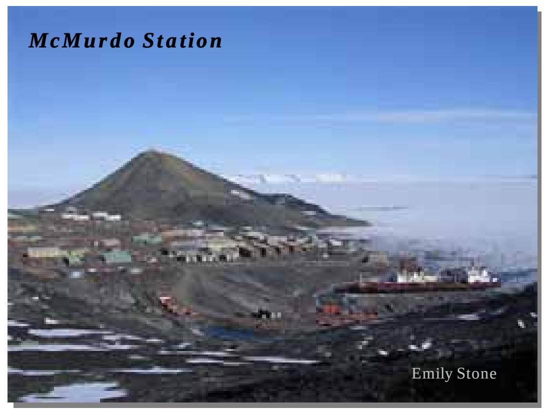
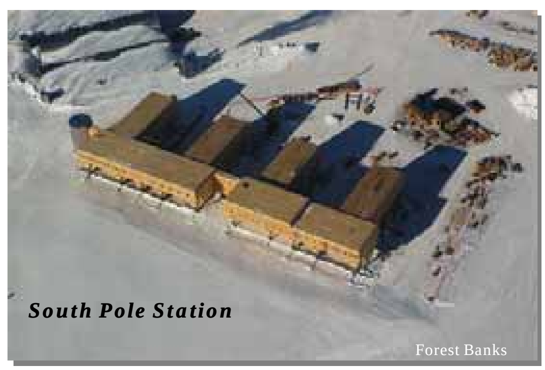
United States Antarctic Program

Summary and Background

2005-2006 Season







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1. Some reasons to perform scientific research in the Antarctic

a. **Largest ocean current.** The Antarctic Circumpolar Current transports 130 million cubic meters of water per second towards the east, making it the mightiest of the ocean's currents. It influences formation of cold, dense, and nutrient-rich bottom water that extends throughout much of the world ocean and is a key to understanding change in world ocean circulation and its influence on global climate.[1]

b. **Marine ecosystem.** Research on the marine ecosystem around Antarctica helps to understand levels of harvesting that can take place without damaging the ecosystem and is providing an understanding of the strong coupling in the Southern Ocean between climate processes and ecosystem dynamics.[2]

c. **Sea ice.** The annual eightfold growth and decay of sea ice around Antarctica has been termed the greatest seasonal event on Earth.[3] It affects regional climate and the global heat budget. Particularly near the edges, it nurtures some of the world's most productive ecosystems.[4]

d. **Ozone hole.** Starting in 1979, ozone in the stratosphere over Antarctica has been observed almost to disappear every austral spring. Everywhere else, stratospheric ozone depletions are only incremental. Stratospheric ozone keeps much of the Sun's harmful ultraviolet radiation from reaching the Earth's surface, and the ozone hole has received widespread attention.

   i. **Finding the cause.** Research in Antarctica, particularly at McMurdo, was key to explaining how antarctic natural phenomena conspire with the global buildup of manmade chemicals to cause the ozone hole.[5]

   ii. **Removing the cause.** The research led to an international decision (the Montreal Protocol) to reduce production of the destructive chemicals. Annual consumption of CFCs dropped from 1,100,000 tons in 1986 to 150,000 tons in 1999. Without the protocol, consumption would have reached 3,000,000 tons by 2010.[6]

   iii. **Monitoring the recovery.** While atmospheric concentrations of the harmful manmade chemicals are in decline, it might take another 10 years of observation before we can be sure the antarctic ozone hole is shrinking. Current antarctic research is providing further understanding of the ozone hole.[7]

   iv. **Effect on life.** The ozone hole lets abnormally high levels of the Sun's ultraviolet-B radiation penetrate to the Earth's surface and into the sea. Scientists have documented how UV-B affects bacteria, phytoplankton, and the embryos of antarctic invertebrates and fish.[8]

   v. **Effect on climate.** Research indicates that the ozone hole has increased the winds around Antarctica and reduced rainfall in Australia and elsewhere.[9]

vi. **Awards.**

a. The 1995 **Nobel Prize** in Chemistry was awarded to three professors who explained that the ozone layer is sensitive to anthropogenic emissions.[10]

b. The 1999 **National Medal of Science** (the Nation's highest scientific honor) was awarded to Dr. Susan Solomon, who led U.S. Antarctic Program expeditions in 1986 and 1987 giving the first direct evidence that anthropogenic chlorine depletes stratospheric ozone.

c. The 2002 **National Medal of Technology** (the Nation's highest honor for technological innovation) was awarded to the Dupont Company for leadership in the phaseout and replacement of chlorofluorocarbons (CFCs).[11]

e. **Polar adaptations of biota.** Antarctic cold, desert conditions, and annual light cycles have led to molecular, biochemical, and physiological adaptations that have enabled biota to survive, reproduce, and indeed thrive under environmental extremes not experienced elsewhere. Studies provide basic understanding of these unique adaptations and are leading to understanding how changes in populations can shed insight into changing climate.[12]

f. **Atmospheric background levels.** Antarctica is the planet's farthest region from human population centers and records the world's background levels of atmospheric constituents. Measurements since 1956 at the geographic South Pole have documented changes in world levels of greenhouse gases such as carbon dioxide and methane. Measurements in the data-sparse Southern Hemisphere are important to understanding and predicting world levels of these gases and their impact on (or forerunner to) climate change.[13]

g. **Weather and climate.** The unbroken collection of weather data from manned and unmanned stations in Antarctica, now exceeding 40 years for some locations, provides a data base and real-time information from which to make operational forecasts, study the dynamics of the antarctic atmosphere, and chart the progress of human-induced global warming.[14]

h. **Ice sheets and ice shelves.** Antarctica's ice sheets contain 90 percent of the world's ice. This ice is 70 percent of the world's fresh water. Melted, it would raise sea level 65 meters (200 feet).

i. **Global process.** Antarctica's ice—the world's largest area of cold (the Arctic is 35^{o}F warmer)—affects and responds to world climate change. Just 20,000 years ago, for example, the ice sheet was far larger. Sea level was 11 meters (36 feet) lower, that much water having been evaporated from the world's oceans and precipitated onto Antarctica.[15]

ii. **Climate history.** The ice, deposited annually as snow over millions of years, traps past atmospheric constituents that tell a climate history with a precision not equaled by other proxies such as ocean sediments and tree rings. The world's deepest ice core (3,650 meters) and another core containing the world's oldest ice then sampled (possibly 1 million years old) both were drilled in Antarctica.[16]

iii. **West Antarctic Ice Sheet**. The West Antarctic Ice Sheet if melted would raise sea level 5 meters. It is less stable than the eastern one because its base is below sea level. Its low-probability/high-impact collapse has stimulated vigorous research over the last 30 years indicating that it has largely or completely disappeared after it formed, but at an unknown rate. Portions of it are changing rapidly now, while averages over the whole ice sheet show little change. Some models project stability, while others suggest the possibility of rapid change.[17]

iv. **Ice shelf dynamics.** Ice shelves—extensions of continental ice sheets that are afloat on the ocean—can control the rate at which their parent ice sheets or glaciers move into the sea and can respond quicker than ice sheets to environmental change. The Larsen Ice Shelf on the east coast of the Antarctic Peninsula lost massive sections in 1995 and 2002, possibly in response to atmospheric and oceanic warming over the last several decades. Some scientists call it a model for what could happen to larger ice shelves farther south.[18]

v. **Meteorites.** Since 1969, teams from the United States, Japan, and the European Council have collected 30,000 meteorite specimens from the surface of the ice sheet representing many meteorite classes (including some from the Moon and Mars) and extending our knowledge of the solar system. Antarctica has yielded four-fifths of the meteorites known to science.[19]

vi. **Neutrino detection.** The ice sheet beneath the South Pole is 2,900 meters deep and is homogeneous and clear. Investigators buried downward-looking detectors to observe light produced by neutrinos (ultra-high-energy particles created by cataclysmic collisions in deep space) when they on rare occasions collide with atoms of ice after they pass through the Earth. The data help in descriptions of galactic centers, dark matter, and supernovae. The observatory in March 2001 became the first in the world to detect neutrinos.[20]

vii. **Subglacial lakes.** More than 70 lakes lie beneath the ice sheet, most of them several kilometers long. One, Vostok Subglacial Lake, is an order of magnitude larger and represents the closest analog to both Europa (a moon of Jupiter) and a Neoproterozoic ("Snowball Earth") subglacial environment. Lake Vostok is oligotrophic—an environment with low nutrient levels and low standing stocks of organisms. Life there may depend on alternative energy sources and survival strategies.[21]

i. **Polar landmass.** Almost 10 percent of the Earth's continental crust resides in Antarctica. The continent is old and stable and has been in a near-polar position for over 100 million years. It thus contains unique high latitude environmental records of a time when Earth changed from greenhouse to icehouse conditions. The landmass is different from the other continents in that Antarctica's crustal structure—or its underlying mantle—has allowed the continent to remain essentially fixed on Earth's surface for a long time.

j. **Astronomy by balloon.** Antarctica's summer weather provides a stable ride for instruments suspended from a balloon, which floats around Antarctica at a steady height above most of the atmosphere, providing a cheap way to get scientific experiments into near-space.[22]

k. **Astrophysics and astronomy from the surface**. The cold, clean, dry atmosphere over the South Pole provides viewing conditions that in some wavelengths are equal to those in space. South Pole Station has become a major astronomy and astrophysics center.[23]

l. **Mount Erebus — one of Earth's few long-lived lava lakes.** The world's southern-most active volcano, Mt. Erebus is one of the few volcanoes in the world with a long-lived (decades or more) convecting lava lake. Although the volcano was discovered by James Ross in 1841, scientists still know relatively little about its geology because of extensive snow and ice cover, its remoteness, the extreme environment, and the short field season.[24]

2. **Season project highlights**

The table shows this year's number of U.S. Antarctic Program research projects and related activities in Antarctica and the Southern Ocean.[25] Projects range in size from one person to tens of people, and time in the Antarctic ranges from a few days to years. Some of these 165 science and technical projects are active at more than one location. A few are described in the paragraphs below.

Discipline	**1**	**2**	**3**	**4**	**5**	**6**	**7**
McMurdo and camps	14	30	17	12	5	6	4
South Pole	25	0	2	1	4	0	2
Palmer	2	12	2	0	2	1	3
Ships	0	29	2	0	6	0	1

Disciplines:

1 Aeronomy, astrophysics
2 Biology, medicine
3 Geology, geophysics
4 Glaciology
5 Climate, ocean sciences
6 Artists, writers
7 Technical projects

a. **Ten-meter telescope**. A foundation was built for a new 10-meter telescope at the South Pole to investigate properties of the dark energy that pervades the universe and accelerates its expansion, to constrain the mass of the neutrino, to search for the signature of primordial gravitational waves, and to test models of the origin of the universe.[26]

b. **IceCube**. Work will continue on the world's largest neutrino detector, which — after 6 years of work — will occupy a cubic kilometer of ice beneath South Pole Station, deploying 4,800 photomultiplier tubes into holes that a hot water drill will make in the ice. Neutrinos are special but hard to detect astronomical messengers that can carry information from violent cosmological events at the edge of the universe or from the hearts of black holes. The history of astronomy is that work in new energy regions invariably has discovered unexpected phenomena. By peering through a new window on the universe, IceCube could open new frontiers of understanding. During the 2005-06 austral summer, participants will drill 10 ice holes and deploy 10 IceCube strings and 20 Ice-Top tanks.[27]

c. **International Graduate Training in Antarctic Biology.** This NSF-sponsored international course will be held at McMurdo Station for one month, starting in January 2006. Up to 20 graduate students, postdoctoral fellows, and other research scientists interested in studying extreme environments and the biology of antarctic organisms will participate. The course's emphasis is on integrative biology, with laboratory- and field-based projects focused on adaptations in an extreme polar environment. A diverse teaching faculty will offer students the possibility of working on a wide range of antarctic organisms (bacteria, algae, invertebrates, and fish), as well as working at several different levels of biological analysis (molecular biology, physiological ecology, species diversity, and evolution). [28]

d. **Long-term ecological research (LTER)**. Two sites in Antarctica — in the McMurdo Dry Valleys and along the west coast of the Antarctic Peninsula centered on Palmer Station — are among the world's 25 NSF-sponsored LTER sites being investigated to increase understanding of ecological phenomena over long temporal and large spatial scales (all but one of the other sites are in the United States).[29]

e. **Weddell seal population dynamics.** Weddell seals in McMurdo Sound have been studied since 1968—one of the longest intensive field investigations of long-lived mammals anywhere. More than 15,000 animals have been tagged, and 145,000 resightings have been recorded. The project is a resource for understanding the population dynamics of not only Weddell seals, but also other species of terrestrial and marine mammals. New work this season includes assessing the role of food resources in limiting the populations.[30]

f. **Foraminifera studies by remote control.** Research divers have detailed summer "snapshots" of the ecology of giant (>1mm) foraminifera in McMurdo Sound, but winter observations are needed when algae are not growing. This project has installed an unmanned underwater observatory connected to shore by fiber optic cable and linked through the Internet to a lab in the United States for operation and data collection all year long.[31]

g. **Genomic study of invertebrates.** Cold-ocean ecosystems are 72 percent of Earth's biosphere by volume, yet they are sparsely inhabited and relatively unexploited. Environmental adaptations of the few animals that manage to exist on this verge of intracellular freezing are ideal subjects for exploration at the genomic level. This project is quantifying gene expression in sea stars and sea urchins to find out if it is more or less difficult for an organism to grow in a polar extreme. To interest students in the developing field of environmental genomics, the project has an intern program for minority students and a K-12 education program.[32]

h. **DMSP and DMS in the Ross Sea.** Phytoplankton blooms spectacularly in spring and early summer in parts of the Southern Ocean. A dominant species, *Phaeocystis antarctica*, is a prolific producer of the organic sulfur compound DMSP, which degrades to dimethyl sulfide, or DMS. The sulfur in DMS transfers to the atmosphere, where it can affect the chemistry of precipitation, influence cloud components, and possibly influence climate. This project during a cruise of the research icebreaker *Nathaniel B. Palmer* from New Zealand to McMurdo is investigating the biogeochemical cycling of DMSP and DMS during the height of the bloom. The goal is to find out how light and nutrients influence DMS production and to examine the role of DMSP in the carbon and sulfur cycles of the Ross Sea.[33]

i. **Influence of UV radiation on Ross Sea productivity.** The antarctic ozone hole has increased the amount of ultraviolet radiation reaching the surface of the Southern Ocean, and earlier studies have indicated reduced biomass productivity and other damaging effects. This project, aboard the research icebreaker *Nathaniel B. Palmer*, is examining the impact on productivity in the Ross Sea, an area of intense interest because open water and continuous daylight occur in a location well within the ozone hole. The project will provide a valuable comparison with prior work in the Weddell Sea and near Palmer Station.[34]

j. **Demonstration ocean-bottom drilling in the James Ross Basin.** Scientists will deploy a drill rig on the research icebreaker *Nathaniel B. Palmer* to test the feasibility of ship-based diamond coring along the antarctic continental margin. If successful, this Shaldril mobile system will be able to explore the "no man's land" between the nearshore (where the fast-ice-based Cape Roberts Project was successful) and the upper slope (where ODP's JOIDES Resolution becomes most efficient).[35]

k. **Seismograph.** The world's quietest earthquake detector is 8 kilometers from the South Pole, 300 meters beneath the ice sheet surface. Completed in 2002, the station is detecting vibrations four times smaller than those recorded previously. Other seismographs have been there since 1957, and long-term, high-latitude data have helped to prove that the Earth's solid inner core spins faster than the rest of the planet. Also, Antarctica is the continent with the fewest earthquakes, so the new station will record small regional earthquakes, leading to new insights into the Antarctic Plate.[36]

l. **Behavior of the world's largest icebergs**. This research team will investigate the basic principles governing the calving, drifting, melting, break-up, and environmental impact of large icebergs. Because the northward drift of large tabular icebergs represents a natural "climate change" experiment on an accelerated time-scale, the melting of the icebergs being studied over the next decade will foretell events that may occur in parts of Antarctica as climate conditions change over the coming century. Understanding the natural drift patterns and regions where icebergs accumulate near inhabited parts of the globe may someday prove useful for supplying fresh water to populations in need, as far-fetched as that may be with current technology.[37]

m. **WAIS Divide.** This 5-year science program, involving a dozen research teams, will develop a detailed record of greenhouse gases for the last 100,000 years; determine if changes in the Northern and Southern Hemispheres initiated climate changes over the last 100,000 years; investigate past and future changes in the West Antarctic Ice Sheet; and study the biology of deep ice. During the 2005-2006 austral summer, the camp infrastructure for the drilling program will be assembled at a site on the West Antarctic ice sheet divide. Construction crews will establish a skiway and a camp capable of supporting approximately 45 personnel, which will eventually support the science and drilling teams who will collect a 3,400-meter ice core to bedrock. A 200-foot steel arch will be constructed that will house the drilling and core processing facilities for the deep drilling project.[38]

n. **A mobile sensor web for Polar Ice Sheet Measurements (PRISM).** PRISM research objectives are to develop sensors (imaging and sounding radars), wireless communications, intelligent systems, robotics, and ice-sheet modeling, using innovative radar sensors that image the ice-bedrock interface, measure ice thickness, and map internal layers in the ice. The sensors will provide key glaciological measurements for studying the contribution of polar ice sheets to sea-level rise. Researchers integrate and operate the radar sensors from an autonomous rover and a tracked vehicle equipped with communication and navigation systems. An intelligent system determines an optimum sensor configuration for imaging the ice-bedrock interface and the operational requirements for the rover.

o. **Tidal influence on ice stream flow**. Ice from the West Antarctic Ice Sheet flows to the sea through a number of ice streams, but the factors controlling the flow of the ice streams are not well understood. Earlier work at the Whillians Ice Stream on the Siple Coast demonstrated that the flow of these ice streams is surprisingly sensitive to changes in the tide beneath the Ross Ice Shelf. By measuring the rise and fall of the tide, researchers hope to improve their understanding of the controls on ice streams and gain information important for modeling the ice sheet.[39]

p. **Old buried ice**. Ice has covered Antarctica for millions years, but the ice is not that old; most of it arrives as snow and leaves as icebergs within a few hundred thousand years. Buried ice in the McMurdo Dry Valleys thus is a rare archive of atmosphere and climate potentially extending back millions of years. This project will study the surface processes that preserve ice, test ways of dating tills above buried ice, assess ways to date buried ice, and use these data to help resolve a debate over whether the deposits are as old as some scientists think they are.[40]

q. **Infrared measurement of the atmosphere.** Winter measurements of atmospheric chemistry are providing data for predicting ozone depletion and climate change. Since most satellites do not sample polar regions in winter, these ground-based measurements are expected to make important contributions.[41]

r. **Surface carbon dioxide in the Drake Passage.** The Southern Ocean is an important part of the global carbon budget, and the Drake Passage is the narrowest place through which the Antarctic Circumpolar Current goes. This chokepoint is an efficient site to measure the latitudinal gradients of gas exchange, and the ice-strengthened research ship *Laurence M. Gould* will support a project to measure dissolved and total CO_2, providing data that, with satellite images, will enable estimates of the net production and export of carbon by oceanic biota.[42]

s. **Antarctic Artists and Writers Program.** Seven artists and writers will deploy to Antarctica this season. Six of them will deploy to the McMurdo area between August and January and one, a writer, is part of a research team at Palmer station. Among them are two photographers, a sculpture, two writers, a poet, and a painter.

t. **Ice Coring Drilling Services.** This project, one of the technical services in support of antarctic science, provides ice core drilling to the U.S. Antarctic Program and NSF's Arctic Research Program.[43]

3. Construction highlights

a. **McMurdo power plant replacement**. Having gone past their design life, the diesel engines and the switchgear in the power plant are being replaced. To provide redundancy should a building be lost, two of the six new diesel generators will go in the water plant building next door, and one of the three reverse-osmosis water desalination units will go in the powerhouse building. The engines' waste heat—in both the liquid coolant and the exhaust—will be captured to heat McMurdo buildings. Thermal efficiency in the new power plant is expected to rise from the current 70 percent to about 90 percent. Increased use of renewable energy is planned: while solar power for McMurdo is not practical, installation of a wind turbine that can withstand McMurdo's cold and its fierce winter winds is being investigated; a midterm goal is a wind turbine that can generate a third of McMurdo's peak electrical requirement.

b. **McMurdo gasoline tanks**. Three new 250,000-gallon gasoline storage tanks with secondary containment have been erected. During the 2006-2007 austral summer, a new vehicle refueling facility will be built, on a more environmentally appropriate site than now used. The old tanks will be taken out of service and removed.

c. **South Pole Modernization Project.** Major construction and renovation are under way to replace most of the 30-year-old South Pole Station's central facilities, which have exceeded their design life and cannot meet projected science demands. Construction to date has included a new fuel storage facility, a new garage and shop, a new electric power plant, the kitchen and dining room, some of the living facilities, station services, medical facilities, science labs, emergency power plant, store/post office, food-growth chamber, and computer lab. In addition, to further building construction this season, the station's old communication center will be relocated from the Dome to the Elevated Station. The 2005-2006 austral summer represents a major project milestone with conditional occupancy and transition of all related station operations into the new Elevated Station. The 2005-2006 summer operating season will be 120 days. The modernization is scheduled for formal dedication in January 2007.

d. **Palmer Station improvements.** An upgrade, lasting several years, of the two major buildings at Palmer Station has been completed, increasing the effectiveness of science support and living facilities. A ground station installed in 2002 has extended the station's Internet communications to 24 hours per day. Replacement of, or major repair to, the station's pier is being studied.

e. **McMurdo Station Satellite Communications Upgrade**. The Black Island Telecommunications Facility, which provides McMurdo Station with its primary satellite communications service, will be upgraded to support a doubling of McMurdo's satellite capacity from 1.5 Mb/s to 3 Mb/s by February 2006.

f. **National Polar-orbiting Operational Environmental Satellite System (NPOESS) Site Survey**. A field team will investigate site location requirements for the construction of a NPOESS receptor ground station at McMurdo as apart of a global network for recovering weather and environmental sensor data in near real time from the upcoming new fleet of US weather satellites due for launch at the end of the decade.

4. Environmental protection; waste management

a. Cradle-to-grave management of supply/waste stream

b. Source-point sorting and removal of all solid and hazardous waste from Antarctica, of which approximately 65 percent is recycled

c. Environmental monitoring and research

d. Comprehensive spill prevention and cleanup program (e.g., fuel lines and hoses, double-walled or bermed fuel tanks, cleanup training and equipment)

e. Permitting system in place for all scientific and other activities involving antarctic fauna and flora

f. Educational and enforcement procedures for waste management and environmental protection

g. Sewage treatment plant at McMurdo, fully operational as of January 2003

h. Improvement of management plans for Specially Protected Areas, in cooperation with other Antarctic Treaty nations

i. Antarctic Specially Managed Area in 2004 to enhance environmental stewardship of the McMurdo Dry Valleys; management plan written and submitted to the Antarctic Treaty by the United States and New Zealand

j. In compliance with all applicable treaties and U.S. laws[44]

5. Personnel

a. The total number of people entering and leaving Antarctica and the ships over the course of the summer will be about 3,000. The U.S. Antarctic Program peak population at any given moment will be about 1,600 on land and 300 on the ships.

b. Approximately 70 percent of U.S. Antarctic Program science personnel and >90 percent of operations personnel transit New Zealand and McMurdo

c. About one-fourth of science personnel and <10 percent of operations personnel transit South America to Antarctic Peninsula locations

6. Year-round research stations

a. **Palmer** (65°S 64°W), Anvers Island, west coast of Antarctic Peninsula—marine biology and other disciplines, population 10 to 44

b. **McMurdo** (78°S 168°E), Ross Island, southwest corner of Ross Sea—all research disciplines, operational hub, logistics center, population 235 to about 1,200

c. **Amundsen-Scott South Pole** (90° S), continental interior at geographic South Pole—astronomy and astrophysics, meteorology and climate studies, population 100 to 240

7. **Summer research camps**

a. **Siple Dome** (Siple Coast, West Antarctica). Geophysics[45] including a GPS array; automatic weather stations.

b. **Western Antarctic Ice Sheet (WAIS) Divide Camp** (West Antarctica). Glaciology, including ice-core sampling, radar surveys, and installation of a magnetometer; automatic weather stations; GPS monitoring of bedrock motion.

c. Small field camps at Beardmore Glacier (Transantarctic Mountains), Fosdick Mountains, and Patriot Hills

d. Numerous camps in the McMurdo Dry Valleys, on sea ice, and on Ross Island.

e. **Odell Glacier** (central Transantarctic Mountains), alternative landing site

8. Traverse

Extending prior work, a South Pole Proof of Concept Heavy Traverse is planned from McMurdo to South Pole and back. This will extend previous efforts from as far as the head of the Leverett Glacier, or about 262 nautical miles. If this experiment is successful, traverses will move cargo between the two stations, reducing the demand on LC-130 airplanes.

9. Ships (research and support)

a. RV *Nathaniel B. Palmer*, length 94 meters, icebreaker, purpose-built in 1992 for long-term charter to U.S. Antarctic Program.[46] The ship supports research throughout the Southern Ocean the year-round.

b. RV *Laurence M. Gould*, 71 meters, ice-strengthened, purpose-built in 1997 for long-term charter to U.S. Antarctic Program (replaces RV *Polar Duke*, chartered 1984-1997). Year-round research and Palmer Station support.

c. *Polar Star*, 122 meters, U.S. Coast Guard icebreaker,[47] and a second commercially contracted icebreaker. Annual summer channel break-in to McMurdo and some summer-season research support.

d. *American Tern*, 159 meters, Military Sealift Command chartered ice-classed cargo ship.[48] Annual cargo delivery to, and waste retrograde from, McMurdo.

e. *USNS Lawrence Gianella*, tanker, Military Sealift Command (MSC) chartered. Annual fuel delivery to McMurdo.

f. *Krasin*, 135 meters, Russian icebreaker, commercially chartered to be the primary icebreaker to open the channel to McMurdo and escort the re-supply vessels.

10. Runways (wheeled operations near McMurdo)

a. McMurdo Sound (78°S), annual sea ice, October–December

b. Pegasus (78°S), prepared glacial ice; previously not used in the warmer summer months, this runway was groomed for year-round use in 2001.

11. Skiways (ski operations only)

a. Williams Field (78°S), near McMurdo, available year-round

b. South Pole (90°S)

c. Open field (various locations)

12. Antarctic mission and policy

a. **White House Memorandum 6646 (1982)[49]**

i. United States will maintain an active and influential presence in Antarctica that supports the range of its interests under the Antarctic Treaty.

ii. National Science Foundation will budget for and manage the National program, including university and Federal research and logistics, as a single package.

iii. Departments of Defense and Transportation will provide logistics (reimbursed).

iv. NSF will use commercial support and management where cost effective and not detrimental to the National interest.

v. Other agencies may do short-term science when operations in Antarctica are coordinated with NSF.

b. **Presidential Decision Directive NSC-26 (1994)**

   i. Protect antarctic environment.

   ii. Protect opportunities for scientific research.

   iii. Maintain Antarctica as an area of international cooperation for peaceful purposes.

   iv. Conserve living resources in the oceans surrounding Antarctica.[50]

c. **President's National Science and Technology Council review (1996)[51]**

   i. Presidential Memorandum 6646 continues to be appropriate at the current funding level.

   ii. U.S. Antarctic Program is cost effective in advancing American scientific and geopolitical objectives.

   iii. Continue three stations with year-round presence.

d. **U.S. Antarctic Program External Panel (1997)[52]**

   i. Program is well managed, involves high quality science, and is important to the United States.

   ii. An Optimized South Pole Station should replace the existing station.

13. Overall National achievement

a. **Peace.** Antarctica has been reserved for peace as a result of international cooperation stimulated in part by a 1948 U.S. international initiative, by U.S. leadership during the 1957–1958 International Geophysical Year, and by the Antarctic Treaty signed in 1959 by 12 nations in Washington, D.C.

b. **Knowledge.** Antarctic research has enabled discoveries of fundamental societal importance that could not have been achieved without a substantial scientific and operational presence in Antarctica and the Southern Ocean. Research since the IGY has provided the basic understanding of Antarctica and its key role in global processes. Antarctica is the last continent to be explored and studied; more than 90 percent of the world's antarctic research literature has been published in the 46 years since the IGY.

c. **Leadership.** Through its year-round presence in Antarctica and participation in international antarctic affairs, the United States has maintained scientific and political leadership and assured U.S. participation in future uses of the region.

14. National Science Foundation[53]

a. **Mission.** The National Science Foundation is a catalyst for progress in discovery and learning. NSF provides leadership, stewardship, and funds to sustain and strengthen the Nation's science, mathematics, and engineering capabilities and education and to promote the use of those capabilities in service to society.

b. **Organization.** NSF, a U.S. Government agency established in 1950, has a staff of 1,200 and directorates or offices for mathematics and physical sciences (including chemistry and astronomy); geosciences (earth, atmosphere, ocean); biological sciences; sociological, behavioral, and economic sciences; engineering; computer sciences and information systems; education; international activities; environmental studies; crosscutting programs; and polar programs.

c. **Primary activity.** Scientists, engineers, and educators at U.S. institutions compete for support by submitting proposals that respond to NSF program areas.[54] Annually:

   i. 30,000 proposals competitively reviewed

   ii. 10,000 new awards to 2,000 institutions

d. **Budget (NSF Overall).** The National Science Foundation requests $5.6-billion for FY 2006, $132-million or 2.4 percent over the FY 2005 request of $5.47 billion.[55]

e. **Budget (NSF Antarctic).** NSF spending in FY 2005 for the U.S. Antarctic Program was $329.6-million, of which $45.50-million was for research grants, $216.58-million was for operations and science support, and $67.52-million was for logistics. NSF funds about 97 percent of all Federally supported Antarctic research and research support. For FY 2006, NSF has requested $325.69-million, of which $44.59 is for research grants, $213.58-million for operations and science support, and $67.52-million is for logistics. NSF also will receive an additional transfer of $48.0 million for U.S. icebreaking operations in the Antarctic and Arctic, formerly the responsibility of the U.S. Coast Guard.

U.S. Antarctic Program aircraft and supply ship operations, 2005-2006 season

LC-130 missions (round trips) within Antarctica		
Amundsen-Scott South Pole Station		333
WAIS Divide		49
Beardmore Glacier		5
Fosdick Mountains		5
Long-duration balloon support		2
Patriot Hills		3
Siple Dome		9
FAA missions		5
Total LC-130 within Antarctica (USAF/109th)		411
Twin Otter operations within Antarctica		900 to 1,000 flight hours
AS-350-B2 and Bell 212 helicopter operations within Antarctica		
1,936 flight hours in support of 74 groups or activities (PHI)[56]		
Christchurch/McMurdo round trips		
C-17 (USAF/AMC, August)		4
C-17 (USAF/AMC, October/November, December/February)		19/21
LC-130 (USAF/109th, Oct.–Feb.)		60
C-130 (RNZAF, November-December)		13
Cargo ship *American Tern* (Military Sealift Command, February)		1
Tanker (Military Sealift Command ship, January)		1
Load comparisons, Christchurch/McMurdo		
Equipment	Maximum load	Passengers (RT)
Cargo ship	15,000,000 pounds	
Tanker	9,000,000 gallons	
C-17	120,000 pounds	140
C-130	20,000 pounds	50
LC-130 (ski or wheel)	10,500 pounds	36
LC-130 (ski or wheel)	10,500 pounds	36

KB	Kenn Borek Air Ltd.[57]
MSC	Military Sealift Command[58]
PHI	Petroleum Helicopters Inc.[59]
RNZAF	Royal N.Z. Air Force[60]
USAF/109th	N.Y. Air Natl Guard, 109th Airlift Wing[61]
USAF/AMC	U.S. Air Force, Air Mobility Command[62]

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[1] "The Southern Ocean," by Arnold L. Gordon, *Current* 15(3): 4-6, 1999. The bountiful recent literature on the topic includes "What drove past teleconnections?" by Frank Sirocko, p. 1336-1337, *Science*, 5 September 2003.

[2] http://www.ccpo.odu.edu/Research/globec_menu.html

[3] The area of sea ice around Antarctica varies between 1 and 8 million square miles annually. See images 4 and 5 in http://www.nsf.gov/od/opp/antarct/imageset/start.jsp

[4] http://www.antcrc.utas.edu.au/aspect/

[5] "Overview of the polar ozone issue," by Solomon, S.; Schoeberl, M.R.(ed), *Geophysical Research Letters*, 15(8), p.845-846 (August 1988), introduces a special issue on polar ozone.

[6] "Montreal Protocol Benefits Cited," page 395, 30 September 2003 *EOS*.

[7] http://www.cmdl.noaa.gov/ozwv/ozsondes/spo/ozhole.html (historical significance of the ozone hole)

[8] Scroll down to "Ozone Hole Consequences" in http://www.theozonehole.com/

[9] "Ozone and climate change," p. 236-237, and "Simulation of recent Southern Hemisphere climate change," p. 273-275, *Science*, 10 October 2003. www.sciencemag.org.

[10] http://www.nobel.se/chemistry/laureates/1995/

[11] http://www.technology.gov/Medal/p_Recipients.htm#2002

[12] See, for example, *The Adélie Penguin: Bellwether of Climate Change*," Columbia University Press, October 2002 http://www.columbia.edu/cu/cup/catalog/data/023112/023112306X.HTM

[13] The Climate Monitoring and Diagnostics Laboratory, National Oceanic and Atmospheric Administration, operates four baseline observatories worldwide, including the one at the South Pole in cooperation with NSF. See http://www.cmdl.noaa.gov/

[14] The automatic weather station project, University of Wisconsin, is described at http://amrc.ssec.wisc.edu/aws.html

[15] http://igloo.gsfc.nasa.gov/wais/articles/perspective.html

[16] Russian, French, and U.S. investigators drilled and analyzed the world's deepest ice core (3,650 meters). The core spans four glacial-interglacial cycles, furnishing an unparalleled archive. "Climate and atmospheric history of the past 420,000 years from the Vostok ice core,

Antarctica," by J.R. Petit and others, *Nature* (London), 399(6735), 429-436, 1999. European coring at Dome C, East Antarctica, in 2003 reached 3,200 meters, yielding some of the world's oldest ice, possibly 1 million years old.

[17] http://igloo.gsfc.nasa.gov/wais/

[18] "Warmer ocean could threaten antarctic ice shelves" (p. 759) and "Larsen Ice Shelf has progressively thinned" (p. 856-859), *Science*, 31 October 2003, www.sciencemag.org. See also http://nsidc.org/sotc/iceshelves.html.

[19] http://geology.cwru.edu/~ansmet/

[20]http://amanda.berkeley.edu/

[21] http://www.ldeo.columbia.edu/~mstuding/vostok.html

[22] A microwave telescope borne for 10½ days 120,000 feet over Antarctica provided detailed evidence that the large-scale geometry of the universe is flat (*Nature*, 27 April 2000). Following the Big Bang 12-15 billion years ago, the universe was smooth, dense, and hot. The intense heat still is detectable as a faint glow called cosmic microwave background radiation. Scientists had sought high-resolution images of the radiation since 1965, when a ground-based radio telescope discovered it. http://www.nsf.gov/od/lpa/news/press/00/pr0025.htm

[23] The University of Chicago (Yerkes Observatory) and 15 institutions from four nations installed telescopes at South Pole Station emphasizing infrared and submillimeter wavelengths. This large project, one of NSF's 24 Science & Technology Centers, in 2001 provided science with the strongest evidence to date for the theory of inflation, the leading model for the formation of the universe. http://www.nsf.gov/od/lpa/news/press/01/pr0138.htm

[24] http://www.ees.nmt.edu/Geop/mevo/mevo.html

[25] For each project with an NSF grant, a description including contact information and grant amount is in the Foundation's grants database, http://www.fastlane.nsf.gov/a6/A6SrchAwdf.htm. U.S. Antarctic Program participants also can request access to the *2005-2006 Science Planning Summary, United States Antarctic Program*, which describes all projects.

[26] http://astro.uchicago.edu/scoara/may2004workshop/TALKS/spt-carlstrom/

[27] http://www.icecube.wisc.edu

[28] http://antarctica.usc.edu

[29] LTER network: http://lternet.edu/; McMurdo LTER: http://huey.colorado.edu/LTER/; Palmer LTER: http://iceflo.icess.ucsb.edu:8080/ice_hp.php?

[30] http://www.homepage.montana.edu/~rgarrott/index.htm

[31] http://www.bowserlab.org

[32] http://www.ocean.udel.edu/cms/amarsh/

[33] http://www.southalabama.edu/marinesciences/fac_kiene.html

[34] http://uwf.edu/wjeffrey/rosssea.html

[35] http://www.arf.fsu.edu/shaldril.cfm

[36] http://www.iris.washington.edu/about/GSN/

[37] http://amrc.ssec.wisc.edu/iceberg.html

[38] http://waisdivide.unh.edu/

[39] http://www.geosc.psu.edu/~sak/Tides/

[40] http://people.bu.edu/marchant/themesBuriedIce2.htm

[41] https://www.fastlane.nsf.gov/servlet/showaward?award=0230370

[42] http://www.ldeo.columbia.edu/res/pi/CO2/

[43] http://www.ssec.wisc.edu/icds/

[44] The Antarctic Conservation Act, Public Law 95-541, authorizes U.S. regulations for compliance. See http://www.nsf.gov/od/opp/antarct/aca/aca.jsp

[45] http://www.geosc.psu.edu/~sak/Tides

[46] http://www.usap.gov/vesselScienceAndOperations/

[47] http://www.uscg.mil/pacarea/iceops/homeice.htm

[48] http://www.msc.navy.mil/N00p/pressrel/press04/press31.htm (MSC announcement); http://www.amo-union.org/Newspaper/Morgue/10-2002/Sections/News/newjobs.htm (*American Maritime Officer* news item)

[49] For the full text, see appendix B in http://www.nsf.gov/od/opp/ant/memo_6646.jsp

[50] http://swfsc.nmfs.noaa.gov/aerd/

[51] The 67-page report *United States Antarctic Program*, April 1996, is in the NSF web site at http://www.nsf.gov/pubs/1996/nstc96rp/start.htm

[52] The 94-page report *The United States in Antarctica*, April 1997, is at http://www.nsf.gov/publications/pub_summ.jsp?ods_key=antpanel

[53] http://www.nsf.gov

[54] http://www.nsf.gov/funding/ (Browse NSF funding opportunities)

[55] http://www.nsf.gov/about/budget/

[56] These amounts do not include flight-hours provided to Antarctica New Zealand as part of the logistics exchanged *quid pro quo* between the two national programs in Antarctica.

[57] http://www.borekair.com/

[58] http://www.msc.navy.mil/

[59] http://131.103.214.67/ (Petroleum Helicopters Inc.)

[60] http://www.airforce.mil.nz/

[61] http://www.dmna.state.ny.us/ang/109.html

[62] http://www.af.mil/factsheets/factsheet.asp?fsID=159