November 2007 Edition

LAURENCE M. GOULD near Petermann Island by Christine Hush

A science field camp at the Dufek Massif, Pensacola Mountains by Craig Grimes

The recently constructed South Pole 10-meter Telescope at Amundsen-Scott South Pole Station by Forest Banks

United States Antarctic Program

2007-2008 Season

Summary and Background

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1. Why 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] Recent research has shown that understanding the carbon cycle in the Southern Ocean is critically important to understanding the global carbon cycle.

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

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.** One of the best examples of basic research about Earth's environment that led to important public policy decisions is the story surrounding the Antarctic ozone hole. The discovery of the annual Antarctic ozone depletion, the research that uncovered the cause of the ozone depleting reactions, and the subsequent decisions about phasing out ozone depleting CFC's is a compelling illustration of the value of science to society. Starting in 1979, ozone in the stratosphere over Antarctica has been observed almost to disappear every austral spring. In the 1990's seasonal ozone depletion in the Arctic was first observed. Elsewhere, stratospheric ozone depletions are only incremental. Stratospheric ozone keeps much of the Sun's harmful ultraviolet radiation from reaching the Earth's surface and therefore, 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. The best estimates are that annual depletion will occur for another 50 years. Current Antarctic research continues to provide 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 oceans. 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] Some research indicates that the annual ozone depletion allows additional heat loss from the earth resulting in the minor cooling observed in the Antarctic interior.

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 phase-out and replacement of chlorofluorocarbons (CFCs).[11]

e. **Polar adaptations of biota.** Antarctica's cold, desert conditions, and annual light cycles have led to molecular, biochemical, and physiological adaptations that enable biota to survive, reproduce, and indeed thrive under environmental extremes not experienced elsewhere. Studies provide basic understanding of these unique adaptations and help understand how changes in populations may be linked to 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 global 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 and 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°F warmer)—affects and responds to world climate change. Just 20,000 years ago, the ice sheet was far larger, and correspondingly, sea level was 11 meters (36 feet) lower, as the water was locked into the Antarctic ice.[15]

ii. **Climate history.** The ice, deposited annually as snow over millions of years, traps past atmospheric constituents that reveal 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 East Antarctic ice 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 more quickly 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. **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 likely oligotrophic—an environment with low nutrient levels and low standing stocks of organisms. Life there may depend on alternative energy sources and survival strategies.[19]

vi. **Monitoring Ice Mass Change and Sea Level Rise.** The Gravity Recovery and Climate Experiment (GRACE) satellite mission offers important observations about changes in mass in the Antarctic region. This mass change is predominantly due to two interwoven processes—1) changes in ice mass and 2) the response of the lithosphere beneath the ice sheet to change in ice loading. However, GRACE observations alone cannot separate these processes. Consequently, the ground observations of crustal response to changes in ice loading that will be provided by the Polar Earth Observing Network (PoleNet) are essential to fully understanding how total ice mass is changing.

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 high-altitude balloons.** 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 an inexpensive way to get scientific experiments into near-space. [20]

    i. The 2006 Balzan Prize for Astrophysics (one of four 1-million-Swiss-Franks awards made annually with the stipulation that half of each award must be used to support research of young investigators) was awarded to Dr. Andrew Lange of CalTech and his co-investigator Dr. Paolo de Bernardis of Italy in recognition of their contributions to cosmology, in particular the BOOMERANG Antarctic Long Duration Balloon experiment that produced the first images of structure in the Cosmic Microwave Background.[21]

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. Amundsen-Scott South Pole Station has become a major astronomy and astrophysics center.[22]

    i. **Cosmic Microwave Background Radiation (CMBR)** has been studied at the South Pole with unprecedented accuracy. Predicted in 1980s, the CMBR polarization was revealed for the first time in experimental data obtained by the University of Chicago Degree Angular Scale Interferometer (DASI)[23] in 2002. Current studies are trying to detect the B-mode polarization with the Caltech small telescope BICEP[24]. The 10-m South Pole Telescope[25] received its first light in February 2007, and now focuses on determining the nature of dark energy and dark matter and tests cosmological models aimed at explaining the origin of the Universe.

    ii. **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 ice molecules after they pass through the Earth. The data help in descriptions of galactic centers, dark matter, and supernovae. The observatory became the first in the world to detect neutrinos in March 2001.[26]

l. **Meteorites.** Meteorites offer important information about the origin of our solar system and Antarctica is the principal source of meteorites for science. Since 1969, teams from the United States, Japan, and Europe have collected more than 30,000 meteorite specimens from the surface of the ice sheet and represent many meteorite classes (including some from the Moon and Mars), extending our knowledge of the solar system. Antarctica has yielded four-fifths of the meteorites known to science.[27] Martian and lunar meteorites provide information about processes that helped form the crust of these bodies. The large numbers of meteorites available from the Antarctic collections have allowed unprecedented discoveries because more material has been available for both destructive analysis that was not previously possible. For example, common chondrites have yielded diamonds and other highly refractory grains that are remnants of the dust clouds that coalesced to form our solar system.

m. **Mount Erebus — one of Earth's few long-lived lava lakes.** The world's southern-most active volcano, Mount 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.[28]

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.[29] 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 161 science and technical projects are active at more than one location. A few are described below.

Discipline	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
McMurdo and camps	16	27	18	11	3	4	2	1	5
South Pole	13	1	2	2	2	2	3	0	1
Palmer	2	5	1	0	2	2	1	0	0
Ships	1	19	6	0	11	0	0	0	1

Disciplines:

1 Aeronomy, astrophysics
2 Organisms, ecosystems
3 Earth Sciences
4 Glaciology
5 Ocean and Atmospheric Sciences
6 Artists, writers
7 Technical Projects
8 Integrated System Science
9 IPY Education and Outreach

a. **Ten-meter telescope**. Construction of the 10-meter telescope, or South Pole Telescope (SPT), was completed as planned with the first light achieved in February 2007. The SPT Shield will be erected in the austral summer of FY09 or FY10.[30] The first winter of observations has proven the operational capabilities of the telescope and first observations of early galaxy clusters with the S-Z effect were achieved. The SPT will investigate properties of the dark energy that pervades the universe and accelerates its expansion, to search for the signature of primordial gravitational waves in the Cosmic Microwave Background Radiation, and to test cosmological models aimed at explaining the origin of the Universe.

b. **IceCube**. Work continues on the world's largest neutrino detector, which—after 6 years of work—will occupy a cubic kilometer of ice beneath the South Pole Station on Antarctica, 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. Historically, astronomical work in new energy regions has invariably discovered unexpected phenomena. By peering through a new window on the universe, IceCube could open new frontiers of understanding. Deployment of 13 new detector strings in the 2006-2007 season brought the array to 22 strings, or about 30 percent of the planned volume. Science operations to begin exploitation of the data have also commenced. During the 2007-2008 austral summer, the project expects to drill and deploy detector strings in 14-18 ice holes, as well as install a similar number of Ice-Top Stations.[31]

c. **Long-term ecological research (LTER)**. Two sites in Antarctica —the McMurdo Dry Valleys and the marine environment on the west coast of the Antarctic Peninsula— are among 26 NSF-sponsored LTER sites dedicated to understanding ecological phenomena over long temporal and large spatial scales (most of the other sites are in the continental United States).[32]

d. **Weddell seal population dynamics.** Weddell seals in McMurdo Sound have been studied since 1968—providing one of the longest intensive field investigations of long-lived mammals in the world. More than 15,000 animals have been tagged, and 145,000 re-sightings have been recorded. The project is a resource for understanding the life history and 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. [33]

e. **Adelie penguin populations and climate change.** The Adelie penguin is tied to sea ice, a key environmental variable affected by rapid climate change. Researchers will investigate the populations of Adelie penguins on Ross and Beaufort Islands, where colonies have recently expanded, relative to colonies at Cape Crozier that declined during the 1960s and 1970s. The information will be related to sea ice, as quantified by satellite images. Understanding the mechanisms behind this sensitivity will contribute greatly to predicting the effects of climate change on Antarctic marine organisms.

f. **Ocean acidification and marine ecosystems.** As global carbon dioxide levels rise, the acidity of the southern ocean will increase. Excessive acidity in the marine environment can negatively affect the metabolism of planktonic marine organisms, including the ability to form shells. Researchers will evaluate the impact of elevated carbon dioxide on calcification, metabolic physiology, and organismal performance in Antarctic pteropods, an abundant, butterfly-like snail that lives in the southern ocean waters. They will begin to evaluate how impacts on the pteropod population affect the function of the larger marine ecosystem.[34]

g. **Protein function in cold-adapted fish.** Antarctic fish live in an unusually cold environment where basic processes such as protein synthesis are thermodynamically challenging. Researchers are examining whether Antarctic fish have unique adaptations for making proteins and are uncovering the genetic basis for these functions. Comparative studies with temperate fish will help to illuminate the evolutionary pathways of cold-adaptation and life in extreme environments.[35]

h. **Influence of light, iron and carbon dioxide on Ross Sea productivity and biogeochemical cycling.** The Ross Sea is a region of intense biological productivity, where phytoplankton biomass is dominated by two main taxonomic groups: diatoms and Phaeocystis. It is well known that these two phytoplankton groups have different impacts on biogeochemical cycles in the Ross Sea, but the factors that control their relative abundance are not well understood. Researchers will investigate the effects of iron, carbon dioxide, and light levels in the Ross Sea on phytoplankton community structure. These studies will contribute to a broader understanding of carbon and sulfur cycling in the Southern Ocean.[36]

i. **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 in place 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.[37]

j. **West Antarctic Ice Sheet (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 and 2006-2007 austral summer seasons, the camp infrastructure to support the drilling program was assembled at a site on the WAIS divide. Construction crews established a skiway and a camp capable of supporting approximately 60 personnel. This camp is opened for the austral summer seasons only and is supported by LC-130 Hercules aircraft for all heavy cargo loads and fuel deliveries. The entire camp is taken down for winter storage because of the high snow accumulation rates that occur over the austral winter period. A 184-foot steel arch building that will house the drilling and core processing facilities for the deep drilling project was constructed last season with interior construction continuing during the 2007-2008 austral summer. The facility will support the 12 science projects and drilling teams who will collect a 3,400-meter ice core to bedrock. Drilling will begin toward the end of December (this austral summer) season. [38] As ice cores are produced in the field, the cores will be flown back to McMurdo Station for shipment to the National Ice Core Laboratory in Denver, Colorado (NICL). NICL will then distribute core samples to individual researchers.[39]

k. **International Transantarctic Scientific Expedition (ITASE)** Researchers will continue studies of the last 200 years of environmental history of East Antarctica by means of ice coring and data collection along a traverse route from Taylor Dome to South Pole. These proxy climate histories will help determine anthropogenic influence on air temperature, atmospheric circulation, and atmospheric chemistry. This research enables regional comparisons of inter-annual variability of climate and the records can be extended from the last two decades of satellite and field observations to the last 200 years, through the interpretation of ice core-derived climate and environmental proxies. The traverse will end at the Pole toward the end of December (this austral summer season).

l. **U.S.-Norway Scientific Traverse.** This 2-year IPY project supports scientific investigations along two overland traverses in East Antarctica; one going from Norway's Troll Station to the U.S. South Pole Station in 2007-2008; and a return traverse starting at South Pole Station and ending at Troll Station by a different route in 2008-2009. The project will investigate climate change in East Antarctica to understand climate variability on time scales of years to centuries and to determine the surface and net mass balance of the ice sheet in this sector to understand its impact on sea level. Researchers also will investigate the impact of atmospheric and oceanic variability and human activities on the chemical composition of firn and ice in the region and will revisit sites first explored by traverses in the 1960's to detect possible changes and to establish benchmark data sets for future research. The project is a genuine collaboration between nations. The scientists involved have complementary expertise, and the logistics relies on assets unique to each nation. It is truly an endeavor that neither nation could accomplish alone. This project is a part of the Trans-Antarctic Scientific Traverse Expeditions Ice Divide of East Antarctica (TASTE-IDEA), which is also part of IPY.

m. **Grounding line forensics: Kamb Ice Stream.** This project will address key questions concerning the mechanisms governing changes in ice streams by studying the dynamics of ice stream interaction and shutdown, in particular ice stream outlet dynamics (i.e. grounding line migration). Researchers intend to investigate several key features in the Kamb/Whillans ice stream area that will provide additional details to the evolving description of ice flow history in the region. The research effort is targeted at sites that can be used to test scenarios implied by satellite image analysis, modeling studies, and prior field work. The information obtained will contribute to a fundamental understanding of ice sheet dynamics and the effects of global warming and sea level rise on ice sheets.

n. **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]

o. **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]

p. **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 research icebreaker *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]

q. **Antarctic Artists and Writers Program.** Seven artists and writers will deploy to Antarctica this season between November and February. Five of them will deploy to the McMurdo area, a few with trips to the South Pole Station. Among them are a science writer (cosmology), a time lapse photographer, a data and sound sonification artist, a photographer, and a painter who will record the extended season in the Dry Valleys. Palmer station will host two artists and writers, one a children's author and the other a sculptor. [43]

r. **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.[44]

3. Construction Highlights

a. **McMurdo Power and Water Plant Upgrade.** The current McMurdo Power Plant was completed and brought on line in 1982 with equipment that specified in the 1970's design of the new facility. The facility is presently the only centralized power generation plant for McMurdo Station with emergency power provided by distributed units. The distributed units are not capable of providing power to all facilities. Therefore, any significant failure in the present power plant could require shutting down a portion of the station.

The plant upgrades will add redundancy to the power and the water systems by placing both power generation and water production in each of the water and the power plants, eliminating the single point of failure scenario for both systems without increasing the footprint on the station. The use of more efficient engines and the addition of heat recovery from both the engine jacket and exhaust gases will decrease the fuel required to operate the station.

Water Plant construction activities have continued through the FY07 austral winter with Conditional Occupancy scheduled for October 2007. Phase II of Power Plant construction will commence in the austral summer of FY08 with final acceptance scheduled for January 2010.

b. **McMurdo MoGas (Motor Gasoline) Upgrade.** The Mogas Upgrade Project is a complete design/build effort focused on modernization of McMurdo Station fuel systems. The project will essentially replace the existing tank (M-3) and dispensing station. The pipeline portion of this project will tie-in at the distribution center near the ice pier and terminate at the new tanks in the pass. Construction activities include installation of 6,300 feet of carbon steel pipe, erection of three 250,000-gallon, single-wall, steel storage tanks, containment berms, and related electrical, control and operational elements. The tanks were installed in the FY05 austral summer, distribution and dispensing systems were designed in FY06 and construction will be complete in FY08.

c. **McMurdo Fuel Tanks Upgrade.** This project will add four 2-million gallon fuel storage tanks, one 2-million gallon redundant tank and associated distribution systems at McMurdo. Currently, a fuel tanker delivers petroleum products to McMurdo station every year. The additional storage capacity provides risk mitigation should there be circumstances that delay or prevent a scheduled tanker. Installation of additional fuel tanks at McMurdo station will also produce sufficient storage capacity to potentially skip delivery of fuel every fourth year, thus saving annualized shipping costs of approximately $1M. The project includes the construction of a pump house to transfer fuel from the redundant tank back to the existing and proposed storage tanks, which will replace the existing AN8/JP5 pump facility (Building 150).

d. **South Pole Station Modernization Project.** Major construction and renovation have replaced most of the 30-year-old South Pole Station's central facilities, which exceeded their design life and could not 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, living facilities, station services, medical facilities, science labs, emergency power plant, store/post office, food-growth chamber, and computer lab. The 2005-2006 austral summer represented a major project milestone with conditional occupancy and transition of all related station operations into the new Elevated Station. In addition, the station's old communication center was relocated from the Dome to the Elevated Station.

Conditional Occupancy of the Cryogen Laboratory, completion of the #3 water well and upgrades of satellite signal equipment are scheduled for completion in January/February 2007. Scheduled in FY08 are: completion of final cladding/siding of the elevated station, final power plant modifications to improve plant efficiency and formal dedication of the station. Construction of the Cargo Facility is scheduled to begin FY08 with completion in FY09. SPTR-1 will be upgraded boosting the throughput from 5 Mbps to 45Mbps to meeting increasing data transport demands of the scientific community.

e. **Palmer Station Improvements.** A new 1,567 square foot science research building was constructed in FY06 for electronic observations and the installation of atmospheric monitoring equipment. Design for the replacement of the station's pier will begin in FY07.

f. **McMurdo Station Satellite Communications Upgrade**. This project is formally titled the McMurdo Wide Area Network Bandwidth Improvement (MWBI) project. All primary voice and data traffic for McMurdo Station to the continental U.S. is provided by a sophisticated microwave link to the Black Island Telecommunications Facility (BITF). Black Island is approximately 22 miles south of McMurdo Station and its location allows unobstructed communication signals. The BITF houses all communication and satellite equipment required to relay communications with a satellite in orbit over the equator. NSF has undertaken a two-year effort to address lifecycle replacement needs and to improve the bandwidth available for McMurdo Station. As a result of this effort bandwidth will increase in January 2008 to 10Mbps.

g. **National Polar-orbiting Operational Environmental Satellite System (NPOESS) Site Survey**. National Polar-orbiting Operational Environmental Satellite System (NPOESS). The NPOESS project will construct, operate, and maintain earth-station receptor(s) at McMurdo Station to receive NPOESS-stored mission data for the Department of Commerce, Department of Defense and National Aeronautics and Space Administration. The project implementation work for the 2006/2007 season includes:

i. Define/upgrade McMurdo and Black Island infrastructure (power, network, etc), facilities, telecommunications, satellite communications equipment, and other services to meet the needs of the aforementioned agencies.
ii. Conduct a survey of McMurdo for the development of the environmental assessment.
iii. Investigate site for the design of roads, utilidors and pad placement for the receive-only earth stations.
iv. Design a shelter for housing the upgraded electronics for the 7.2 meter Antenna, including structural, mechanical and electrical elements.
v. Ship purchased Raytheon IIS antenna feed for 7.2 meter antenna from Port Hueneme to McMurdo station.

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.[45]

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 160 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 60 to 240

7. Summer research camps

a. **Siple Dome** (Siple Coast, West Antarctica). Geophysics [46]including a GPS array; automatic weather stations. [47]

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. **Taylor Dome (East Antarctica).** Initial base camp for the ITASE Traverse. During the traverse to the Beardmore Glacier Basin, they will collect ice cores and perform radar and GPS surveys every 100 kilometers.

d. Small field camps at Beardmore Glacier (Transantarctic Mountains), Fosdick Mountains, Patriot Hills, Shackleton Glacier, and the Gamburtsev Mountains (East Antarctica)

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

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. [48]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). [45] Year-round research and Palmer Station support.

c. *Polar Sea*, 122 meters, U.S. Coast Guard icebreaker.[49] Annual summer channel break-in to McMurdo and some summer-season research support.

d. *Oden*, 107.8 meters, Swedish Maritime Administration, chartered to assist the *Polar Sea* with the annual summer channel break-in to McMurdo and escort of the *Tern* and the tanker.

e. *American Tern*, 159 meters, Military Sealift Command chartered ice-classed cargo ship.[50] Annual cargo delivery to, and waste retrograde from, McMurdo.

f. Tanker, Military Sealift Command (MSC) chartered. Annual fuel delivery to McMurdo.

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)**[51]

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.[52]

c. **President's National Science and Technology Council review (1996)[53]**

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)[54]**

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[55]

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.

Primary activity. Scientists, engineers, and educators at U.S. institutions compete for support by submitting proposals that respond to NSF program areas.[56]

c. 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 $6.02 billion for FY 2007, $439 million or 7.9 percent over the FY 2006 request of $5.58 billion.

e. **Budget (NSF Antarctic).** NSF spending in FY 2006 for the U.S. Antarctic Program was $318.51 million, of which $46.76 million was for research grants and Science & Technology Center, $140.90 million was for operations and science support, $5.13 was for Environment, Health & Safety, $67.52 million was for logistics, and $58.20 was for USCG polar icebreakers operating in the Arctic and the Antarctic. NSF funds about 97 percent of all Federally supported Antarctic research and research support. For FY 2007, NSF requested $348.51 million, of which $56.98 was for research grants and the Science & Technology Center, $161.09 million is for operations and science support, $5.92 is for Environment, Safety & Health, and $67.52-million is for logistics. NSF also budgeted $57 million for operation and maintenance of the USCG polar icebreakers. For FY 2008, NSF has requested $ 368.63 million, of which $64.49 was for research grants and the Science & Technology Center, $173.14 million is for operations and science support, $6.48 is for Environment, Safety & Health, and $67.52-million is for logistics. NSF also budgeted $57 million for operation and maintenance of the USCG polar icebreakers.

   i. In FY 2007 to fund and support research during the International Polar Year, NSF requested $61.57 million of which $47.27 million has been requested as part of the Office of Polar Programs budget. In FY 2008, NSF has requested $58.67 million of which $47.27 million will support IPY research and education projects supported by the Office of Polar Programs.[57]

U.S. Antarctic Program aircraft and supply ship operations, 2007-2008 season

LC-130 missions (round trips) within Antarctica		
Amundsen-Scott South Pole Station		319
WAIS Divide		64
AGAP South		9
AGO 1		3
Long Duration Balloon Beardmore 2 Byrd Station 1 Siple Dome 8		3
Shackleton Glacier		5
Patriot Hills		7
FAA missions		10
Total LC-130 within Antarctica (USAF/109th)		431
Twin Otter and Basler operations within Antarctica		900 to 1,000 flight hours
AS-350-B2 and Bell 212 helicopter operations within Antarctica		
1992.5 flight hours in support of 70 groups or activities (PHI)[1]		
Christchurch/McMurdo round trips		
C-17 (USAF/AMC, August)		3
C-17 (USAF/AMC, October /April)		54
LC-130 (USAF/109th, Oct.–Feb.)		44
C-130 (RNZAF,October)		4
Cargo ship *American Tern* (Military Sealift Command, February)		1
Tanker Paul Buck (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	102
C-130	20,000 pounds	50
LC-130 (ski or wheel)	10,500 pounds	36

[1] 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

References

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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/images/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://www.ldeo.columbia.edu/~mstuding/vostok.html

[20] 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

[21] See http://www.balzan.com/index_en.cfm

[22] 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

[23] http://astro.uchicago.edu/dasi

[24] http://www.astro.caltech.edu/~lgg/bicep_front.htm

[25] http://spt.uchicago.edu/

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

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

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

[29] 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 *2006-2007 Science Planning Summary, United States Antarctic Program*, which describes all projects.

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

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

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

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

[34] http://www.csusm.edu/Biology/bios/fabry.htm

[35] http://hofmannlab.msi.ucsb.edu/

[36] http://www.whoi.edu/sites/corsacs

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

[38] http://www.waisdivide.unh.edu/about/schedule.html

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

[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.nsf.gov/od/opp/antarct/artist_writer/fy07awards.jsp

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

[45] 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

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

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

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

http://www.uscg.mil/pacarea/iceops/homeice.htm

[50] 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)

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

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

[53] 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

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

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

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