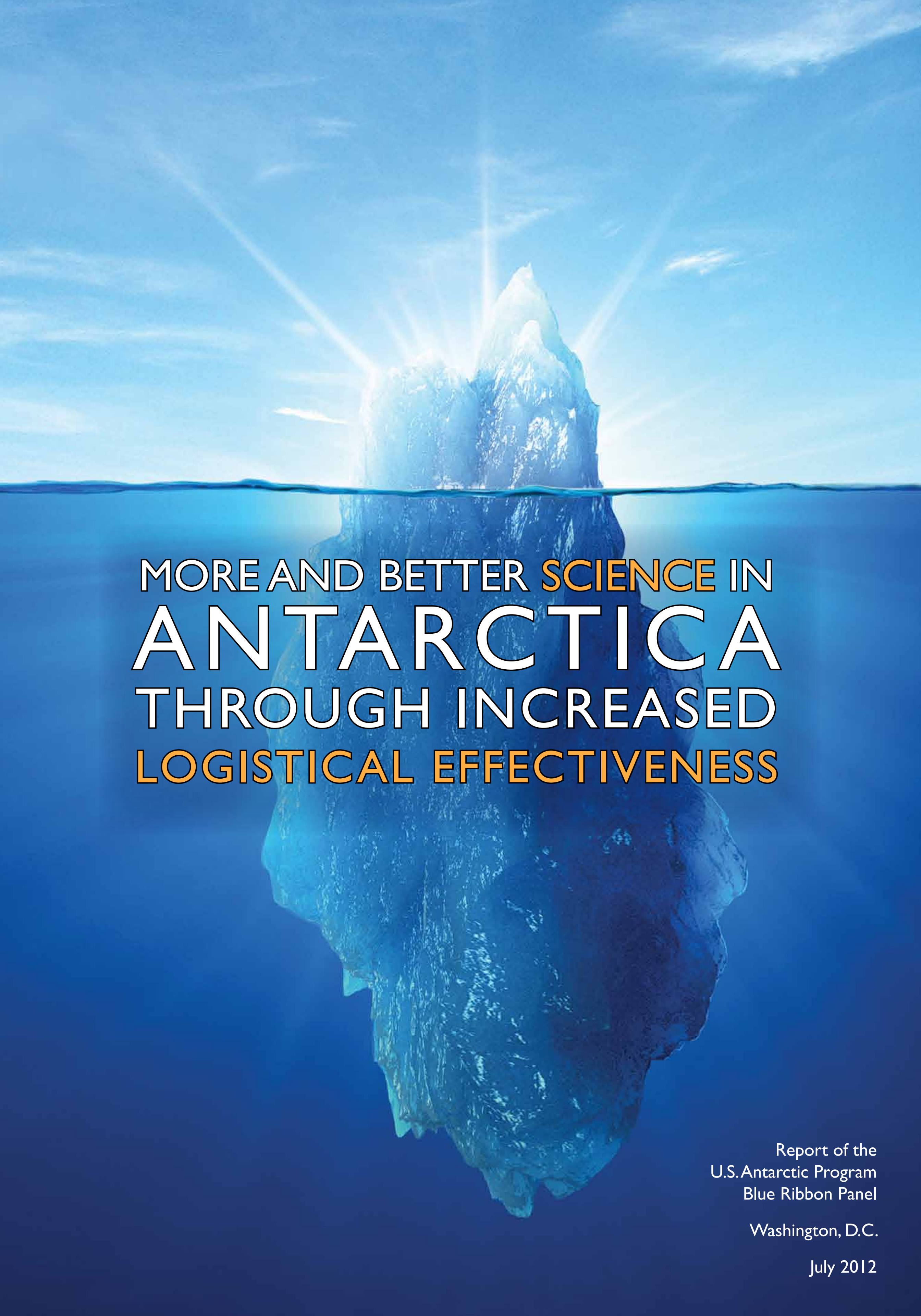

MORE AND BETTER SCIENCE IN ANTARCTICA THROUGH INCREASED LOGISTICAL EFFECTIVENESS

Report of the
U.S. Antarctic Program
Blue Ribbon Panel

Washington, D.C.

July 2012

This report of the U.S. Antarctic Program Blue Ribbon Panel, *More and Better Science in Antarctica Through Increased Logistical Effectiveness*, was completed at the request of the White House Office of Science and Technology Policy and the National Science Foundation. Copies may be obtained from David Friscic at dfriscic@nsf.gov (phone: 703-292-8030). An electronic copy of the report may be downloaded from http://www.nsf.gov/od/opp/usap_special_review/usap_brp/rpt/index.jsp.

Cover art by Zina Deretsky.

MORE AND BETTER SCIENCE IN ANTARCTICA THROUGH INCREASED LOGISTICAL EFFECTIVENESS

REPORT OF THE

U.S. ANTARCTIC PROGRAM BLUE RIBBON PANEL

AT THE REQUEST OF

THE WHITE HOUSE OFFICE OF SCIENCE AND TECHNOLOGY POLICY

AND

THE NATIONAL SCIENCE FOUNDATION

WASHINGTON, D.C.

JULY 2012

U.S. ANTARCTIC PROGRAM BLUE RIBBON PANEL

WASHINGTON, D.C.

July 23, 2012

Dr. John P. Holdren
Assistant to the President for Science and Technology
& Director, Office of Science and Technology Policy
Executive Office of the President of the United States
Washington, DC 20305

Dr. Subra Suresh
Director
National Science Foundation
4201 Wilson Boulevard
Arlington, VA 22230

Dear Dr. Holdren and Dr. Suresh:

The members of the U.S. Antarctic Program Blue Ribbon Panel are pleased to submit herewith our final report entitled *More and Better Science in Antarctica through Increased Logistical Effectiveness*. Not only is the U.S. logistics system supporting our nation's activities in Antarctica and the Southern Ocean the essential enabler for our presence and scientific accomplishments in that region, it is also the dominant consumer of the funds allocated to those endeavors.

It is our unanimous conclusion that substantial cost savings can be realized and more science therefore accomplished, some through rather straightforward operating changes and others requiring initial investment. The latter offer long-term gains that are justified on a discounted cash-flow basis, from safety considerations, or from science returns. The essence of our findings is that the lack of capital budgeting has placed operations at McMurdo, and to a somewhat lesser extent at Palmer Station, in unnecessary jeopardy—at least in terms of prolonged inefficiency due to deteriorating or otherwise inadequate physical assets. In this report we have sought to identify areas where increases in logistical effectiveness are particularly promising in comparison with their cost.

We are honored to have been asked to conduct this review and have been privileged to work with the many remarkable and dedicated individuals associated with the United States Antarctic Program.

Very truly yours,

Norman R. Augustine, Chair

Thad Allen

Craig E. Dorman

Hugh W. Ducklow

Bart Gordon*

R. Keith Harrison

Don Hartill

Gérard Jugie

Louis J. Lanzerotti

Duncan J. McNabb

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* Mr. Gordon's membership on the Panel spanned from the Panel's creation (October 12, 2011) until May 11, 2012, when a change of his employment activities necessitated his withdrawal.

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PREFACE

In 1996–1997, an independent panel established by the Director of the National Science Foundation, at the suggestion of the President's National Science and Technology Council, conducted an examination into the United States' activities in Antarctica. Its report noted the strategic importance of the nation's presence in that region and the significance of the scientific research being performed there. It also noted that the aging station located at the South Pole had become a safety hazard to those deployed there and recommended that it be replaced. In response, the National Science Foundation requested funding for that purpose. Congress appropriated the necessary funding, and a new and much more effective facility was constructed to replace the then-existing structure.

More recently, in 2010/11, in consultation with the White House Office of Science and Technology Policy, the National Science Foundation tasked the National Research Council of the National Academies of Science to conduct the first phase of a review of the U.S. Antarctic Program: an assessment of scientific research planned to be conducted in Antarctica and the Southern Ocean during the next few decades. The resulting report, *Future Science Opportunities in Antarctica and the Southern Ocean*, published in 2011, identified several trends that are emerging in Antarctic science. Among them is an increasing emphasis on integrated networks of sensors widely distributed across Antarctica making year-around measurements.

The White House Office of Science and Technology Policy and the National Science Foundation initiated the second phase of the review, the results of which are reported herein. The purposes of this follow-on Blue Ribbon Panel (hereafter called "the Panel") on Antarctica and the Southern Ocean are to identify demands placed on the logistical enterprise if it is to support future scientific effort in the Antarctic region, to discern any mismatches with currently projected capabilities, and to propose appropriate opportunities and corrective actions. The present report addresses these issues, including the identification of steps that could substantially increase the amount and value of science pursued in the Antarctic region through greater overall effectiveness of the logistics system.

ACKNOWLEDGEMENTS

The Panel was greatly assisted in its deliberations by presentations from, or conversations with, the following individuals from the National Science Foundation's Office of Polar Programs:

- Ms. Gwendolyn Adams, Safety Manager
- Mr. George Blaisdell, Operations Manager
- Dr. Scott Borg, Antarctic Sciences Division Director
- Mr. Arthur J. Brown, Specialized Support Manager
- Ms. Jessie Crain, Research Support Manager
- Dr. Karl A. Erb, Director (retired)
- Dr. Kelly K. Falkner, Director (acting)
- Mr. Guy Guthridge, Information Specialist (retired)
- Mr. Jim Karcher, Safety Officer
- Ms. Susanne M. LaFratta, Senior Advisor for Policy, Analysis and Operations; Co-Executive Director for the Blue Ribbon Panel
- Mr. Tim McGovern, Marine Projects Manager
- Dr. Polly Penhale, Medical Officer (acting) and Environmental Officer
- Mr. Mike Scheuermann, Aviation Projects Manager
- Mr. Paul Sheppard, Systems Manager
- Mr. Pat Smith, Information Technology & Communications Manager
- Mr. Brian Stone, Antarctic Infrastructure & Logistics Division Director
- Dr. James Swift, Antarctic Research and Logistics Integration Program Manager; Co-Executive Director for the Blue Ribbon Panel

Special thanks are also in order for the Office of Polar Programs' administrative staff that worked to make our meetings possible and paved the way for successful site visits to Antarctica and other U.S. Antarctic Program operating locations: Ms. Karen Sloane and Ms. Nadene Kennedy. Ms. Winifred Reuning is recognized for ensuring that the information used by the Panel for orientation to the program and in its deliberations was readily accessible on the Web.

Dr. Scot Arnold, assisted by Ms. Ji Byun, of the Institute for Defense Analyses Science & Technology Policy Institute provided expert financial analysis.

The Panel is also most appreciative of the contribution by Ms. Laura Ahlberg who shared her expertise in the editorial sphere. Ms. Zina Deretsky, an accomplished artist, prepared the report's cover. The Panel thanks Dr. Ellen Kappel and Ms. Johanna Adams of Geosciences Professional Services for the expert editing and layout of this report under extreme time pressure.

In addition, the Panel is grateful for the time and information provided by our hosts and the communities at McMurdo, South Pole, and Palmer Stations and on board the Research Vessel Icebreaker *Nathaniel B. Palmer* and Antarctic Research and Supply Vessel *Laurence M. Gould*. U.S. Antarctic Program personnel at Lockheed Martin's headquarters in Colorado and at the cargo facility in Port Hueneme, as well as members of the 109th Airlift Wing in New York all spent time with members of the Panel, providing valuable information and insight. In addition to visiting Scott Base in Antarctica, while in Christchurch, New Zealand, discussions with the New Zealand Antarctic Programme were extremely valuable, as was time spent discussing the city's plans for rebuilding and improving its infrastructure with the Mayor of Christchurch and officials from Christchurch International Airport and the Lyttelton Port of Christchurch. Panelists also had fruitful discussions with officials of the Chilean station on King George Island.

Many federal agency officials were also generous with their time, providing background information regarding their current activities in Antarctica and their future needs:

- Dr. Waleed Abdalati, National Aeronautics and Space Administration
- Ambassador David A. Balton, Department of State
- Mr. Evan Bloom, Department of State
- Dr. James Butler, National Oceanic and Atmospheric Administration
- Ms. Susannah Cooper, Department of State
- Mr. Morgan Geiger, Department of Homeland Security
- Mr. Ron Salazar, Department of Homeland Security
- Mr. Gordon Tanner, Department of Defense

Last—but by no means least—we thank the members of the National Research Council Committee on *Future Science Opportunities in Antarctica and the Southern Ocean*. Without the work done by this committee, our panel would not have had a basis upon which to conduct the review that is the subject of this report.

EXECUTIVE SUMMARY

INTRODUCTION

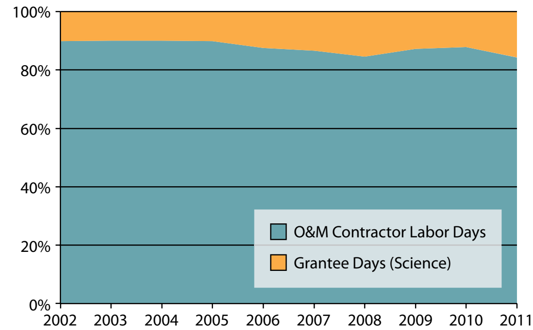
Conducting world-class science is a centerpiece of U.S. activities in the Antarctic and the Southern Ocean, but the substantive research itself is only the visible part of the iceberg. The logistics effort supporting that science is the vast base of the iceberg—representing, in terms of person-days in Antarctica, nine times the number devoted to research activity (Figure 1). Interestingly, the 1:9 ratio of science to support is almost exactly the same as that of an iceberg's weight above and below the water. Substantial opportunities exist to devote a greater share of scarce resources to science by reducing the cost of logistics efforts. Addressing these opportunities is essential to prevent expenditure for support from consuming funding that is currently dedicated to science projects.

In 2011, the National Research Council published the report *Future Science Opportunities in Antarctica and the Southern Ocean*. The report focused on discovery-driven research and global change research. "Discovery" addresses fundamental questions such as the nature of dark energy and dark matter that make up 96 percent of our universe—yet neither has yet been observed. "Global Change Research" includes the study of trends in and the causes and impacts of climate change, such as sea level rise and changes in major ocean currents. Changes are occurring with the most pronounced effects in the polar regions, making those environments important bellwethers for these global issues.

Results of past research in discovery and global change have been significant. Such research discovered the ozone hole and its cause, leading to a ban on the manufacture and use of chlorofluorocarbons as refrigerants. It also determined that the Antarctic Peninsula has been the fastest-warming region on Earth over the past half-century, with temperatures rising an astonishing 5°F (2.8°C). Antarctica captures 61 percent of Earth's fresh water as ice. If the West Antarctic Ice Sheet disintegrated, sea level is projected to rise by approximately 10 feet (3.3 meters). If the Antarctic ice sheets melted in their entirety, sea level would rise some 200 feet (66 meters), threatening the one-fourth of Earth's population that lives along coasts at an elevation less than 200 feet.

Current scientific efforts in Antarctica include the IceCube Neutrino Observatory, one of the largest single research activities underway. A cubic-kilometer array of 5160 optical sensors has been emplaced deep in the 9000-foot (2745-meter) thick ice sheet near the South Pole to form the world's largest detector of neutrinos—chargeless, nearly massless particles that rarely interact with other matter. A principal goal of IceCube is the search for point sources of neutrinos, to explore high-energy astrophysical processes and help uncover the origin of the highest-energy cosmic rays. The combination of small neutrino interaction probability and these very rare events drives the need for a large detector. For most of these experiments, Earth itself acts as a shield against high-energy particles other than the neutrinos that are used for the research being pursued.

Figure 1. O&M Contractor Labor and Grantee Days (Science)



The National Research Council report concluded that future science activity in the Antarctic region will involve substantial organizational changes, broader geographical spread, increased international involvement, and a growth in the quantity and duration of measurements. Implanting and maintaining long-term observing systems require additional data storage, communications capacity, transportation reach, and autonomous operation. Accomplishing these goals simply by expanding traditional methods of logistical support would be costly, if possible at all.

THE PANEL

John P. Holdren, Science Advisor to the President and Director of the White House Office of Science and Technology Policy, and Subra Suresh, Director of the National Science Foundation, established a Blue Ribbon Panel (hereafter called "the Panel") in October 2011 to examine U.S. logistical capabilities likely to be needed in Antarctica and the Southern Ocean in the decades ahead and to seek means of enhancing their efficiency. The 12 panel members came from diverse professional backgrounds and, during their careers, have collectively undertaken 82 trips to Antarctica, including 16 to the South Pole and numerous trips aboard research vessels in the Southern Ocean. One member has wintered-over.

In addressing the Panel's work, the Department of State indicated the continuing importance of the U.S. presence in Antarctica. Correspondingly, the National Science Foundation and other U.S. federal agencies discussed the importance of research in Antarctica to their overall science pursuits on behalf of the nation during meetings with the Panel.

In carrying out its responsibilities, the Panel met in the Washington, D.C., area a total of six days, heard over 100 briefings, read thousands of pages of reports, and traveled to McMurdo Station, Palmer Station, South Pole Station, and various logistics centers—including Christchurch in New Zealand, Punta Arenas in Chile, the Antarctic Support Contract headquarters in Colorado and cargo facility in Port Hueneme, California, the 109th New York Air National Guard in New York State—and the National Science Foundation's headquarters in Arlington, Virginia. The Panel's members went aboard the U.S. Antarctic Research and Supply Vessel *Laurence M. Gould* and Research Vessel Icebreaker *Nathaniel B. Palmer*, and witnessed on the U.S. West Coast the off-loading of the chartered supply ship *Green Wave*. During its deliberations, the Panel held Town Hall Meetings at all three U.S. permanent locations in Antarctica and established a website to receive comments and suggestions. It also visited Chilean and New Zealand stations in Antarctica and met with the New Zealand air and port authorities and the managers of the New Zealand Antarctic Programme in Christchurch.

Allotted 270 days to pursue its work, the Panel completed its effort on schedule.

MEMBERS	
Norman R. Augustine, Chair	Don Hartill
Thad Allen	Gérard Jugie
Craig E. Dorman	Louis J. Lanzerotti
Hugh W. Ducklow	Duncan J. McNabb
Bart Gordon*	Robert E. Spearing
R. Keith Harrison	Diana H. Wall

* Mr. Gordon's membership on the Panel spanned from the Panel's creation (October 12, 2011) until May 11, 2012, when a change of his employment activities necessitated his withdrawal.

OVERALL ASSESSMENT

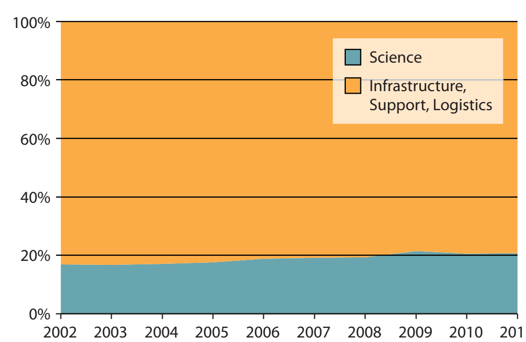
U.S. activities in Antarctica are very well managed but suffer from an aging infrastructure, lack of a capital budget, and the effects of operating in an extremely unforgiving environment. Construction of the new station at the South Pole, requiring all personnel, building materials and supplies to be transported by air, was a truly remarkable achievement, accomplished on schedule and nearly within the initially established budget.

The Panel concludes that by making changes to the logistics support system, such as those proposed, substantial cost savings can be realized using net present value as the basic financial metric. In some instances, more detailed analyses will be warranted prior to making substantial funding commitments—a consequence of the amount of time and the number of individuals available for this independent assessment. In some instances, achieving the savings identified will require front-end investments that could be supported with additional funding, temporary reductions in research, or both. Funding derived solely from reductions in research, however, can support only a small fraction of the investments because of the scale of the logistical effort relative to science (Figure 2).

The Panel identifies the lack of a capital budget for the U.S. Antarctic Program (USAP) as the root cause of most of the inefficiencies observed—a situation that no successful corporation would ever permit to persist. If a formal, federally endorsed capital budget cannot be provided, then the National Science Foundation (NSF) should, at a minimum, formulate a capital plan for U.S. activities in Antarctica that adapts to the needs of science and can be used as a basis for subsequent annual budgeting. The funding of maintenance would likewise benefit from more rigorous planning.

Under current practice, when NSF and its contractors must choose between repairing a roof or conducting science, science usually prevails. Only when the science is seriously disrupted because the roof begins to collapse will it be replaced; until then, it is likely only to be repaired. Examples of this phenomenon abound: a warehouse where some areas are avoided because the forklifts fall through the floor; kitchens with no grease traps; outdoor storage of supplies that can only be found by digging through deep piles of snow; gaps so large under doors that the wind blows snow into the buildings; late 1950s International Geophysical Year-era vehicles; antiquated communications; an almost total absence of modern inventory management systems (including the use of bar codes

Figure 2. Breakdown of Total NSF Antarctic Science and Infrastructure Expenditure



in many cases); indoor storage inefficiently dispersed in more than 20 buildings at McMurdo Station; some 350,000 pounds (159,000 kilograms) of scrap lumber awaiting return to the U.S. for disposal; and more. The status quo is simply not an option; sooner or later the atrophying logistics infrastructure will need to be upgraded or replaced. Failure to do so will simply increase logistics costs until they altogether squeeze out funding for science. A ten percent increase in the cost of logistics will consume 40 percent of the remaining science budget.

Whatever the source of funds, the USAP logistics system is badly in need of remediation and will cost more to restore as each year of inattention passes. In the longer term, increased logistical efficiency could yield savings that would substantially increase the amount of research supported by NSF. Based on the current $125,000 median annual size of NSF grants, the savings achievable from just one of the Panel's recommendations—to reduce contractor labor costs by 20 percent—could fund nearly 60 new grants each year.

U.S. FACILITIES IN ANTARCTICA

The three principal U.S. research stations are McMurdo, where 90 percent of USAP participants are based or pass through on their way to research sites; the Amundsen-Scott South Pole Station at 90° South Latitude ; and Palmer Station on the Antarctic Peninsula.

MCMURDO STATION

The population of McMurdo Station (Figure 3a), including scientists, the contractor workforce, and support personnel from NSF and other government agencies, varies from 130 to 1100. The total number depends principally on the time of year and the level of ongoing science and construction activity. The facility, initially established in 1955, nominally operates at full capacity 147 days of the year. Other months are devoted to station-based research and maintenance activities. McMurdo Station is the land, sea, and air portal to the South Pole, the Dry Valleys, major camps in West Antarctica, the Mt. Erebus volcano, ocean and penguin research locations, and numerous other field sites. Some of the U.S. facilities at McMurdo are relatively new, such as the Albert P. Crary Science and Engineering Center (21 years old), known locally as the "Crary Lab." Most structures are old and in imminent need of repair or replacement. The site, essentially a small town, was constructed with no clear master plan but rather in response to the tasks at hand and the availability of funds over the years. This somewhat haphazard arrangement inevitably leads to wasted resources and also raises serious safety concerns.

AMUNDSEN-SCOTT SOUTH POLE STATION

The new South Pole Station (Figure 3b) was dedicated in 2008 and is a state-of-the-art facility. It was constructed based upon an extensive assessment of future needs and concern for human safety. The station can be accessed for only about 100 days each Austral summer. It supports some 50 occupants during the winter and approximately 250 during the summer, and can be accessed by air or, as in recent years, by overland vehicle traverse from McMurdo. Appropriate maintenance is critical to sustaining the facility's operations.

PALMER STATION

Palmer Station (Figure 3c) began operation in 1968. It is the smallest of the U.S. permanent stations, housing 15 to 45 people, depending on the season, and it can be accessed throughout the year. Most of its research activity is constrained to a two-mile (three-kilometer) distance from the base because of the limited operating radius of the small boats that provide local transportation (and the need to maintain proximity to rescue boats). There is no useful access by air for logistics support at the present time. A limited

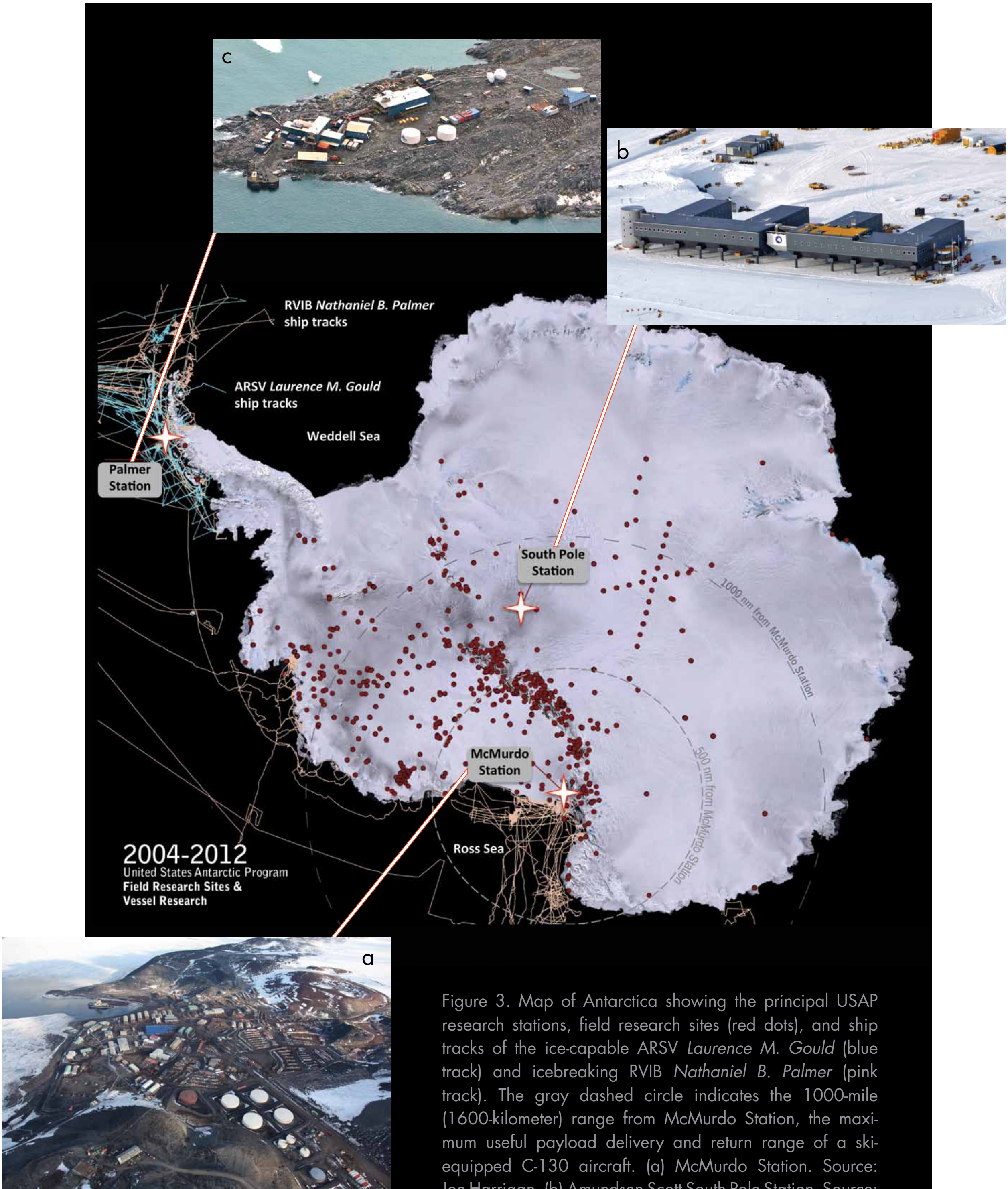


Figure 3. Map of Antarctica showing the principal USAP research stations, field research sites (red dots), and ship tracks of the ice-capable ARSV *Laurence M. Gould* (blue track) and icebreaking RVIB *Nathaniel B. Palmer* (pink track). The gray dashed circle indicates the 1000-mile (1600-kilometer) range from McMurdo Station, the maximum useful payload delivery and return range of a ski-equipped C-130 aircraft. (a) McMurdo Station. Source: Joe Harrigan. (b) Amundsen-Scott South Pole Station. Source: Andrew Williams. (c) Palmer Station. Source: NASA.

and aging dock is used for USAP research support and resupply vessels, primarily Antarctic Research and Supply Vessel (ARSV) *Laurence M. Gould* (*Gould*). Research Vessel Icebreaker (RVIB) *Nathaniel B. Palmer* (*Palmer*) cannot safely dock at Palmer Station due to an underwater rock spire near the pier. The dock and the boat ramp are in urgent need of repair or replacement, but Palmer Station's overall condition has not yet reached the level of obsolescence observed at McMurdo Station.

FIELD SITES

The United States annually supports more than 50 field sites from its primary Antarctic bases during the summer months. Typically, these sites are reached by helicopter, small fixed-wing aircraft, or ski-equipped C-130 Hercules aircraft, designated LC-130 (Figure 4). Among the most commonly visited sites are those in the Dry Valleys near McMurdo (pictured on the inside covers of this report). This region is categorized as being among the driest and windiest deserts on Earth, yet it is surrounded by glaciers and contains lakes fed by glacial runoff.

Figure 4. (a) Basler, (b) Twin Otter, (c) helicopters, and (d) LC-130 aircraft used by the USAP in Antarctica. Sources: (a) Kevin Bliss, (b) Dominick Dirkse, (c) Charles Hood, and (d) George Blaisdell.

Figure 5. The USAP ice-capable ARSV *Laurence M. Gould* (left) and icebreaker RVIB *Nathaniel B. Palmer* (right). Source: Zee Evans.

OCEANGOING VESSELS

Two USAP-chartered research ships support the U.S. program in the Southern Ocean and Antarctic perimeter (Figure 5). The *Gould*, which operates primarily from Punta Arenas, Chile, and Palmer Station, works almost exclusively in the Antarctic Peninsula region. The *Palmer* operates from Punta Arenas in Chile, Lyttelton in New Zealand, and McMurdo Station. In recent years, the vessel has worked most frequently in the Ross Sea region and east of the peninsula, but historically also worked in other Antarctic marine regions. At 15 and 20 years old, respectively, these ships are well into their 30-year operating expectancy and undergo continual maintenance to sustain their operations in the demanding Antarctic marine environment.

THE ENVIRONMENTAL CHALLENGE

Antarctica is the coldest, driest, windiest, most remote, highest (on average), darkest (for half the year) continent on Earth. Temperatures as low as −128.6°F (−89.2°C) and wind speeds of 154 miles per hour (248 kilometers per hour) have been recorded—as have temperature drops of as much as 65˚F (36°C) in 12 minutes. It is the most challenging place on Earth where continuous logistical support has ever been attempted (Figure 6). At the South Pole, the ice is over 9000 feet (2700 meters) thick. Buried under the ice in other parts of the continent are mountain ranges the size of the Alps and freshwater lakes larger than Lake Ontario.

The pressure-altitude at the South Pole is approximately 11,000 feet (3350 meters) and the absolute humidity is lower than that encountered on the Sahara Desert. In many places, water is available only in the form of ice. The combination of dryness and wind makes fire an ever-present danger. As the Panel landed at King George Island on its way to visit Palmer Station, they were alerted that the Brazilian station 21 miles (34 kilometers) away had been destroyed by fire, resulting in two fatalities. A few years earlier, a Chilean station was destroyed by a volcanic eruption, and the approach to McMurdo Station was partially blocked by an iceberg, nearly the size of Connecticut, calved from the Ross Ice Shelf.

Logistics lines to support activities in Antarctica are immense: 6900 miles (11,100 kilometers) from Port Hueneme to Christchurch; 2415 miles (3887 kilometers) from Christchurch to McMurdo; 840 miles (1340 kilometers) from McMurdo to the South Pole; 6700 miles (10,800 kilometers) from Port Hueneme to Punta Arenas; and 810 miles (1300 kilometers) from Punta Arenas to Palmer Station—the latter requiring a three-day crossing of the Drake Passage, considered by many to offer some of the roughest seas on Earth.

Almost all activities in the Antarctic Continent and the Southern Ocean must be considered to be expeditionary. Extraordinary effort must be devoted to safety and contingency planning. Opportunities for unanticipated hazards abound.

Figure 6. Digging out oil drums buried by winter weather. Source: USAP.

UNCERTAINTIES IN LOGISTICS PLANNING

Setting aside the ambiguities associated with the federal budgeting process, logistics planning in Antarctica is complicated by the shortness of the season during which the continent can be reliably accessed for logistical purposes, nominally 21 weeks by air at McMurdo Station and 15 weeks at South Pole Station. Using U.S.-owned heavy icebreakers, McMurdo Station could be accessed by ship during about ten weeks each year. As these ships have become unavailable and less-powerful icebreakers are used, the time in which to accomplish resupply by sea has been reduced to the four-week annual sea ice minimum—a challenging and unreliable practice.

In Antarctica, weather changes frequently and abruptly, necessitating contingency plans for most activities, particularly those in remote areas. The cost of energy is high and uncertain, and the behavior of the ice pack can hinder the delivery of energy and other critical supplies. During late 2011, a series of storms affecting harbor conditions left too little time for the McMurdo ice pier to thicken to sufficient strength, thus requiring deployment of a portable modular causeway system loaned by the Department of Defense (DoD). The Panel itself made the final landing of the season at the Sea Ice Runway, the airfield closest to McMurdo Station, before sea ice conditions deteriorated

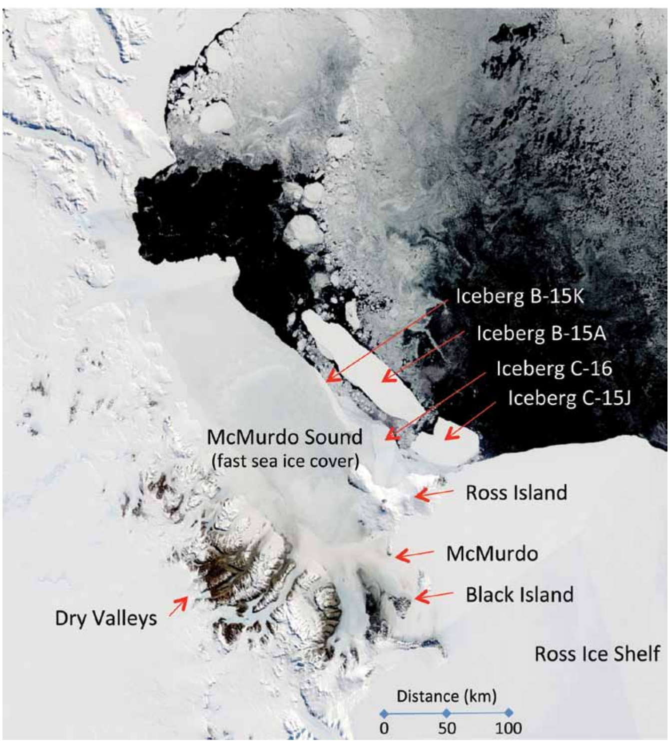


Figure 7. Satellite photo of the McMurdo area, 9 November 2004. The large iceberg B-15 and other icebergs reduced flushing of the sea ice near McMurdo Station, increased the extent of ice from the station from the typical 10 to approximately 50 miles (18 to 93 kilometers), and also increased the amount of hard, multi-year ice in the vicinity, greatly increasing the difficulty of accessing the station from 2001 through 2004.

to the point that air operations had to be moved to a more solid but more remote location. At the Pegasus Runway, constructed on glacial ice, temperatures now rise more frequently to within a few degrees of the point where air operations are precluded.

Long-term uncertainties abound. Some Antarctic research activity will continue to shift from relatively simple to more highly integrated research that requires more complex support. Further, the impact on the Antarctic region of greatly expanded tourism remains to be determined. Many nations do not participate in the Antarctic Treaty. Seven countries have made claims to parts of Antarctica that remain in abeyance while the Treaty is in force—pointing to the importance of maintaining an influential U.S. science presence as a stabilizing influence. Finally, climate change in Antarctica could significantly complicate future runway and ice pier construction and thereby impact both air and sea operations.

ACTIVITIES OF OTHER NATIONS

Researchers from many nations cooperate well in conducting science in Antarctica. Mutual logistical support among nations, while already highly constructive, offers significant opportunities for further expansion, with associated cost savings. The mutual activities of the U.S. and New Zealand polar programs offer an outstanding example of the benefits of cooperation.

Many nations around the world are currently making significant investments to expand their activities in Antarctica (Figure 8). For example, South Korea is in the process of establishing a new station in the Terra Nova Bay region of the Ross Sea. Germany replaced an existing station in 2009. At approximately the same time, the United Kingdom replaced its Halley Station. Russia has stated its intent to launch five new polar research ships and reconstruct five research stations and three seasonal bases. Argentina recently announced plans to construct a new scientific base to replace one that was partially destroyed by fire. Belgium's Princess Elizabeth Station, now in summer operation, is said to be Antarctica's first zero-emission base. Chile's plans include developing Punta Arenas as a gateway to Antarctica for research, tourism, and mineral research traffic. China is proceeding with upgrades to three existing sites as well as building the new Kunlun

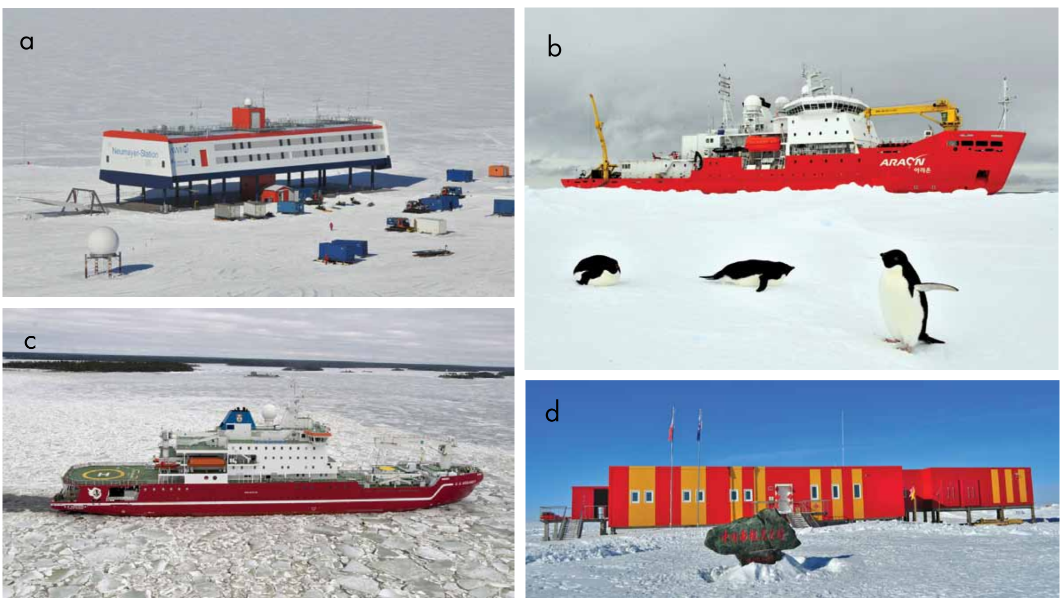


Figure 8. (a) German research station Neumayer III. Source: Ude Cieluch. (b) South Korean research and resupply icebreaker *Araon*, completed in 2009, which supplies the King Sejong Station and will supply their new Jang Bogo Station. Source: Dongmin Jin. (c) South African research and resupply icebreaker *Agulhas II,* completed in 2012. Source: *Engineering News* (online). (d) Chinese Kunlun Station, completed in 2009. Source: Hu Yi, CHINARE.

Station and constructing several telescopes at Dome A, the highest site on the Antarctic Plateau (13,428 feet/4093 meters). India is preparing to occupy its third station, and other nations are undertaking projects to expand their presence and scientific activity in the Antarctic.

ECONOMIC CONSIDERATIONS

The cost of providing logistics support on the Antarctic Continent is to a considerable degree driven by the number of person-days on the ice and the amount of fuel consumed in supporting their activities. Any actions that reduce either cost component can potentially generate significant financial savings.

Numerous expenditures need to be calculated to determine fully burdened costs. For example, placing fuel at the South Pole currently requires flying or traversing the fuel from McMurdo. Skiways for the LC-130 must be constructed or refurbished annually. To move the fuel and cargo from the United States to McMurdo requires oceangoing vessels, which in turn require an icebreaker to open a path in the sea ice on the approach to McMurdo. Docking the vessels requires periodic construction and maintenance of an ice pier for off-loading. The people involved in this process generally fly to New Zealand and then to assignments at McMurdo or the South Pole, and must be provided housing, food, clothing, medical care, and other elements of life support.

Considering all that is involved, the true value of a gallon of fuel at the South Pole is, on average, nearly *eight* times its original purchase price. The large premium that will be realized from reducing energy consumption would seem to be evident; however, this and most other cost calculations affecting the USAP are highly nonlinear. That is, it is generally not possible to contract for "part" of a ship to transfer supplies to Antarctica or to conduct Southern Ocean research. Similarly, significant savings cannot be realized from flying partially loaded aircraft. On the other hand, at certain points there may be opportunities for significant savings, for example, by chartering smaller commercial vessels for resupply.

When it comes to the number of person-days on the ice, the opportunity for cost savings is clearer. It is always in the interest of economy to minimize the number of people traveling to the ice and their duration of stay, as well as to emphasize energy conservation. Doing so always produces at least some savings and the cumulative effects of individual actions can often eventually lead to major savings.

The Panel found that USAP researchers and other personnel possess limited awareness of the true cost of the resources provided to them. The same is true for personnel from many other nations who periodically use U.S. resources, such as runways, rescue support, and logistical assets. Educating users about the true costs of Antarctic research would promote greater conservation, and should become a major communications goal for the USAP.

Recent advances in technology, if adopted, could also substantially reduce costs. Examples range from making greater use of autonomous robotic field stations to employing underwater gliders to collect oceanographic data. To cite just one example, a single "flight" of a glider generated as much data as previous monitoring techniques produced in a decade.

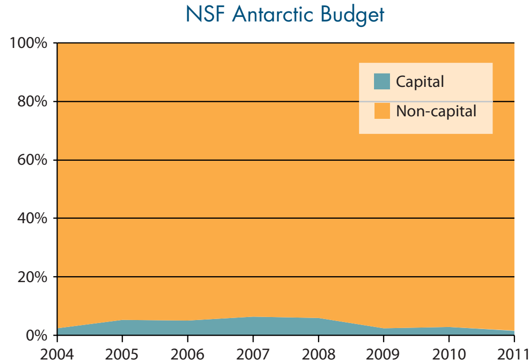
MAJOR ISSUES

The Panel's deliberations led it to focus on eight major issues, although numerous other important but generally less-consequential matters were also evaluated. All are addressed in the body of the main report. Here, we provide a brief overview of each of these major considerations.

1. CAPITAL BUDGETING

Capital investment by the USAP is extremely limited (Figure 9). The lack of a capital budget and supporting plan to replace out-of-date facilities, together with the lack of a funded plan to address major maintenance needs, has led to a deteriorating and inefficient infrastructure, particularly at McMurdo Station. Opportunities exist for significant financial savings over the longer term through improved maintenance and modernization. In a few instances, shortcomings have led to hazardous conditions. At present, problems associated with the U.S. government's prolonged budgeting cycle (well over a year) are compounded for the Antarctic program by its seasonal nature. Consequently, an item approved in the budget normally will not arrive in Antarctica for at least two years after its need was established. In the case of structures, matters are further complicated by a useful building season that stretches only a few months.

Figure 9. Capital as Fraction of Total NSF Antarctic Budget



2. ALTERNATIVES TO MCMURDO STATION

McMurdo has been a preferred location for accessing central Antarctica from the time of the earliest explorers until the present day, but its susceptibility to heavy sea ice nonetheless makes its scientific activities dependent upon the availability of icebreakers, which are frequently in short supply and always expensive. If another location on the continent were capable of supporting activities at the South Pole, within reasonable proximity to a major Southern Hemisphere port, and offered the possibility of a deepwater landing for resupply ships as well as a nearby runway for heavy wheeled-aircraft operations, the USAP could avoid its dependency upon icebreakers. The Panel conducted a search using aerial photography, maps, in situ observations, and other sources to determine if such a location exists (Table 1). No reasonable alternative to McMurdo was found that would permit transshipping (sea, air, and land), or that would justify abandoning the investment made in fixed plant at McMurdo. It would cost on the order of $220 million in 2012 dollars to replace McMurdo as it currently exists.

Table 1. Comparison of Potential Options for Location of USAP Activities Now Carried Out at McMurdo Station

	McMurdo	Bay of Whales	Terra Nova Bay	Western Coats Land
Harbor for 9 m Draft Ship	Yes	No	No	No
Direct Off-load to Shore or Ice Shelf	Yes	Yes*	No	Yes*
Distance to South Pole (air)	1340 km	1270 km	1700 km	1370 km
Suitability for Wheeled Aircraft	Good; all year	No; only skiway	Moderate	No; only skiway
Sea Ice Extent at Minimum (typical)	10 nm	0 nm	0 nm	30 to >100 nm
Icebreaker Required to Access? (typical)	Yes	Yes	Yes	Yes
Suitability for Infrastructure	High	Low	Moderate	Low
Surface Access to Antarctic Interior	Easy	Easy	Difficult	Easy

most favorable / favorable / somewhat favorable / unfavorable

*Off-load onto ice shelf, followed by traverse.

3. ICEBREAKERS

The task of maintaining a U.S. icebreaking capability transcends NSF's responsibilities and resources. During the Boreal winter of 2011/12, the need unexpectedly arose to provide an icebreaker, U.S. Coast Guard Cutter (USCGC) *Healy*, for access to Nome, Alaska, which has no road or rail connectivity to the rest of the United States. An intensive storm followed by rapid sea ice formation prevented the usual barge-based fuel delivery to Nome—an incident that served as a reminder of the importance of icebreaking vessels. In recent years, NSF has contracted with Russian or Swedish firms to enable access to the Antarctic Continent, but these ships have not been reliably available to the USAP. As a contingency measure, the USAP has stored sufficient fuel at McMurdo to support activities at that base and at South Pole Station for at least two consecutive seasons in case sea resupply is interrupted for any one year. In such a case, a concurrent increase in air operations could, for the most part, substitute for ship-based cargo delivery, albeit at approximately four or ten times the cost per pound, depending on the aircraft used.

Figure 10. USCGC *Polar Star* with Military Sealift Command tanker *Paul Buck* at the McMurdo Station ice pier (in the foreground from left to right), with RVIB *Nathaniel B. Palmer* and icebreaker *Krasin* (Russia) in the background (left to right). Source: Brien Barnett.

Even so, the fuel reserve and the ability to fly some of the required cargo serves more as an insurance policy than a long-term solution to U.S. national interests in both the Arctic and the Antarctic that might require icebreaking capability.

Repairs and renovations to USCGC *Polar Star* that are now underway could make that heavy icebreaker available to support McMurdo ship-based resupply operations beginning with the 2013/14 Austral summer. This project will extend the useful life of the vessel for approximately eight more years. Even with *Polar Star's* return to sea, however, the United States will possess only a single heavy icebreaker, one that is nearing the end of its service life.

The President has requested $8 million in the FY 2013 budget "to initiate survey and design for a new Coast Guard polar icebreaker." But even if construction is fully funded in the planned budget years, it will likely be at least eight years before such a ship becomes available. The Panel concludes that the budget request should be vigorously supported and encourages consideration of a design that addresses the USAP's needs, including for example the potential ability to conduct science from the icebreaker itself.

If the United States is to maintain an assured research capability and presence in Antarctica, particularly at the South Pole, it is essential to provide the U.S. Coast Guard (USCG) with the resources needed to conduct the break-in at McMurdo while at the same time meeting its responsibilities elsewhere. In accordance with Presidential Memorandum 6646, the USCG should be in a position to provide icebreaking services upon NSF's request. The USCG and many independent reviews have identified the vessels and associated funding that would be required. The Panel believes that ensuring U.S. government control of the above icebreaking assets is vital to U.S.-stated interests in Antarctica. If for any reason the USCG may not be able to provide the needed support, NSF should seek long-term commitments from U.S. commercial or foreign icebreaking services such as those that have been supplied in the past on a short-term basis from Russia and Sweden

4. TRANSPORTATION ON THE CONTINENT

The most critical logistics link on the Antarctic Continent is arguably that which extends from McMurdo Station to the South Pole. Until recently, the only access to the South Pole was by air, and because the South Pole has only a skiway, only the LC-130s that can land on skis could be used for resupply. The 840-mile (1340-kilometer) air distance between the two stations begins to approach that aircraft's useful range, limiting the payload delivered to the South Pole to about 26,000 pounds (11,800 kilograms). More recently, introduction of overland traversing from McMurdo to the Pole (Figure 11) now enables resupply of 780,000 pounds (354,000 kilograms) per trip but the round trip takes 45 days. Modern technology for crevasse-detection and formation-following vehicles would make it possible for a

Figure 11. Tractor and fuel bladders on the overland traverse. Source: Paul Thur.

Figure 12. U.S. Air Force C-17 aircraft on the Pegasus Runway at McMurdo Station. Source: Dominick Dirksen.

single driver to operate more than one tractor in a traverse, further reducing the cost of maintaining the facility at the South Pole. It would also reduce the demand for LC-130 flights and, ultimately, could enable reducing the size of the LC-130 fleet.

Based on projected demand for flights to support USAP science and operations, if the traverse platform is automated as the Panel recommends, it is estimated that a 40 percent reduction in the number of LC-130 aircraft in service (from ten to six) is realizable. The most straightforward approach would be to retire the four NSF-owned aircraft and outfit one of the remaining six as a research vehicle. This all-Air National Guard fleet would maintain the U.S. reach across Antarctica while also permitting important science data to be acquired from an aerial platform rather than costly field camps.

In addition to producing substantial cost savings, such a streamlined fleet would be substantially freed from fuel and cargo deliveries to the South Pole, affording the USAP considerable flexibility. LC-130 aircraft could be allocated to support ground-based research, conduct airborne research, and provide backup in case of an interruption of traverse operations.

5. HARD-SURFACE ICE RUNWAY AT THE SOUTH POLE

As noted, the only large aircraft currently capable of operating at the South Pole is the LC-130. Snow compaction techniques have been developed that could make it possible to construct a runway at the South Pole capable of supporting wheeled aircraft. C-17 aircraft (Figure 12) flying from McMurdo Station could deliver a payload of 110,000 pounds (50,000 kilograms, four times the LC-130's capability). Use of the C-17s would further free the LC-130 fleet to support field research sites that are anticipated to increase in number, importance, and remoteness throughout the Antarctic Continent.

6. ENERGY

Significant cost savings could be realized by making greater use of alternative energy sources in Antarctica, accompanied by a reduction in fossil fuel consumption. Examples include expanding the use of wind power at McMurdo (Figure 13), better insulating buildings not scheduled for near-term replacement, and burning scrap

Figure 13. Wind turbines at McMurdo Station. Source: George Blaisdell.

wood and used oil in modern furnaces rather than returning it to the United States for disposal. Such action would have the important ancillary benefit of reducing the environmental footprint of U.S. activities in the region.

7. COMMUNICATIONS

The communications connectivity and bandwidth available at the South Pole significantly limit the science that can be conducted in the Antarctic interior today and in the future. For example, IceCube, after on-site data processing, transmits 100 gigabytes of data daily—about 15 percent of the data collected—via the National Aeronautics and Space Administration's (NASA) "high" data rate (150 Mbits/sec) Tracking and Data Relay Satellite System (TDRSS) (Figure 14). Other projects also demand support from TDRSS, leaving the satellite communications system at the limit of the USAP's current capacity. Further, satellite service is fragmented into small windows of time averaging no more than four hours daily. The only continuous satellite communications capability at the South Pole is extremely slow (28 Kbits/sec), with a limited seven-hour window of additional satellite availability at higher speed (the Geostationary Operational Environmental Satellite [GOES]-3, at 1.5 Mbits/sec). With the exception of the low-speed service, these satellites have already lasted well beyond their design life and are at risk of imminent failure due to age.

Many research projects are best performed when data-gathering protocols can be adjusted in near-real time. Severe bandwidth limitations encourage researchers to be on site rather than at their home laboratories in the United States.


Figure 14. Tracking and Data Relay Satellite. Source: NASA.

These barriers to remote access work against reducing costs sought by minimizing the number of people on the ice.

8. SAFETY AND HEALTH

Although gradual improvements in safety conditions and practices have resulted in a "reportable-injury" rate that is generally comparable to similar commercial activities (for example, the North Slope in Alaska), the Panel noted a variety of safety concerns. They include compactors with safety interlocks that can be overridden, a dangerous boat access ramp, a pier meant to support shallow-draft oceangoing ships that has a large underwater rock adjacent to it, and a woodshop with no fire sprinkler system.

The infirmary at McMurdo was described to the Panel as representative of a 1960's clinic serving a U.S. community of comparable size located in a much less hazardous environment (Figure 15a). Some dormitory rooms designed for two occupants house five residents (Figure 15b), virtually guaranteeing that if one person becomes ill with a contagious disease, all will be afflicted.

Figure 15. (a) The McMurdo Medical Clinic. Source: Don Hartill. (b) Original two-person room at McMurdo Station, now housing five persons. Source: Travis Groh.

During a 2007–2008 influenza outbreak, at least one-sixth of the McMurdo population (48 percent of the 330 persons tested) suffered from the flu. Mandatory flu shots have largely alleviated repeat incidents, but the containers of hand sanitizer that have proven extraordinarily effective at controlling disease in many U.S. facilities are largely absent. Improving preventive health measures would have significant economic benefits. When an individual suffers a work-halting illness in Antarctica, not only is that person unproductive, but he or she also becomes a burden to other members of the community.

SINGLE-POINT FAILURE MODES

Perhaps the most effective means of assuring that projects are not unexpectedly disrupted, personnel injured, or equipment damaged is to eliminate "single-point failures." Single-point failures are circumstances in which the failure of one element of a system renders the entire system incapable of performing its function. In cases where total elimination of such modes through the provision of redundancy or other means is not practicable, larger-than-usual margins should be provided for the critical links that remain (Figure 16). This approach, when backed by a "fail-gracefully/fail-safe" philosophy, has been demonstrated to produce a high probability of successfully accomplishing goals.

Figure 16. When ice conditions in McMurdo Sound made the approach to the pier so difficult that the tanker could not make it to the pier, the fuel was off-loaded over the sea ice via hoses. The USAP recognized this vulnerability and has since decreased fuel usage and increased fuel storage capacity so that it now has a two-year supply on hand.

Many USAP features as they exist today raise concerns regarding single-point failures. A list of the more significant of these, in order of deemed concern, follows:

- The Antarctic Treaty and related instruments (potential circumvention)
- U.S. icebreaking capability (lack of assured access)
- Broadband communications for South Pole Station (interruptions to telemedicine, impact on research)
- Pier at Palmer Station (vulnerability to major accident)
- Multimode hub at Christchurch (earthquake, airport restructuring)
- Pegasus Runway at McMurdo (melting, accidents)
- Fire Suppression Systems requiring electric power (inadequate backups)
- *Gould* and *Palmer* (aging with long replacement cycle)
- Single automated dishwasher at McMurdo (food service for as many as 1100 people)

RECOMMENDATIONS

Below is a summary of the Panel's top ten overarching recommendations, in priority order, with brief parenthetical examples of implementing actions. Please see the full report for supporting information.

1. ANTARCTIC BASES. Continue the use of McMurdo, South Pole, and Palmer Stations as the primary U.S. science and logistics hubs on the continent. (There is no reasonable alternative, particularly concerning McMurdo.)

2. POLAR OCEAN FLEET. Restore the U.S. polar ocean fleet (icebreakers, polar research vessels, mid-sized and smaller vessels) to support science, logistics, and national security in both polar regions over the long term. (Follow through on pending action in the President's FY 2013 Budget Request for the USCG to initiate the design of a new icebreaker.)

3. LOGISTICS AND TRANSPORTATION. Implement state-of-the-art logistics and transportation support as identified in this report to reduce costs and expand science opportunities continent-wide and in the Southern Ocean. (Replace some LC-130 flights with additional traverse trips by automating the traverse and by constructing a wheel-capable runway at South Pole Station for C-17 use; reduce the LC-130 fleet.)

4. MCMURDO AND PALMER FACILITIES. Upgrade or replace, as warranted by an updated master plan, aging facilities at McMurdo and Palmer Stations, thereby reducing operating costs and increasing the efficiency of support provided to science projects. (Modify or replace the pier and reconstruct the boat ramp at Palmer Station, install fire suppression—with backup power—in unprotected berthing and key operational facilities, upgrade medical clinics, and improve dormitory use to prevent the transmission of illnesses.)

5. USAP CAPITAL BUDGET. Establish a long-term facilities capital plan and budget for the USAP. (Provide phased plan for modernization of USAP facilities.)

6. SCIENCE SUPPORT COSTS. Further strengthen the process by which the fully burdened cost and technological readiness of research instrumentation and observing systems, as well as overall projects, are considered in the review and selection of science projects. (Increase overall awareness of the true cost of resources provided in Antarctica.)

7. COMMUNICATIONS. Modernize communication capabilities in Antarctica and the Southern Ocean to enable increased science output and reduced operational footprint. (Provide increased bandwidth on as well as to and from the continent.)

8. ENERGY EFFICIENCY. Increase energy efficiency and implement renewable energy technologies to reduce operational costs. (Provide additional wind turbine generators at McMurdo, better insulate selected buildings, and invest in technology for converting trash-to-energy and burning waste oil so that it does not have to be returned to the United States.)

9. INTERNATIONAL COOPERATION. Pursue additional opportunities for international cooperation in shared logistics support as well as scientific endeavors. (The existence of numerous national stations in the peninsula region offers a particularly promising opportunity for an international supply system.)

10. ANTARCTIC POLICY. Review and revise as appropriate the existing documents governing Antarctic Policy (Presidential Memorandum 6646 of 1982 and Presidential Decision Directive 26 of 1994) and implementing mechanisms for Antarctica, taking into account current realities and findings identified by the National Research Council report and the present report. (Focus on policy and national issues as opposed to operational matters.)

IMPLEMENTING AND ANCILLARY ACTIONS

In support of the overarching recommendations cited above and the additional findings cited in the report, the Panel offers a number of specific implementing actions. The ten most important candidates among them are presented in priority order within each of the following separate but related categories: (1) Essential for Safety and Health, (2) Readily Implementable, and (3) Significant Investment/Large Payoff. Additional actions beyond these highest priority actions in each category are noted in the relevant chapters of the report.

Essential for Safety and Health

The Panel considers the following actions to be mandatory because of the potential adverse consequences of failing to pursue them:

- Modify or replace pier at Palmer Station.
- Reconstruct boat ramp at Palmer Station.
- Provide backup power or gravity-feed for all fire-suppression systems.
- Add fire suppression in woodshop at Palmer Station.
- Increase emphasis on workplace health and safety through much greater use of signage, "near-miss" reporting, and widespread use of antibacterial liquids (such as Purell); in addition, modernize medical clinic at McMurdo.
- Move power generators out of housing buildings and move dormitory spaces away from kitchens at Palmer Station.
- Consolidate hazardous materials at Palmer Station into one storage area.
- Manage populations at Antarctic stations such that currently crowded conditions do not remain a health hazard and morale issue.
- Replace compromised flooring in McMurdo warehouse (Building 120).
- Implement a more comprehensive system of safety inspections and ensure that appropriate corrective actions are followed through to completion.

Readily Implementable

The following actions could be undertaken without substantial financial expenditures or inconvenience while offering disproportionately great benefits:

- Establish within NSF's Office of Polar Programs a small systems engineering/cost analysis group to continually seek opportunities for cost reduction and better ways of supporting science needs.
- Conduct a review to reduce contractor personnel requirements by approximately 20 percent, particularly among those positioned on the ice. Place primary emphasis on reducing population at field camps.
- Establish within NSF, and possibly jointly with other agencies, modeled after DoD's Advanced Research Projects Agency, funds for developing enabling technologies that could significantly enhance USAP operations. Examples of the latter include advanced gliders, robotic field stations, and automated formation-keeping for traverse vehicles, all of which may be of use in both polar regions.

- Provide two Rigid-Hull Inflatable Boats at Palmer Station to substantially enhance safety of research performed at that site and cost-effectiveness.
- Use some newly freed LC-130 flight hours to support airdrop operations and deep-field support.
- Work with Christchurch International Airport and Lyttelton Port of Christchurch to assure that USAP needs are considered in the master plans now being produced by New Zealand.
- Review U.S./international logistics activities' "balance sheet" for equity in offsets.
- Adding to existing partnerships with other nations, explore possibility of mutual support between McMurdo and the new South Korean station.
- Continue reliance on NSF's merit review system to ensure that science programs are justified for continued support. (This has been very effectively accomplished by the French and other national Antarctic programs, with significant savings being realized.)
- More stringently enforce requirement for all instrumentation and related devices deployed at unattended field sites be designed for module-level serviceability and undergo pre-deployment environmental qualification.

Significant Investment/Large Payoff

The following actions may require relatively significant up-front investments but also have the potential, on a discounted (and generally conservative) cash-flow basis, to produce material, positive net present values:

- Reduce LC-130 usage by increasing the number of traverse trips between McMurdo and the South Pole by incorporating automated formation-keeping to reduce personnel demands.
- Construct a runway capable of supporting wheeled aircraft at the South Pole to permit C-17 operations.
- Consolidate warehousing at McMurdo into the minimum practicable number of structures and minimize outside storage.
- Designate Pegasus Field as a permanent site, with appropriate fire, rescue, air traffic control, ground transportation, and fuel support. Retain Williams Field to support LC-130 operations. Discontinue constructing the Sea Ice Runway each year.
- Deploy an optimal number of additional wind turbine generators at McMurdo Station.
- Modernize LC-130s with eight-bladed propellers, fuel-efficient engine modifications, and crevasse-detection radars.
- Replace the legacy logistics management software applications with a commercially available Enterprise Resource Program, and significantly expand use of bar coding.
- Implement a phased program for ground vehicle modernization.
- Construct a solar heated vehicle storage building at South Pole Station.
- Determine feasibility of converting waste wood, cardboard, and paper at McMurdo (that must otherwise be retrograded to the United States) into clean electric power and useful heat.

CONCLUDING OBSERVATIONS

During its evaluation, the Panel discerned a widespread and commendable "can-do, make-do" culture within the USAP. Flaws in the system, however, diminish the ability of the program's participants to make the most of their research. These flaws persist despite substantial financial and human investment. Overcoming these barriers requires a fundamental shift in the manner in which capital projects and major maintenance are planned, budgeted, and funded. Simply working harder doing the same things that have been done in the past will not produce efficiencies of the magnitude needed in the future. Not only must change be introduced into *how* things are done, but *what* is being done must also be reexamined. In this regard, the ongoing introduction of a new prime support contractor provides an extraordinary, albeit brief, window to bring about major change.

Although many opportunities for cost savings have been cited, this report has not attempted in all cases to determine the required front-end investment. For example, it is the Panel's collective judgment, based primarily upon years of experience, that a reduction in contractor personnel of some 20 percent should be feasible. A more detailed analysis will be needed before implementing this.

The Panel emphasizes that the USAP is facing major expenditures for the replacement of existing inefficient, failing, and unsafe facilities and other assets. Delays in initiating the needed work will only increase the cost and further squeeze the research funding that is already only a fraction of total dollars allocated to the program. While significant savings are in fact achievable through operational efficiencies, some of the front-end investments that are needed if the United States is to continue USAP activities at the present level cannot all be justified solely on an economic basis. Some upgrades are essential for personnel and equipment safety. The Panel has sought to identify changes that hold initial investment to the minimum reasonable level.

In spite of the above challenges, USAP science and science support could be vastly enhanced within about five years. The improvements could be funded by increasing for each of the

Table 2. Net Present Value Analysis

	INVESTMENT, $M	NET PRESENT VALUE, $M
Automate and Double Number of Traverses	1.80	15.00
Increase Number of Wind Turbines at McMurdo	0.50	1.40
Construct Solar Garage at South Pole	0.03	0.75
Install Wood Burner at McMurdo	0.40	0.70
Burn Waste Oil at McMurdo	0.09	0.70

next four years the USAP's annual appropriation for support by six percent (real dollars) relative to the FY 2012 appropriation (an additional $16 million per year), diverting six percent of the planned science expenditures over the next four years to upgrades of the science support system ($4 million), and permitting the savings accrued from five high payout projects (Table 2) and the 20 percent reduction in contractor labor to be reinvested in upgrading support capabilities (averaging $20 million net per year for four years).

The investments thus made would be repaid in approximately seven years if five high payout projects produce the expected return and a 20 percent reduction in contractor staff is in fact possible and implemented. Thereafter, the annual savings generated will allow the USAP to increase science awards while ensuring safe and effective science support and appropriately maintained facilities. Given the important improvements in safety and science opportunities contained within the above option, a seven-year financial breakeven is considered by the Panel to be a reasonable investment, particularly when compared to the cost of not making one.

In making this proposal the Panel has sought to be mindful of the severe budgeting challenge facing the nation while at the same time respond to the serious need to rebuild much of the nation's Antarctic infrastructure.

Once the recommendations made herein have been implemented, it will be possible to substantially increase science activity—assuming a stable overall budget.

It should be noted that this construct does not address the extremely important icebreaker issue that transcends the Antarctic program's resources and responsibilities, at least as they are understood by the Panel.

1. INTRODUCTION

The primary stated objectives for United States activities in Antarctica are to conduct science and to maintain a U.S. presence in the region. The two goals are often mutually reinforcing. Since the first "permanent" U.S. facilities on the continent were established in 1955, American scientists and international partners have used them to conduct valuable research. These collaborative efforts, in turn, have bolstered a U.S. presence in the region that, many believe, facilitates the international control of the continent mandated by the Antarctic Treaty, under which no nation exerts ownership of all or any part of Antarctica.

Antarctica's hostile environment and distance from the United States make logistical support of scientific research complicated and expensive. Foods that require refrigeration must be stored indoors because of the harshness of the cold outdoors. Vehicle tires must be stored indoors because the intense ultraviolet radiation from the summer sun damages them. Conventional aviation fuels turn to slush at the prevailing temperatures. In its report, the National Research Council examined trends likely to affect future science activities in Antarctica and the Southern Ocean. As a follow-on, the White House Office of Science and Technology Policy

Figure 1.1. The South Pole Telescope during the long polar night. Source: Keith Vanderlinde.

and the National Science Foundation initiated this review of the support effort that enables the conduct of science, an aspect that dominates the cost of the U.S. Antarctic Program (USAP). Because the expense of logistical activities affects both the feasibility of conducting science and maintaining a presence in the Antarctic region, it is logical to consider new approaches to logistical support that might substantially reduce costs and permit expanded scientific pursuits. This report concludes that both goals are possible.

Analyzing the relevant cost issues and executing tradeoffs among various options for providing logistical support are not simple tasks. A key issue involves consideration of fully burdened, "wraparound" costs. With Antarctic activities, these costs are highly nonlinear. For example, on average it costs $27.50 to purchase and place a gallon of fuel at the South Pole. Avoiding the use of that one gallon, however, saves only about $3.50, the current cost of a gallon of fuel. A tanker ship is still needed to deliver the fuel and an icebreaker is still required to open a path to the continent, whether or not that marginal gallon of fuel is carried. But at some point, if enough fuel can be saved, the USAP may be able to supply fuel to the continent using a smaller and less costly oceangoing vessel, use fewer flights or traverses to carry fuel from McMurdo to the Pole, or maintain less storage. The nonlinear nature of costs and cost savings play a prominent role in making decisions affecting logistical support in Antarctica.

The Panel identified and assessed dozens of opportunities to save costs or enhance performance. Some of these potential improvements are large, some are smaller but cumulatively significant, and others are important for safety or health reasons. In the pages that follow, the Panel begins with a discussion of factors that drive logistical activities in Antarctica and the Southern Ocean, then presents its assessments, and concludes with ten overarching recommendations and a number of implementing actions.

2. THE AUSTRAL ENVIRONMENT

U.S. logistics operations in Antarctica and the Southern Ocean have evolved substantially over the 57 years since the nation's continuous presence began. They respond to the Presidential directive to protect the environment, support science, sustain the peace, and conserve marine living resources in accordance with the Antarctic Treaty and defined U.S. interests. Federal agencies and their grantees and contractors perform these operations, and the National Science Foundation (NSF) and the Department of State have lead roles in coordinating them as components of the U.S. Antarctic Program (USAP).

Scientific research is the principal expression of U.S. Antarctic policy and interest. Science and its operational support also are the principal avenues of international partnering in the region. U.S. logistics operations in Antarctica and the Southern Ocean thus are tasked to safely and

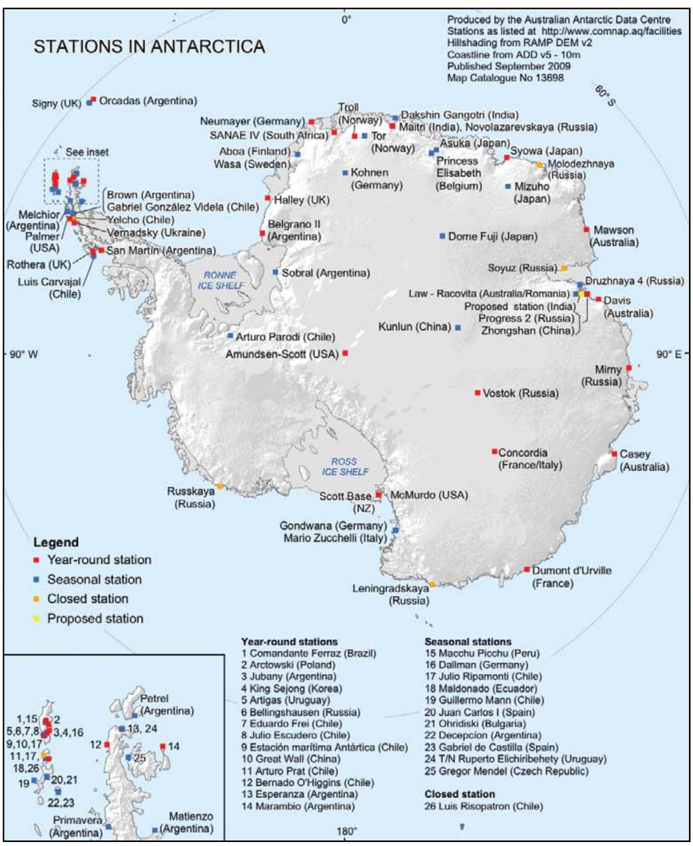


Figure 2.1. Map of Antarctica, showing locations of permanent stations. Source: Scientific Committee on Antarctic Research; http://www.scar.org/information/Antarctica_stations_map.png.

efficiently support U.S. research activities and the U.S. role in international partnerships in the region. These support operations are structured to place science teams where and when they are needed, along with the tools to collect data or specimens and make them available to the scientific community at large.

Research in the Antarctic region—the Antarctic Continent and Southern Ocean—faces unique challenges due to the severe nature of the Austral environment and its isolation from regions of human habitation and activity. The Antarctic—land and sea and the atmosphere above—lies near the limits of human access and habitability and poses major logistical challenges to operations therein, yet provides a uniquely vital and productive environment in which to carry out research and related activities.

Although the Antarctic environment is legendarily harsh, it is also vulnerable, requiring that special considerations be addressed to reduce human impacts and protect the Antarctic region's unique organisms and characteristics. With no true settlements and no underlying commercial infrastructure, support for much of the research—including what would be considered everyday activities in other locales—is expeditionary. Every item from paper clips to bulldozers must be provided from afar and, when its role is complete, removed from Antarctica in accordance with international environmental protection agreements.

2.1. THE CONTINENT

The Antarctic Continent is roughly circular in shape, and is capped by several kilometers of largely ancient ice representing about 89 percent of all the ice on Earth. Less than one percent of Antarctica is not covered by ice.

Antarctica is the highest, driest, coldest, windiest, most pristine, and remotest of the continents. Presenting logistical demands somewhat analogous to those encountered when operating in space, Antarctica has proved to be a vital and productive environment for research and scientific discovery. On the continent, isolated lakes exist underneath several kilometers of glacial ice. Valleys are so dry and perpetually windswept that they remain barren of ice. Novel conditions leave thousands of meteorites on the surface of ice sheets. The geographic pole is atop nearly 1.7 miles (just over 2.7 kilometers) of pure ice, and is overlain by an exceptionally cold, dry, and, for half the year, dark atmosphere. Each of these unique environments, and many more, have proved to be superb natural laboratories.

There are, however, few coastal locations outside the Antarctic Peninsula region, and none in the Antarctic interior, where permanent research stations can be established without contending with exceptional construction and preservation constraints. There are presently 81 active, staffed research stations on the continent, established by 29 nations. Many are located at sea-accessible regions on the Antarctic Peninsula, a few are in the deep interior, and the remainder ring the continent on or near coastal boundaries. Forty of the stations are currently staffed year-around, and the remainder are staffed only during the Austral summer. The USAP operates one of only five runways for wheeled aircraft that offer both direct access from northern land masses to the continental interior and support for routine intercontinental flights (three are operated by national Antarctic programs, two are operated by nongovernmental organizations). Nearly all materials in Antarctica are brought by sea.

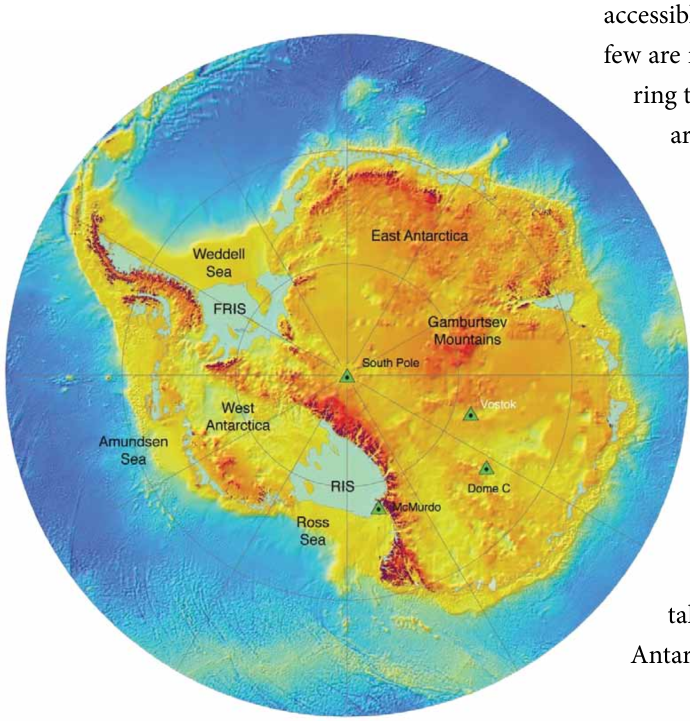


Figure 2.2. Map of Antarctica and the Southern Ocean, showing subglacial Antarctic geography and Southern Ocean bathymetry. Source: Lamont-Doherty Earth Observatory.

2.2. THE ENVIRONMENT AT USAP RESEARCH STATIONS

The USAP Amundsen-Scott South Pole Station is located at the geographic South Pole on the polar plateau at an elevation of 9300 feet (2835 meters). It is situated on a 9000-foot (2745-meter) thick layer of ice. The station is drifting with the ice sheet at about 33 feet (10 meters) a year in a direction parallel to the 80 degree West meridian. The mean annual temperature is –56°F (–49°C). Average monthly temperatures range between –28°F (–33°C) in the Austral summer and –76°F (–60°C) in winter. The record high of –7.5°F (–22°C) was recorded in December 1978, and the record low of –117°F (–83°C) was recorded in June 1982. Precipitation is about 8 inches (20 centimeters) of snow per year, with very low humidity. Drifting is the primary factor in the accumulation of snow around buildings. The South Pole is not especially windy: average wind speed is 12.4 miles per hour (10.8 knots) and a peak wind speed of 58 miles per hour (50 knots) was recorded in September 2011, breaking the previous record of 55 miles per hour (48 knots) set in August 1989.

The USAP McMurdo Station is a coastal facility constructed on volcanic rock and ash at the southern tip of Ross Island in the southern Ross Sea. The mean annual temperature is 0°F (–18°C). Temperatures may reach 46°F (8°C) in summer and –58°F (–50°C) in winter. The average wind speed is 13.8 miles per hour (12 knots), but recorded winds have exceeded 115 miles per hour (100 knots).

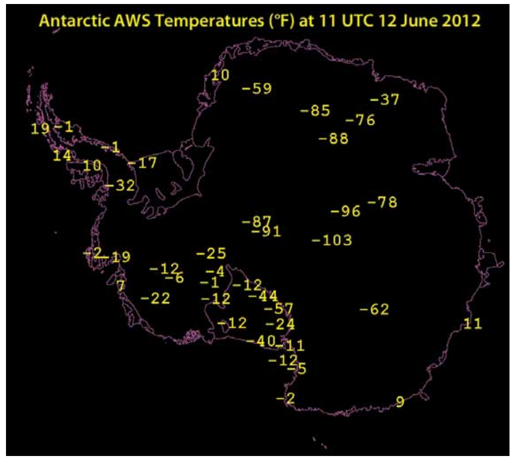


Figure 2.3. Example of Automatic Weather Station winter air temperature observations, showing central Antarctica temperatures below –90°F (–68°C). Source: Antarctic Meteorological Research Center, University of Wisconsin-Madison.

The USAP Palmer Station is a coastal station situated on a small rocky point on Anvers Island in the Antarctic Peninsula region. Air temperatures at Palmer Station typically range from 14 to 36°F (–10 to 2°C). The station frequently experiences high winds, sometimes up to 81 miles per hour (70 knots).

2.3. THE SOUTHERN OCEAN

Antarctica is encircled by Earth's stormiest and only circumpolar waters—the vast Southern Ocean, itself a uniquely challenging and important research environment. The Southern Ocean connects the Atlantic, Pacific, and Indian Oceans. It is not geographically defined in the same sense as the other oceans. Various definitions of its northern boundary range from 60°S (a common definition) to 30°S, or are based on physical characteristics. Most of the Southern Ocean is extraordinarily remote from port facilities. Research expeditions there require extensive planning and strong, high-endurance ships to work in its storm-driven waters. With huge areas—many of intense scientific interest—annually or perennially beset by ice (including during scientifically critical times of year), there are few research ships worldwide that are capable of working this region—and still fewer available to U.S. researchers.

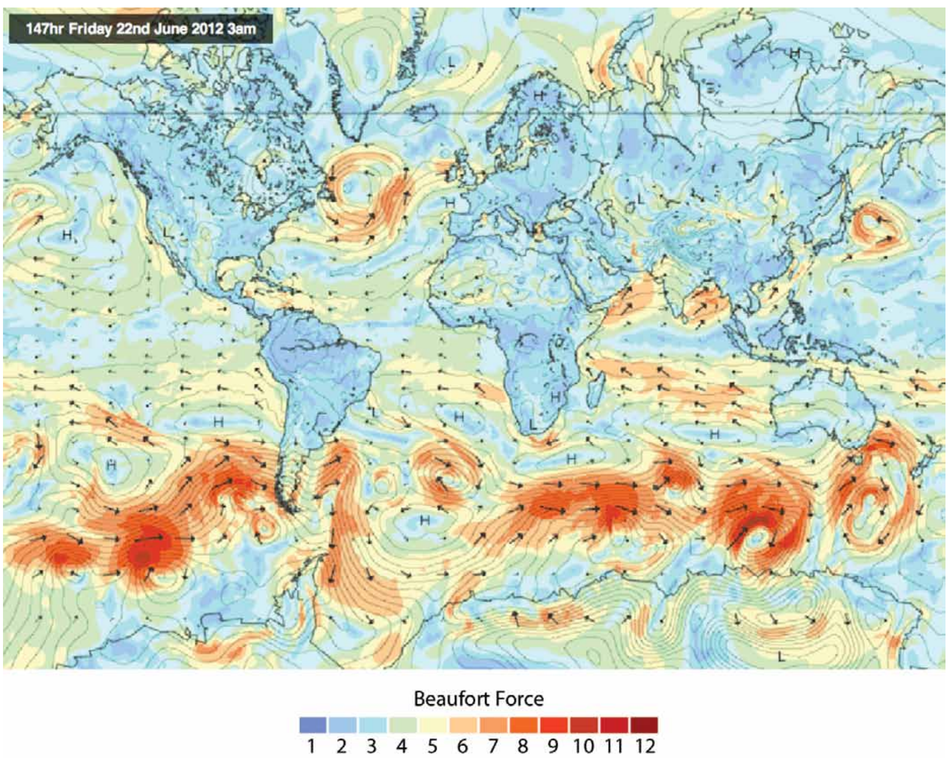


Figure 2.4. Example of surface wind speed forecast, showing several strong storms circling Antarctica, at least two of which were forecast to reach Beaufort 10 (55–63 miles per hour; at sea: "very high waves with overhanging crests; large patches of foam from wave crests give the sea a white appearance; considerable tumbling of waves with heavy impact; large amounts of airborne spray reduce visibility"; on land: "trees are broken off or uprooted, saplings bent and deformed; poorly attached asphalt shingles and shingles in poor condition peel off roofs"). Source: StormSurf.com

2.4. LOGISTICS FOR RESEARCH IN THE ANTARCTIC REGION

While every person going to “the ice” as part of the USAP must meet specified physical standards and receive training for the potential conditions, members of science teams are not themselves required to be technical or polar operations specialists, nor are they expected to provide their own logistical support. The USAP, working with its prime support contractor and other entities, provides the myriad logistical and technical assistance that underlies each research project. USAP-supported stations, camps, ships and a panoply of related facilities in the United States, New Zealand, Chile, and Antarctica provide the essential infrastructure required to support its expeditionary-like activities. USAP-supported personnel operate the stations and camps, ships and planes, laboratories, and outfitting centers of the U.S. program. These personnel substantially outnumber members of science teams.

2.4.1. INDIRECT RESEARCH SUPPORT

The USAP provides considerable indirect research support. USAP infrastructure and logistics capability is currently configured to enable terrestrial- and marine-based research in the range of disciplines funded by NSF and by U.S. mission agencies such as the National Aeronautics and Space Administration (NASA), the National Oceanic and Atmospheric Administration (NOAA), and the U.S. Geological Survey (USGS). The USAP also supports five key observing systems as part of the U.S. contribution to the Comprehensive Test Ban Treaty. In order to do so, stations and other resources have been established, and research ships and related resources are also supported.

2.4.1.1. South Pole

The Amundsen-Scott South Pole Station is the largest facility in the interior of Antarctica and, by virtue of its position, plays a key geopolitical role as well as supporting unique science.

The original South Pole Station was constructed in 1956–1957 and is now entirely buried beneath the snow and ice. The second station, located under a geodesic dome, was completed in 1975. A victim of the passage of time, the environment and the evolving frontiers of

Figure 2.5. South Pole Station. Outdoor storage is visible behind the station. Source: Haley Buffman.

Figure 2.6. The fuel storage facility at South Pole Station. Source: Carlton Walker.

scientific research, the Dome was dismantled in 2009/10 and removed from the continent. The new Elevated Station was dedicated in 2008. The short Austral summer season, when most activity occurs, extends from early November through mid-February. South Pole Station is isolated for the remaining months of the year. The winter population is around 50 and the summer population would be 150 if only the Elevated Station is occupied. With additional, summer-only accommodations, the overall population approaches 250, limited by the operational capacities of the water and sewage systems. The station provides over 5000 meals per week during the summer months and uses approximately 450,000 gallons of fuel annually.

Nearly all USAP personnel reach South Pole Station via a three-hour flight from McMurdo Station aboard LC-130 aircraft that are operated and maintained by the Air National Guard's 109th Airlift Wing located at the Stratton Air National Guard Base in New York. During 2010/11, 215 LC-130 missions were flown to South Pole Station delivering 631 passengers, 3.7 million pounds of fuel, and 1.8 million pounds of cargo—altogether, 5.5 million pounds (2.5 million kilograms).

Since 2007, the USAP has utilized an overland traverse from McMurdo Station to resupply some of the cargo and fuel needed to operate South Pole Station. By using heavy agricultural tractors and specialized sleds, the traverse delivered the equivalent of 30 LC-130 missions to South Pole during the 2010/11 field season. Driving time from McMurdo via traverse is nominally 30 days to the South Pole and a downhill trip back to McMurdo of 15 days.

The new South Pole Station included a 50,000 square foot (4650 square meter) logistics facility, located in underground arches, for indoor storage of materials and supplies. The station confronts a particularly difficult challenge when it comes to storage of some materials and supplies—many items, such as tape and other products with adhesives, lose their effectiveness during the extreme cold temperatures experienced in the underground arches. The station is also heavily reliant on outdoor storage for bulk items and supplies that are used only infrequently. Materials are stored on elevated snow berms marked with inventory locations. Substantial maintenance is required annually to keep the berms free of snow, conduct inventories, and locate items.

Figure 2.7. McMurdo Station. The ice pier is in the lower right. Source: Nathan Hoople.

Figure 2.8. A Dry Valleys field camp (in the McMurdo Station vicinity). Source: Peter Rejcek.

2.4.1.2. McMurdo and Nearby Region

McMurdo Station is the principal U.S. station in Antarctica and its largest scientific base. The original station was constructed in the mid-1950s. From McMurdo Station, a variety of field camps are opened on a seasonal basis, some multiyear, such as sites in the Dry Valleys, and some short-term. With many additions and updates over the years, today's station is the primary logistics facility for resupply and waste management of USAP inland operations (including South Pole Station) and field science projects. The population varies from 130 to 1100, depending on the season and the season's activities. During the summer months, the station serves more than 30,000 meals per week to residents and transients.

The station is normally isolated from late February until early October, except for a brief period in August or September when several closely spaced flights (known as WINFLY, for winter fly-in) deliver personnel to prepare the station for the operating season, supplies, and early science teams.

McMurdo operates three airfields that are used at different times of the summer as a result of environmental/seasonal conditions and aircraft type. The primary means of moving USAP participants from Christchurch, New Zealand, to McMurdo Station is via the C-17 Globemaster III, operated by the U.S. Air Force's 62nd Airlift Wing located at the Joint Base Lewis-McChord near Tacoma, Washington. The planes are able to land at McMurdo during periods of darkness using night-vision goggles, making McMurdo accessible on a year-around basis. McMurdo has a heliport, with a commercial contractor operating and maintaining a helicopter fleet in support of science and operations tasking. Ski-equipped DHC-6 Twin Otter and BT-67 Basler Turbo (modified DC-3) aircraft also operate out of McMurdo, serving science and operational needs in the interior.

McMurdo Station has a deepwater harbor. Resupply activities involving annual visits by a tanker and a cargo ship, chartered from the Military Sealift Command, are intense during a short window each year from late January to

Figure 2.9. McMurdo Station's Pegasus Runway facility. Source: Craig Dorman

Figure 2.10. Cargo ship off-loading at the McMurdo ice pier. Source: USAP photo archives.

mid-February, when sea ice conditions permit. In lieu of a permanent dock, an ice pier at which tankers, cargo ships, icebreakers, and research ships dock is normally used at McMurdo. The pier is constructed in place during the Austral winter and must periodically be replaced. In one recent year, the sea ice did not form completely, preventing successful completion of the pier and necessitating use of a portable modular causeway system shipped from the United States.

The cargo vessel transits from Port Hueneme, California, to New Zealand, and then to Antarctica. The ship carries resupply items for McMurdo and South Pole and returns retrograde cargo and waste to the United States. The annual fuel tanker delivers approximately six million gallons of fuel purchased through the Defense Fuels Agency to support McMurdo, South Pole, and the inland camps. As with all coastal locations in the southern Ross Sea region, heavy icebreaking is needed to open the roughly ten-mile (16-kilometer) channel from the annual sea ice edge to McMurdo Station in order to enable the off-load of cargo and fuel. A total of 11.2 million pounds (5.1 million kilograms) of cargo were shipped to McMurdo via ships and aircraft; 9.3 million pounds (4.2 million kilograms) were shipped out by vessel. (More weight is currently being retrograded than received due to demolition of the old South Pole Station, cleanup of old materials, and large volumes of science samples leaving Antarctica.)

McMurdo Station has approximately 680,000 square feet (63,200 square meters) of dedicated storage space for materials and supplies, with much of it spread out among work centers and frequently moved from one location to another. Materials are stored outside on elevated platforms or in 20-foot shipping containers. Indoor storage is at a premium, with heated storage space being the most difficult to obtain and manage. McMurdo currently has 22 buildings providing indoor storage. Five decommissioned fuel tanks have been converted into covered storage for items such as tires and other equipment subject to damage from ultraviolet rays.

Figure 2.11. Outdoor and indoor storage at McMurdo Station. Sources: (above) Elaine Hood and (left) Craig Dorman.

Figure 2.12. Palmer Station, where cargo from Antarctic Research and Supply Vessel *Laurence M. Gould* is being off-loaded. Source: Peter Rejcek.

2.4.1.3. Palmer Station

Palmer Station, built on solid rock, was completed in 1968 and consists of two major buildings and three small ones, plus two large fuel tanks, a pier, and a helicopter landing site. Palmer Station is logistically isolated from the other USAP stations and is resupplied almost exclusively by sea from South America. Tour ships and private yachts visit periodically during the summer months. Palmer Station is a 230-mile (370-kilometer) voyage by ship from King George Island, which has a 4265-foot (1300-meter) noncommercial gravel airstrip. The Chilean base does not presently have a dock to support research or resupply ships.

At present, there is no runway or other permanent landing site at Palmer Station, although Twin Otter aircraft have landed on the glacier above the station in emergencies. The station supports 40–45 people in the summer and 15–20 people in the three-month, lower-activity winter period. There is no "no-access" time, only periods with reduced activity. Personnel exchange and station resupply is possible year-around, though it is most intense during the summer season. Palmer Station has a rudimentary pier (although no heavy crane and limited material-handling capability) and facilities for research vessels that support logistics and research in the marine sciences. Resupply is carried out approximately every six weeks from South America by the USAP Antarctic Research and Supply Vessel (ARSV) *Laurence M. Gould* (*Gould*). During 2010/11, 354,000 pounds (160,600 kilograms) of cargo and approximately 111,000 gallons of fuel were transported, principally on board the *Gould*. The station serves about 1,000 meals per week during the peak summer months of October through March.

Palmer Station has very little on-station warehouse space and, as a result, no more than a three to four month supply of materials may be maintained on site. With the exception of stores of food and fuel, the station effectively operates on the premise of receiving regular resupply from South America. Some indoor storage is available and the remainder is kept in containers stored outside. Hazardous materials storage and segregation is a particular challenge due to the station's small footprint.

Figure 2.13. A large deep field camp in the Central Transantarctic Mountains. Source: Peter Rejcek.

2.4.1.4. Continental Deep Field

The USAP has the capability to establish both large and small field camps throughout the continent, which covers an area similar in size to the United States and Mexico combined, and which offer venues for scientific discovery in virtually every discipline. The nature of the field camps varies, depending on the type and duration of the research activity. Extended backpacking trips generally are not practicable in Antarctica owing to the weight of the equipment and the fuel required to melt ice for water, cook and combat the cold, and so camps are established. These camps, operating during the summer, are tailored to the particular missions they support. Geology, geophysics, glacial geology, glaciology and terrestrial biology have been pursued at these camps, which are located at some of the most remote, isolated spots on Earth's surface, sometimes at very high elevations. The camps can support small teams or teams as large as 80 or more people, and may be in place for very short time periods or be revisited over a period of years. Transportation and resupply are generally by LC-130, smaller fixed-wing aircraft, helicopter, or tracked vehicle from McMurdo Station, and helicopters or smaller fixed-wing

Figure 2.14. A small deep field camp at Bull Pass in the Dry Valleys. Source: Peter Rejcek.

Figure 2.15. Basler aircraft at a deep field camp in Antarctica. Source: USAP photo archives.

aircraft may be used to support local scientific operations. Snowmobiles are also extensively used for travel over short distances.

Small parties requiring temporary shelter use single- or double-walled tents of several designs, both modern and traditional. One design still used is the Scott tent, a pyramidal-shaped tent similar to the design used by Robert F. Scott in the early twentieth century. These structures are stable in high winds and can be erected quickly. Cold-weather sleeping bags are used on ground cushions, and cooking is accomplished with portable stoves. If summer research projects are expected to continue over several seasons at the same location, pre-fabricated huts or temporary structures may be erected, providing heated space, stable working areas, and comfort not achievable with tents. In addition, the USAP partners with the Antarctic programs of other nations to share existing or purpose-built camps. For some large campaign efforts, more elaborate camps are constructed that are capable of serving as base camps for helicopter and fixed-wing aviation. These types of camps are highly effective at supporting a number of projects during intense periods of observation in a particular area. Access to the interior by air/traverse now also allows camps to be established that until recently tended to be clustered in West Antarctica. In recent years, South Pole Station has begun to function as a hub for field activity on the Antarctic Plateau. All deep field sites are required to have radios and to maintain daily contact with the nearest monitoring station for safety purposes.

Figure 2.17. ARSV *Laurence M. Gould*. Source: Jeffrey Kietzmann.

2.4.1.5. Southern Ocean

The USAP operates two ships for research and related operations in Antarctic waters, the Research Vessel Icebreaker (RVIB) *Nathaniel B. Palmer* (*Palmer*) and the *Gould*[1]. Ships owned or operated by various institutions, such as the U.S. academic fleet and the scientific ocean drilling ship, also periodically undertake research in Antarctic waters, and occasionally USAP vessels operate in concert with the research vessels of other national Antarctic programs. For example, in recent years, the Swedish icebreaker *Oden* has been contracted to conduct Southern Ocean research (and to break the channel to McMurdo Station).

Figure 2.16. RVIB *Nathaniel B. Palmer*. Source: H. William Detrich.

The *Palmer* began conducting science operations in late 1992 when it sailed from Punta Arenas, Chile, in support of the U.S. Ice Camp Weddell jointly operated with Russia. Since then, the 308-foot (94-meter) ship has sailed on more than 110 science cruises, and is now into its second long-term charter in support of marine science research for the USAP. If all options are exercised, the charter will expire in the year 2022.

The *Palmer's* main engines provide total horsepower of 12,700, a rating that, along with hull strength and other criteria, combine to qualify it for classification as an Ice Class A2 icebreaker, able to break three feet (one meter) of ice at a continuous forward speed of three knots[2]. A modern, multidisciplinary research vessel, the *Palmer* has six laboratories totaling 3800 square feet (353 square meters) and

[1] Both ships are owned and operated under charter to the Antarctic Support Contractor by Louisiana-based Edison Chouest Offshore (ECO) and were built by North American Ship Building, a subsidiary of ECO located in Larose, Louisiana.

[2] This classification is done by the American Bureau of Shipping (ABS); the *Palmer's* full classification is ABS Maltese Cross A1, Maltese Cross AMS, Ice Class A2, icebreaker.

Figure 2.18. The USAP facility in New Zealand. Source: Christchurch Photo Library.

can accommodate 39 scientists and technical support staff. The *Palmer* has worked in many areas of the Southern Ocean, including the Ross and Weddell Seas and Bransfield Strait, and has completed two circumnavigations of Antarctica in support of research projects, a distance of 10,500 miles (16,900 kilometers).

The *Gould* began its service in Antarctica in 1998, and a new contract ensures that the vessel will continue its USAP mission until the year 2020. Its missions include both direct support of marine research and also transport of passengers to and resupply of Palmer Station. The *Gould* has sailed in support of more than 80 science cruises. The vessel is a 230-foot (70-meter) ship with an available horsepower rating of 4576 in open-water operations and 3900 horsepower during operations in ice. The vessel carries an Ice Class A1 rating, making her capable of breaking one foot (0.3 meters) of first-year ice while maintaining continuous forward progress. It has berthing space to accommodate a total of 28 scientists and technical support personnel, with nine additional bunks available in berthing vans in the ship's hold for USAP personnel transiting to or from Palmer Station.

2.4.1.6. New Zealand and Chile

Nearly all transportation to McMurdo Station, and thus most USAP on-continent research with the exception of that in the Palmer Station region, is staged though New Zealand. The principal USAP facilities are in Christchurch, in the International Antarctic Centre at the Christchurch International Airport. The complex also houses the New Zealand and Italian Antarctic programs. Over 75 percent of the world's scientists flying to continental Antarctica depart from this facility, including most USAP scientists and support staff—3400 passengers were transported by air between Christchurch and McMurdo during the 2010/11 season. USAP facilities in Christchurch include an air complex that has a hanger for storing aircraft supplies and shops for performing maintenance on the aircraft, as well as facilities for flight planning and briefing crews on Antarctic weather conditions. Administrative spaces house offices, a clothing distribution center, warehousing, and a post office. Nearby Lyttelton is the port that services USAP-related ships[3].

Figure 2.19. Loading a C-17 in New Zealand. Source: Christchurch Photo Library.

[3] U.S. Coast Guard icebreakers do not typically call in New Zealand ports for reasons related to U.S. and New Zealand policy and instead call on Australia when the need arises.

Figure 2.20. The USAP facility in Punta Arenas, Chile. Source: James Swift.

In contrast, USAP operations and research support for Palmer Station are staged through Punta Arenas, Chile, where 132 passengers embarked for transit to the station in 2010/11. The principal USAP facility in Punta Arenas is located at the main port and consists of a contractor-operated, multipurpose warehouse for storage of transient cargo and inventory, a clothing distribution center, administrative and meeting spaces, and a light industrial area for fabrication and repair of materials for shipboard and station use. The USAP research vessels operate primarily out of Punta Arenas and berth directly adjacent to the USAP facility on the main pier. The pier currently lacks the capacity to provide power to the vessel while berthed. The USAP itself operates no aviation facilities in Punta Arenas.

2.4.1.7. Continental United States

Equipment, materials, and supplies are generally purchased in the United States and consolidated for shipment either to New Zealand or South America at the USAP shipping and receiving hub, located at the Naval Base Ventura County in Port Hueneme, California. The base was the operating site of the former Naval Support Force Antarctica and has continued as the USAP point of presence since the Navy completed its service to the program in the late 1990s.

Most items for shipment to Antarctica are repackaged for rough-duty shipping because commercial packaging generally does not withstand the severe environmental conditions encountered during travel to the ice. In addition to using an annual resupply vessel, some items are sent from Port Hueneme to New Zealand by commercial surface ship and also by commercial air. Commercial surface transport from California to Christchurch takes approximately three weeks, and commercial air takes anywhere from 24 to 72 hours, depending on the time of year and nature of the cargo. The majority of science cargo and equipment is shipped via commercial air due to the long lead times associated with shipping on the annual resupply vessel and the timing of the annual approval of research projects. Emerging requirements that are not compatible with the annual resupply vessel schedule also often drive the use of more costly airlift.

Figure 2.21. Registering incoming items prior to repacking at the USAP cargo facility in Port Hueneme, California. Source: Peter Rejcek.

Shipments from Port Hueneme to South America are also accomplished by commercial surface and commercial air. A commercial surface shipment takes approximately 30 days to reach Punta Arenas, while commercial air shipments take roughly three to seven days. These longer shipment times are due to the greater distances involved and the more limited transportation options available in South America.

2.4.1.8. Support Contractor

NSF manages the majority of operations in Antarctica through a large, multiyear contract for base operations and science support[4]. The principal contractor facilities are located in Centennial, Colorado, a suburb of Denver. The contractor is responsible for most activities associated with supporting the USAP—from research laboratory operations, remote field camp support and vessel operations to clinic operations, fire fighting, food service, and recreation. In briefing the Panel, Lockheed Martin said that it will seek to reduce employment and services in selected areas. Reductions will be accomplished by analyzing project needs and opportunities to integrate services, and by rebuilding the science support program with a strategic longer-term vision that is backed with a budget plan. In this regard, the contractor's science planning section will move to the Washington, D.C., area to be located closer to NSF headquarters. This can be expected to increase interactions and efficiencies in science planning as well as to reduce overall costs. The Panel applauds this arrangement. Another area being explored is increasing communication between USAP management and scientists, an effort that should pay dividends. As required by NSF, the contractor is developing a master plan that integrates all station activities, and is appropriately considering the transition to be an opportunity to reexamine many present activities, such as frequency of training for contractors and scientists, whether a driver's license "test" is needed every year for the same person on the same vehicle, and whether a refresher course is needed annually.

2.4.2. DIRECT RESEARCH SUPPORT

USAP direct research support bridges research in the Antarctic and the underlying logistics with project-specific assignments of personnel, equipment, and transportation.

The driver of USAP activity in Antarctica and the Southern Ocean is the operational support needed by research projects approved by NSF as well as other federal agencies and departments. The 2011/12 Austral summer and the 2012 winter (typical of recent years) involved 163 projects—the vast majority funded by NSF (nearly all university-based) and the remainder by NASA, NOAA, and USGS. The amount of operational support per project varies widely; for example, data collection at an existing station often needs relatively little support, whereas ice coring at a remote location requires a great deal of support.

Noting that a project can range in size and scope from a single individual at a station to an international team deployed throughout an entire region, Amundsen-Scott South Pole Station supported 26 projects in the 2011/12 Austral

[4] The prime support contractor for many years had been Raytheon Polar Services Company; however, in late 2011, Lockheed Martin was selected to succeed it. During the period the Panel was active, a transition of the Antarctic Support Contract was underway.

summer. McMurdo Station and field sites supported from there handled 86 projects. Palmer Station supported 19, and the two research vessels, *Gould* and *Palmer*, supported 32 projects. Examples of research support activities are described in greater detail in Appendix VI.

Many research projects, particularly those at South Pole Station, operate year-around. In the summer, scientists and technicians arrive to service and upgrade their equipment. They leave behind a small crew to operate the equipment and to transmit data to home institutions during the eight and one-half month winter isolation period, when low or no daylight and extreme cold make sustained outdoor work impracticable.

The immediate vicinity of McMurdo Station—including Ross Island, the southwest corner of the Ross Sea, the Dry Valleys, and the Ross Ice Shelf—is itself a region of high research interest in a range of disciplines. While substantial science is pursued in McMurdo's laboratories, the majority of effort requires science teams to collect data, samples, or specimens at field locations away from the station. The teams represent the span of scientific disciplines active in the Antarctic and the projects are generally seasonal (October to February), when it is practicable for people to operate in the field. On 13 January 2012, to pick a date, while McMurdo's population was about 1000, 211 researchers were at 26 camps in the field—some in tents, some in more complex semi-permanent summer facilities. Of them, 57 were within helicopter range of McMurdo (mostly on Ross Island and in the Dry Valleys), 136 were far enough away to need fixed-wing support (deep field), and 18 were supported by traverses.

Palmer Station, the northernmost and smallest of the U.S. year-around stations, principally supports local-area projects. Its small boats are presently capable of operating within approximately two miles (three kilometers) of the station, although the range can in limited circumstances be extended to five miles (eight kilometers) based on a risk analysis of weather and sea conditions.

In the Southern Ocean, most, if not all, research cruises require the *Palmer's* capabilities to navigate and carry out scientific operations in sea ice. The *Gould* also extends researchers' range up and down the Antarctic Peninsula and into the Drake Passage between South America and Antarctica. The range has been further extended in recent years through the use of underwater gliders for data collection. University-National Oceanographic Laboratory System or NOAA research vessels support some U.S. research in the Southern Ocean that does not require working in ice-covered waters. NSF is presently arranging for the *Palmer* to be available to NOAA on a reimbursable basis when it would otherwise be in port, thus permitting NOAA to execute its responsibilities under the Convention on the Conservation of Antarctic Marine Living Resources.

In most all of these research activities, USAP-supported and sponsored scientists increasingly use data collected by satellites. Satellite-based communications are also essential to USAP efforts, both for directing and reporting research and for health and safety applications, and will be discussed in greater detail in subsequent sections.

3. FORECAST OF FUTURE SCIENCE NEEDS

The U.S. Antarctic Program (USAP) supports a broad array of research in virtually all areas of science. Although research during and since the International Geophysical Year (IGY) focused on research in geology, glaciology, biology, oceanography, atmospheric sciences and space physics, research topics have broadened in recent years to include the fields of astronomy and astrophysics. Meanwhile, newer technologies such as gene sequencing and remote sensing are changing the character of research. In addition, the tradition of international collaboration in research and logistical support has been strengthening, as exemplified by experiences in the 2007–2009 International Polar Year. The USAP supports National Science Foundation (NSF) researchers and the mission needs of other federal agencies, notably the U.S. Geological Survey, the National Oceanic and Atmospheric Administration (NOAA), and the National Aeronautics and Space Administration (NASA), whose research projects require access to the Antarctic. As previously noted, the USAP currently supports research throughout the Antarctic Continent and Southern Ocean, with focused activities at two coastal stations, a station at the South Pole, and on two research vessels, coupled with measurements made from satellites and autonomous instruments.

The 2011 National Research Council (NRC) report, *Future Science Opportunities in Antarctica and the Southern Ocean*, identifies a number of major scientific thrusts that will warrant particular attention over the next two decades and discusses opportunities to leverage the effectiveness of USAP contributions in those areas. The priority research questions cited in the report are categorized under the two, sometimes-related, topics of "Global Change" and "Discovery":

1. Global Change
- How will Antarctica contribute to global changes in sea level?
- What is the role of Antarctica and the Southern Ocean in the global climate system?
- What is the response of Antarctic biota and ecosystems to change?
- What role has Antarctica played in changing our planet in the past?

2. Discovery
- What can records preserved in Antarctica and the Southern Ocean reveal about past and future regional and global climates?
- How has life adapted to the changing Antarctic and Southern Ocean environments?

- How can the Antarctic platform be used to reveal interactions between Earth and the space environment?
- How did the universe begin, of what is it made, and what determines its evolution?

The 2011 NRC report establishes the following priorities to address these key science questions:

- Lead an international effort to improve observing networks and Earth system models.
- Continue to support basic scientific research toward new discoveries.
- Increase international collaboration.
- Exploit emerging technologies.
- Coordinate integrated polar education.
- Continue strong logistical support for Antarctic science while improving efficiency, flexibility, and mobility.

The following sections describe current and future science pursuits and the resources needed for their support.

3.1. SCIENCE AT THE SOUTH POLE

The South Pole's remote location, many thousands of kilometers from major sources of anthropogenic effluents, makes it the premier location for monitoring the well-mixed global atmosphere. Atmospheric carbon dioxide measurements made at the South Pole date back to 1957. The total column ozone record over the South Pole has been measured since the early 1960s. The decreasing amounts of stratospheric ozone led to the genesis of the term "Antarctic ozone hole" when these data were highlighted in a scientific paper published in 1985. One of the main stratospheric ozone-depleting gases, CFC-11, was measured by NOAA at South Pole Station nine years before the ozone hole was discovered. There is a marked decrease in CFC-11 growth following the 1992 Montreal Protocol limiting its production and ozone hole recovery is underway. These data are a dramatic verification of the importance of long-term atmospheric monitoring at the South Pole. These data are also used to verify satellite measurements.

The cold, clean, dry atmosphere over the South Pole provides viewing conditions that, at some wavelengths, are equivalent to those in space. As a consequence, the Amundsen-Scott South Pole Station has become a major astronomy and astrophysics research site, enabling measurements of cosmic microwave background radiation—important because its distribution provides direct evidence about the energy

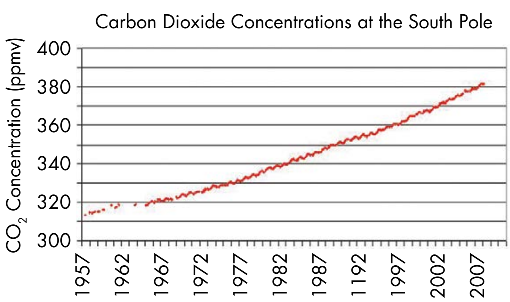


Figure 3.1. Long-term measurements of carbon dioxide (CO_2) made at the South Pole by the Scripps Institution of Oceanography Air Sampling Network showing a steady increase in concentration. The annual sawtooth pattern reflects the spring-summer growth of plants. Source: http://cdiac.ornl.gov/trends/co2/graphics/South_Pole_CO2.jpg.

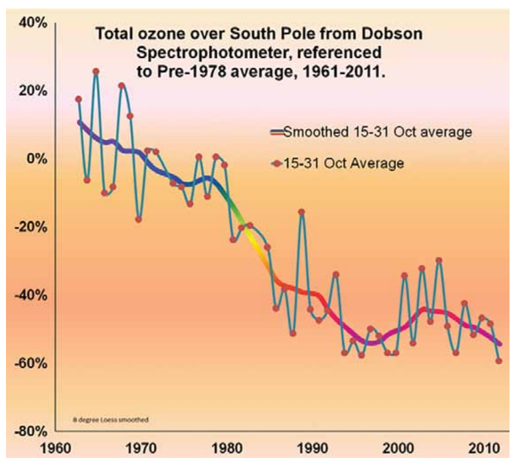


Figure 3.2. Total column ozone measured during the peak stratospheric ozone depletion season measured by NOAA from the South Pole in a program initiated in the early 1960s. Note that stratospheric ozone was decreasing well before the Antarctic ozone hole was observed in 1985. The negative slide in stratospheric ozone over the South Pole halted during the 1990s.

distribution in the universe immediately after the Big Bang and because it can be used as a kind of backlight to detect concentrations of mass not otherwise detectable—with unprecedented accuracy by the 10-meter South Pole Telescope. The IceCube Neutrino Observatory opens a new window on distant and unknown parts of the universe. To best advance scientific understanding of astrophysical processes, observations from the telescopes (and other experiments) at the South Pole must be linked to observatories elsewhere in the world. For example, in addition to conducting research into the origin, evolution, and nature of the universe, the observatories at the South Pole are significant components of a global network for the detection and study of episodic events such as supernovae or even asteroid collision with planets of our solar system, for example, the Shoemaker-Levy 9 event. Studies like these depend on the availability of significant satellite connectivity in order to enable the timely transmission of data to laboratories in the United States and around the world.

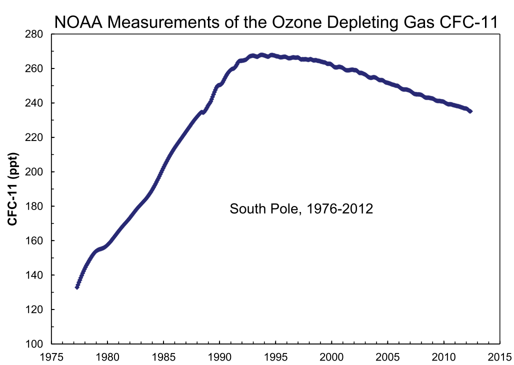


Figure 3.3. Concentrations of the ozone-depleting gas CFC-11 measured by NOAA at South Pole Station. NOAA was measuring CFC-11 about a decade before it was implicated in the formation of the Antarctic ozone hole in 1985. The data clearly show the immediate effect of the 1992 Montreal Protocol in reducing ozone depleting gases.

3.2. SCIENCE ON THE PENINSULA AND WEST ANTARCTICA

The Antarctic Peninsula is of special interest for several reasons, conditioned in part by the pronounced environmental changes underway there. One reason is that unique Antarctic ecosystems offer opportunities for research on the impacts of change as well as adaptation mechanisms. Another reason relates to the spectacular disintegrations of major ice shelves, such as Larsen-B and Wilkins, which had consequences for local environments and accelerated the loss of land-based ice. The future loss of relatively vulnerable land-based ice from the Antarctic Peninsula and West Antarctic Ice Sheet is a key component for predicting the trajectory of global sea level rise. The fastest moving ice on the Antarctic Continent presently drains into the Amundsen Sea from the West Antarctic Ice Sheet. Revealing the driving forces there has been identified as a scientific priority. Ocean-ice shelf interactions in particular are implicated in accelerating ice motions. Changing sea ice conditions may also play a role in those interactions, as well as in ecosystem changes and deep-water formation that is an important driver in global ocean circulation.

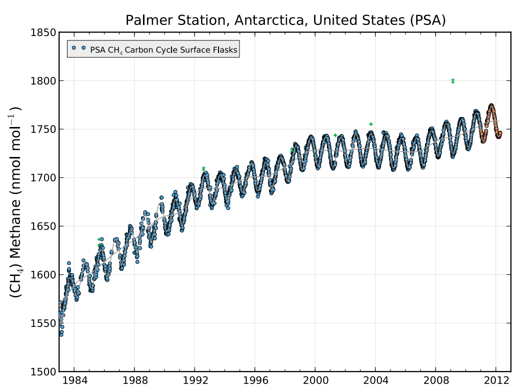


Figure 3.4. Concentrations of methane, the second most important greenhouse gas, sampled at Palmer Station by NOAA. Clearly visible in the data are the methane annual cycle that echoes down from northern latitudes, and changes in the growth rate of global methane over time.

Methane, the second most important greenhouse gas next to carbon dioxide, and dozens of other trace gas species are measured at Palmer and the South Pole Stations.

The most critical need for supporting future science in this region is more effective access—by ship to Palmer Station for research on ice-associated ecosystems and ocean-glacier interfaces, and by air to remote field sites in West Antarctica. Reliable high-capacity air access to Palmer Station and much of the peninsula region is infeasible because of its rugged topography. Palmer Station and U.S. field camps along the peninsula are currently supported by the Antarctic Research and Supply Vessel (ARSV) *Laurence M. Gould* (*Gould*), but this ship was not designed to operate in heavy ice and thus cannot access the areas mentioned above. The Research Vessel Icebreaker (RVIB) *Nathaniel B. Palmer* (*Palmer*) is now 20 years old and, because of her limited icebreaking capabilities, she is not able to reliably access the seaward margins of the West Antarctic Ice Sheet.

The research community has expressed the need for a new vessel with capabilities beyond those currently available on the *Palmer*. The new ship must be able to penetrate heavy pack ice in

Figure 3.5. ARSV *Laurence M. Gould* at Palmer Station. Source: James Swift.

winter to enable investigations of ice shelf processes, high-productivity open water regions, and polynyas (areas of open water) within the ice pack. The science mission requirements for such a Polar Research Vessel (PRV) were recently documented in a study carried out by the University-National Oceanographic Laboratory System (UNOLS) with NSF support.

The *Gould* will be more than 20 years old when her current charter expires in 2020. Either a replacement vessel will be needed or the USAP will need to find different ways of resupplying Palmer Station and transporting personnel between the mainland and the station.

The peninsula hosts 14 year-around research stations operated by eight nations, some with research vessels and some with aircraft landing sites. The concentration of scientific assets in this small, rapidly changing region offers an opportunity for increased international cooperation to reduce duplication and to share responsibility for access to research sites. The possibility for such cooperation in the logistics arena appears equally promising.

Palmer Station has had only occasional incremental enhancements of its basic research capacity since it began operations, and will require key upgrades if it is to continue its mission of anchoring USAP research on the peninsula. The pier is essentially unchanged since the station was constructed and it cannot safely accommodate the *Palmer* or a new PRV; even the smaller *Gould* must take care to avoid hazardous underwater obstructions when calling on the station. Of additional importance is that access to research areas near Palmer Station when the *Gould* is not present is typically limited to a two-mile (three-kilometer) area in which small boats can operate safely. A Rigid-Hull Inflatable Boat could safely work over twice the present operational radius from Palmer Station, extending research to areas of interest. Still, significant processes such as penguin foraging and up-canyon water transport extend well beyond these limits and can be studied only if the observational range is increased to about 25 miles (40 kilometers) from the station, and so some other options should be considered.

Figure 3.6. Conceptual drawing of the Polar Research Vessel.

Unattended moorings and autonomous vehicles such as underwater gliders can supplement and even replace many key observations traditionally made by humans from small boats. Palmer Station will need new information technology and communications capabilities if it is to be successful as a host for expanded unattended observations in the peninsula region.

Field access in West Antarctica, including areas being targeted for drainage glacier behavior studies, is generally afforded by air and traverse from McMurdo Station.

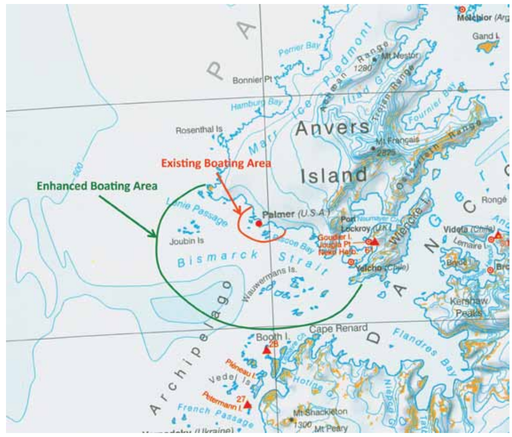


Figure 3.7. Illustration of current small boating area around Palmer Station (red line) and possible extension (green line) if Rigid-Hull Inflatable Boats become available.

3.3. SCIENCE IN MCMURDO AND THE DRY VALLEYS

The Dry Valleys have been a significant research focus since the IGY, and have served as an analog of Mars for NASA research. Numerous discoveries have led to a better understanding of how organisms survive in extreme environments and how the Earth system functions. Continuing to pursue this research is critical for understanding how the Earth system worked in the past so that we may better predict what changes may occur in the future.

The response of ecosystems and biota to ongoing climate change over the long term remains uncertain. The Dry Valleys, with glaciers, freshwater lakes, glacial melt streams and soil ecosystems, have experienced climate fluctuations since continuous observations began in the 1960s. A pronounced warming trend in the 1980s and early 1990s changed to cooling later in that decade. Subsequently, another change occurred. The Dry Valleys are now experiencing an increased frequency of warming events, resulting in rising lake levels and a decline of the dominant animal species in soils across the dry landscape. Across McMurdo Sound from the Dry Valleys is Ross Island, home to four volcanoes and several penguin rookeries and other marine life. Although studies of the geology, glaciology, nutrient and hydrologic cycles, and biodiversity continue, there are insufficient observations available to discern trends in the terrestrial systems, permafrost, glaciers, marine life, and ocean-land atmospheric feedbacks. These data are important to developing a robust understanding of the physical, biological and chemical processes acting in the region, and to developing predictive models of how the environment will respond to changing climate conditions. In particular, improvements in the density of observations, appropriate to the geographic scale of the process of interest, will be necessary to advance across the next threshold of understanding.

In McMurdo, potential Crary Lab modernization and expansion must be balanced against the desire to minimize the on-ice footprint. Possible considerations for analytical facilities include genomic and other "–omics" capabilities, as well as advanced analytical support for field samples. This could include stable isotope and other analytical techniques that are now generally performed off-continent. Having the analytic capabilities on site to check the organism, rock, ice, or atmospheric composition rather than waiting until analyses are performed in the home laboratory could permit more efficient sample collection programs and promote science progress. Developments in

Figure 3.8. USAP research facility at a lake in the Dry Valleys, within helicopter range of McMurdo Station. Source: Craig Dorman.

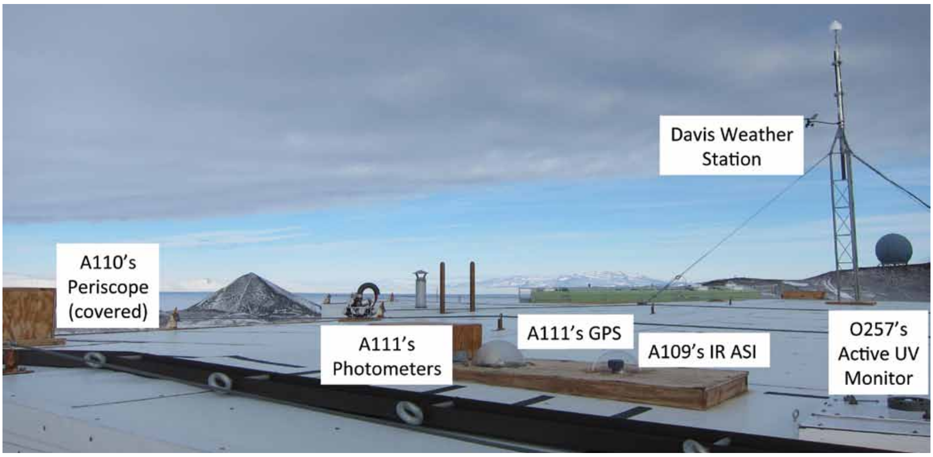


Figure 3.9. A view from the roof of the U.S. Arrival Heights Research Facility, located just north of Hut Point on the west side of Hut Point Peninsula, Ross Island. The facility houses equipment for a host of atmospheric and auroral experiments for universities and other research groups including, by project identification number (principal investigator) and title: O257 (Butler): Ultraviolet (UV) measurements at McMurdo Station for the NOAA/Global Monitoring Division Antarctic UV network; A109 (Moore): Extremely and Very Low Frequency (ELF/VLF) observations of lightning and lightning-induced electron precipitation; A110 (Hernandez): Atmospheric dynamic studies employing high-resolution Fabry-Perot spectrometers; A111 (Weatherwax and Gerrard): Magnetic, Global Positioning System, and optical experiments related to auroras, induced electrical currents, radiowave communications interference, and space weather. Source: Lou Lanzerotti.

this regard should take into account whether efficiencies to be gained justify the fully loaded expense, including the need for specialized personnel on ice.

The 2011 NRC report outlined several pressing areas of atmospheric research, notably improving the representation of clouds and precipitation in climate models used to predict the potential extent of Antarctic climate change. Airborne research campaigns typically span periods of up to a month or more, and can cover a wide range of environments, from offshore to the continental interior. The utility of aircraft for geophysical studies of the ice sheet and underlying earth and hydrologic system was also highlighted. While the airfields at McMurdo have evolved to support wheeled aircraft for a greater part of the year, this is not true elsewhere on the continent, limiting the use of existing advanced research aircraft (almost entirely wheeled). As noted later, a long-range ski-equipped aircraft outfitted and dedicated to science would significantly accelerate scientific progress and facilitate U.S. science leadership in these key areas.

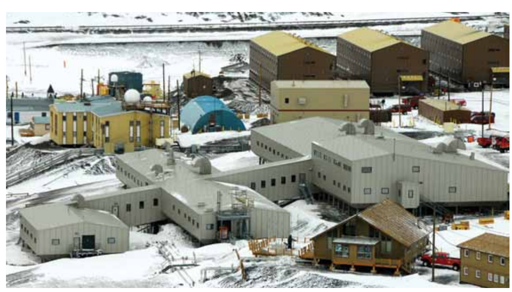


Figure 3.10. Aerial view of the Crary Science and Engineering Center, known as the Crary Lab, at McMurdo Station. Source: Robyn Waserman.

3.4. SCIENCE IN THE CONTINENTAL INTERIOR

The interior of the East Antarctic Ice Sheet is key to understanding both the past and future climate of the planet. The ice in this two-mile (three-kilometer) thick body contains records of past climate because ancient gases trapped inside successive layers in the ice can provide insights into how the global atmosphere has changed through past glacial cycles. Beneath these key climate records rest vast tectonic terrains the size of the United States that have never been sampled. The tectonic history of these terrains is critical to deciphering the evolution of the continent.

Also beneath the Antarctic ice sheets is a vast water system that ranges from deep lakes to networks where water flows intermittently in streams. The deepest, Lake Vostok, rests beneath two miles of ice, is approximately the size of Lake Ontario, and is up to one-half mile deep. These water systems are targets of study as they are likely to contain novel ecosystems and because they influence ice sheet dynamics. For example, floods from the lakes can cause the ice sheets to flow faster.

Effective and efficient ground and remote access to the high plateau of East Antarctica will be needed to support study and sampling of these unique scientific frontiers. Establishing multiuse base camps in the continental interior as hubs for terrestrial, geophysical, and ice dynamics research could provide easier access, enabling critical research related to climate change.

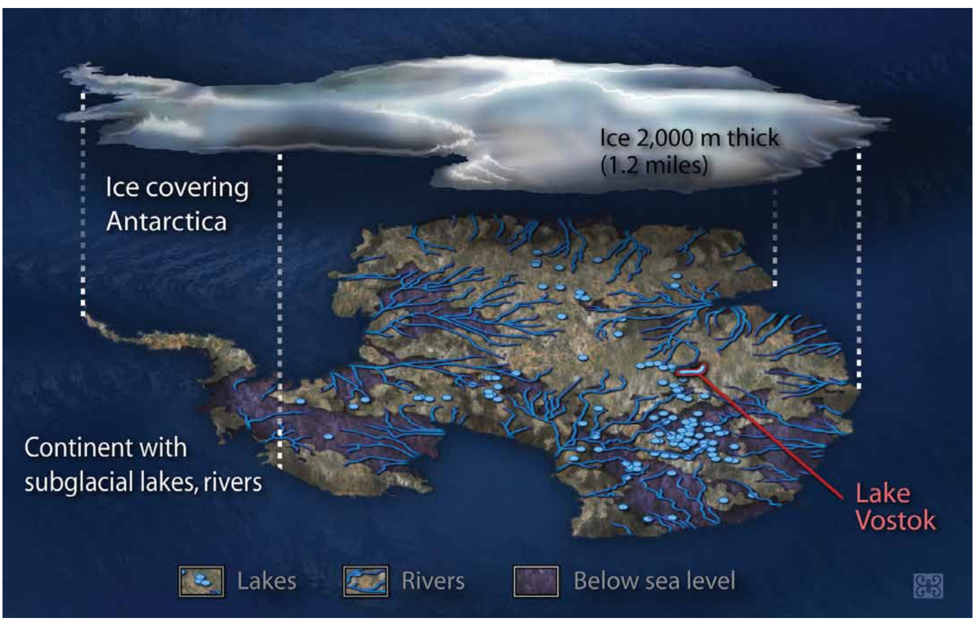


Figure 3.11. Illustration of Antarctic subglacial lakes and drainage. Source: Zina Deretsky, for NSF.

3.5. SCIENCE IN THE SOUTHERN OCEAN

The Southern Ocean is most commonly considered to comprise the vast region located below 60°S, including all the oceans, seas, straits, and embayments surrounding the Antarctic Continent that are influenced by sea ice. This region ranges from the open sea and the Antarctic Circumpolar Current, across rich continental shelf seas to coastal areas permanently covered by dense pack ice, to the seaward margins of the great ice shelves.

As an important and highly variable region of atmospheric carbon dioxide uptake that helps regulate the global climate on timescales ranging from decades to tens of thousands of years, the Southern Ocean plays a critical role in global change. The Southern Ocean is a major controller of global sea level because it influences the stability of ice shelves and the continental ice sheets at their landward boundaries. In addition, the Antarctic coastal seas are highly productive, supporting a rich krill fishery and huge populations of seabirds, seals, and whales. As noted in the 2011 NRC report and in the above discussion of science at Palmer Station, the Antarctic Peninsula is experiencing rapid warming and sea ice loss, and its marine ecosystems are changing as the region warms. The Ross Sea is the largest and most productive of the Antarctic coastal seas, with still-pristine conditions now being affected by global change. In other areas, such as the Amundsen Sea, ocean processes influence the stability of the West Antarctic Ice Sheet, which in turn could affect the future course of sea level rise. The sediments below the Southern Ocean seafloor contain an invaluable

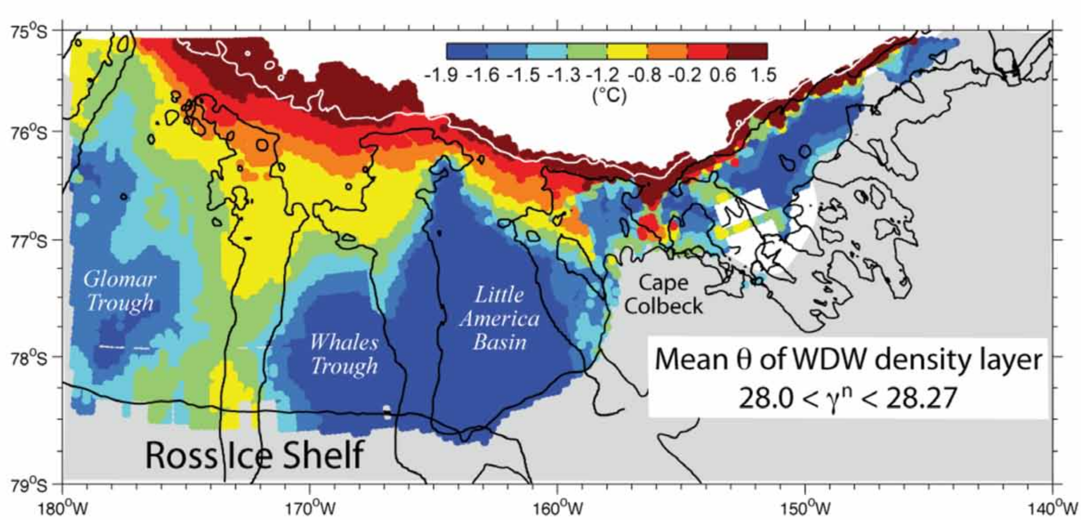


Figure 3.12. Illustration of temperature in the circumpolar Warm Deep Water (WDW) layer, showing intrusion of relatively warm WDW south onto the Ross Sea shelf, under the ice, making the WDW a potential source of heat for melting floating glacial ice. θ is "potential temperature," which corrects a small pressure effect on temperature. γ^n is a measure of density, in this case a density layer in the ocean corresponding to the WDW. Source: Alex Orsi.

archive of past global change that complements records of climate change from ice cores and provides an indicator of future change across the entire planet.

NSF-supported oceanographic ship-borne research is carried out principally from ships coordinated by UNOLS, but no present UNOLS research ship is ice-capable. (A new ice-strengthened ship, the *Sikuliaq*, is operated by the University of Alaska for research principally in North Pacific and western Arctic Ocean waters.) Nearly all marine research near Antarctica must be carried out by ice-capable ships. Hence, U.S. marine research in far-south waters is dominated by that carried out by the two USAP ships.

An expanded and modernized capability to support marine research will be needed if U.S. scientists are to take leadership roles internationally in ocean-based research (notably, take a leadership role in the Southern Ocean Observing System, which could be a significant component of an Antarctic Observing Network). The *Gould* and the *Palmer* have contributed to major discoveries in Antarctic science; however, they do not have the suite of scientific instrumentation nor the capability to support cutting-edge work in many emerging research areas. In addition, they are not capable of operating in the seasons or regions of heavier pack ice that are of interest for ecosystem, ocean circulation, and ocean-ice shelf studies.

Table 3.1. Annual Ship-Days-at-Sea for U.S. Research in Southern Waters, 2001–2010

	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
49–64°S										
UNOLS	36	68	27	0	76	50	30	22	57	71
NOAA	78	64	80	62	72	70	30	116	61	52
USAP	58*	55*	95	210	218	282	182	243	175	138
Total	172*	187*	202	272	366	402	242	381	293	261
64–80°S										
UNOLS	0	45	0	0	2	0	3	5	0	0
NOAA	0	0	0	0	0	0	0	8	0	0
USAP	195*	128*	152	205	234	218	247	226	191	289
Total	195*	173*	152	205	236	218	250	239	191	289
Grand Total	367*	360*	354	477	602	620	492	620	484	550

* No *Laurence M. Gould* data available

4926 total days; 4199 days 2003–2010; avg 525 days/year 2003–2010

3.6. SCIENCE USING AN INTEGRATED OBSERVATION SYSTEM

The lack of geographically extensive, long-term observation records and a paucity of observations south of the peninsula and McMurdo regions are additional factors limiting the ability to reduce uncertainties in climate change models. The 2011 NRC report on which this study draws recommends a comprehensive, coordinated, and networked interdisciplinary observing and prediction system that would encompass all the major elements of the Antarctic environment—the atmosphere; terrestrial, marine, and subglacial ecosystems; permafrost; ice shelves; ice sheets; and subglacial habits of the interior as well as the ocean and sea ice. Thus, observational systems with the latest technology to gather atmospheric, ice, and ecological information will be necessary to provide the means to assess ice, biotic, and meteorologic changes in the relatively unexplored interior of the continent as well as other areas of the continent and Southern Ocean.

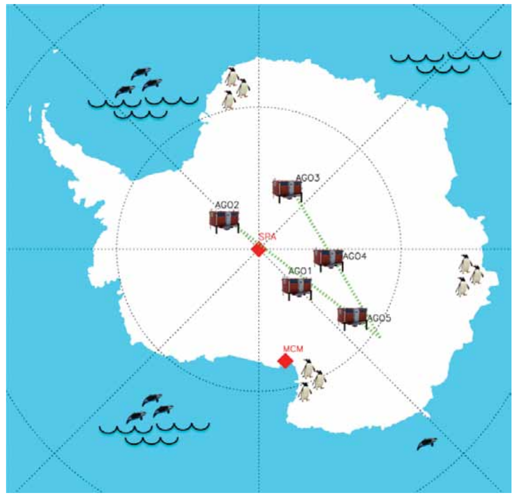


Figure 3.14. Map of Automatic Geophysical Observatory locations. Observatory components are aligned along geomagnetic longitudes that converge at the geomagnetic south pole. Source: Siena College and New Jersey Institute of Technology.

Figure 3.13. Photo of an Automatic Geophysical Observatory from the rear, with two solar panels and close-up of the wind generator. These stations operate year-around, unattended, under sun and wind power. Source: Siena College and New Jersey Institute of Technology.

Currently, the Automatic Geophysical Observatory (AGO), consisting of a suite of nearly identical instruments at six locations on the polar plateau, actively studies the coupling of the solar wind to ionospheric and magnetospheric processes, emphasizing polar cap dynamics, substorm phenomena, and space weather. The Polar Earth Observing Network (POLENET) operates networks of Global Positioning System (GPS) instruments and seismometers for studies of the crustal response to ice sheet change. The experience and understanding gained from the AGO and POLENET programs will prove useful in planning, designing, and implementing an Antarctic Observing Network and meeting the challenge of successfully colocating a diverse set of low-power research instrumentation and supplying reliable, renewable power along with necessary communications year-around.

An effective observing system approach will require enhanced access to the interior of the continent for timely data collection (and subsequent transmission), maintenance, and support as well as other logistics services. Many research topics will span the entire continent in an integrated fashion and are not specifically tied to any one of the major USAP stations. The U.S. capability in Antarctica will need to evolve to enable continent-wide, long-duration, multidisciplinary research, including partnering with and benefitting from other national programs seeking to contribute to such an endeavor.

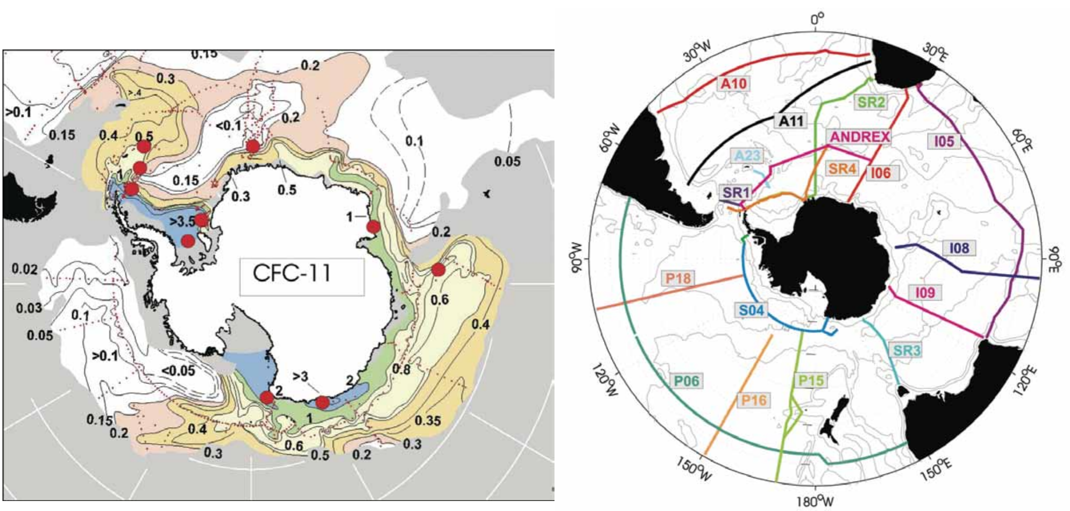


Figure 3.15. Examples of planned components for the SOOS (Southern Ocean Observing System): (left) Map of proposed moored arrays (red dots) to sample primary Antarctic Bottom Water (AABW) formation and export sites, superimposed on plot of AABW CFC-11 inventories, and (right) chart showing repeat hydrographic sections to be occupied by the SOOS. Source: Rintoul et al. (2010).

4. FINDINGS AND IMPLEMENTING ACTIONS

4.1. RESEARCH SUPPORT: RESEARCH FACILITIES AND EQUIPMENT

Scientific research in Antarctica and the Southern Ocean covers a very broad range of topics, making the provision of support an extremely complex challenge. For example, support of the sciences needed to study the various fish species in the Southern Ocean is very different from that needed to study the geology of the Antarctic mountains or the biogeochemistry of the frozen lakes in the Dry Valleys. The infrastructure needed to support the 10-meter telescope and the neutrino observatory at the South Pole is yet again different.

Figure 4.1. Penguin with instruments and transmitter for research. Source: Alex Isern.

The episodic maintenance requirements of long-term, remote deep field sites present further challenges in designing and providing very high reliability instruments and power systems that can operate unattended year-around.

Providing the necessary infrastructure and logistics requires not only increased exploitation of emerging technologies but also a conceptual framework that relies increasingly on international planning and cooperation. Remotely controlled vehicles (aerial drones, autonomous underwater vehicles [AUVs], gliders, and robotic traverse tractors) have the potential to significantly reduce costs while enhancing scientific reach. International collaboration to avoid duplication of research effort is another area that has the potential for expanding scientific output. There exists a high concentration of stations along the Antarctic Peninsula, a sparse distribution along the rest of the coast, and a much lesser distribution in the continental interior. A similar picture emerges for vessels conducting research in the Southern Ocean.

This section briefly describes the current research support structure and a projection of the needed changes to carry out the future research outlined in the 2011 National Research Council (NRC) report—with particular focus on increasing efficiency.

In the future it is likely that remote autonomous instruments will contribute significantly to the suite of observations used by terrestrial and ocean scientists. Such devices will extend the observing time beyond the Austral summer and facilitate collection of longer-term records, creating opportunities, for example, to significantly improve understanding of the response of the biota to darkness and low temperatures. Unmanned remote observation sites are already in use, and expanding this capability to other locations on the continent is an obvious path. Research and development to improve the reliability and capability of equipment, including lighter, more reliable, and cost-effective batteries, would be very beneficial. Use of autonomous instruments may also present opportunities to reduce the number of people that have to work in Antarctica, or otherwise reduce the amount of time they need to spend there.

ACTION 4.1-1. ***Extend the observing season, especially on the continent, and improve the communications network to operate throughout the year to enable automated data collection and transmission from remote instruments.***

Figure 4.2. (top) Underwater glider used for autonomous ocean research. Source: Don Hartill. (bottom) Modern aerial drone for wide-area observations. Source: John Cassano.

ACTION 4.1-2. ***Sponsor workshops to promote the development of remote-sensing and other equipment that will minimize the number of people on the ice and on research vessels.***

The magnitude of Antarctica's future contribution to global sea level rise is projected to be substantial. Reducing uncertainties in the projections requires research into the factors that govern the movement of the continental glaciers toward the sea and the melting of the glaciers at the ocean's edge. National Science Foundation (NSF)-supported research conducted during the International Polar Year (IPY) identified a number of key factors that need further study. Measurements of the motion of those glaciers most likely to be major contributors to sea level

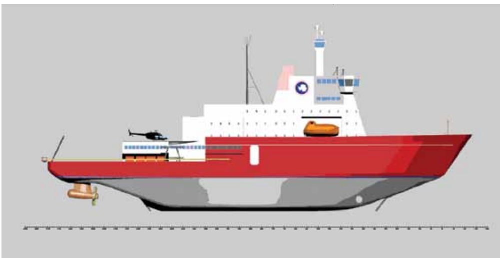


Figure 4.3. Polar Research Vessel concept drawing.

rise will be required. Airborne surveys of ice sheet thickness and elevation, enabled by the long-range science aircraft described in the 2011 NRC report, could provide much critical data. AUVs are needed to obtain detailed measurements of ocean salinity and temperature at the ocean-ice sheet interface to improve melting rate predictions.

Increased access to ice-covered regions of the Southern Ocean adjacent to the continent will be needed in order to measure and monitor factors that help drive global ocean currents as well as to study changes in ecosystems caused by modifications to their physical environment. Almost uniquely among the major nations supporting research in Antarctica, the United States lacks research ships that can provide access to regions of heavy ice. Moreover, the two U.S. Antarctic Program (USAP) ships that work in Antarctic waters will only be under contract for at most (if options are exercised) another eight (Antarctic Research and Supply Vessel [ARSV] *Laurence M. Gould* [*Gould*]) and ten (Research Vessel Icebreaker [RVIB] *Nathaniel B. Palmer* [*Palmer*]) years, when they will be 22 and 30 years old, respectively.

Sediments beneath the Southern Ocean seafloor provide vital information about past changes in the global climate system. Establishing a more comprehensive ocean floor drilling program in the Southern Ocean adjacent to the continent can make a significant contribution to understanding this history and its implications for future change. This activity requires a research vessel with enhanced capabilities compared to those of the *Palmer* or *Gould*—such as greater automation, improved ice capability, and the instrumentation and equipment needed to accomplish present and future studies. It will also be essential for the United States to partner with other nations operating research vessels in the region in order to achieve pan-Antarctic coverage for a Southern Ocean Observing System.

ACTION 4.1-3. ***Aggressively pursue the acquisition of a new polar research vessel with enhanced capabilities to ensure U.S. leadership in pursuing scientific endeavors in the Southern Ocean. Improved capabilities to deploy and recover advanced remote-sensing assets should be a key feature of such a vessel.***

Biosphere-climate interactions are complex and understanding them requires a multiparameter observation system. Antarctica provides an important natural laboratory for monitoring the response of biological and environmental systems to rapid change. The 2011 NRC report highlighted the need for long-term interdisciplinary observations using a broad observing network backed with data integration and scientific modeling. With its track record of long-term observations in Antarctica, the United States is well positioned to play a leading role in such efforts and in establishing standards for data collection, along with guidelines for open data access.

USAP facilities in the Dry Valleys as well as the array of national research stations located along the Antarctic Peninsula afford opportunities to cost-effectively establish long-term environmental observing networks through international collaboration. Collaborations can be enhanced to link such activities on a larger scale, thus forming a pan-Antarctic interdisciplinary observation system with substantial cost savings compared with a U.S.-only system. The United States has an opportunity to play an important role in developing such a network, thereby accelerating the availability of important research.

Consistent with Presidential Memorandum 6646 of February 5, 1982 (United States Antarctic Policy and Programs), since the early 1970s NSF has been, and is expected to remain, fully responsible for managing and coordinating the support of U.S. Antarctic operations. However, the projected trends in science and technology imply more intensive participation by other U.S. agencies, as well as by international bodies, in both planning and operations. As opposed to the "Arctic Observing Network," which evolved from investigator level projects into a formal program, the envisioned integrated, long-term Antarctic observatory already entails a significant component of "top-down" planning and management—as evidenced, for example, in the planning documents for the Southern Ocean Observing System. An Antarctic observatory is called for in the planning documents of the United States and many other nations, as well as international bodies such as the World Meteorological Organization, the International Council for Science, and the Scientific Committee on Antarctic Research (SCAR).

Further, any continental-scale approach to observations and fieldwork will place more emphasis upon new communications and data management capabilities and remote sensing from space and air, as well as access to research sites that are well beyond the reach of U.S. air, land, and sea assets. The implications are that new NSF multidirectorate and national multiagency planning mechanisms will be needed, and that new ways must be found to overcome the programming and operating challenges associated with more integrated international efforts. This will likely extend to a more international approach to operation of stations on the continent, as well as access to ice-strengthened vessels in the Southern Ocean.

Issues that will need to be addressed include the logistical and environmental implications of autonomous system installation, operation, servicing, and eventual removal. Both the observing system and the associated design, management, and operating structure will require investment well above existing levels (as will the associated information technology resilience)—as indicated by a review of current grants—especially if the United States desires to take the international lead in their development. An additional central consideration will be the need for significantly expanded communications capacity across the continent[5], with the

[5] Continuity of an arrangement with Iridium for satellite services (discussed later) is likely to remain essential for the economic viability of much of the planned U.S. contribution.

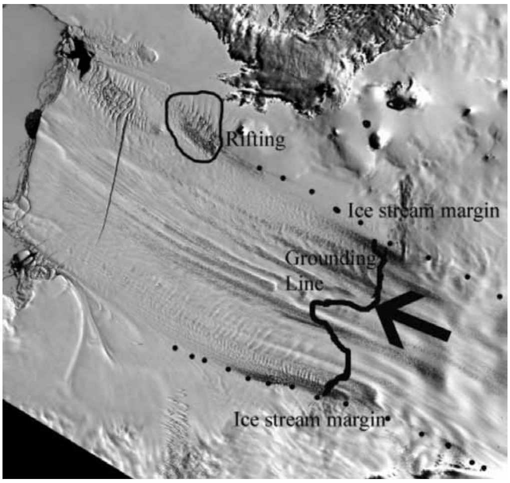


Figure 4.4. Annotated satellite image of Pine Island Glacier showing glacial flow and the grounding line. The Ross Sea is on the extreme upper left of the image. Just above the grounding line, the glacier's surface shows some large-scale roughness that is evidence of subglacier topography. Seaward of the grounding line, the glacier is no longer in direct contact with the bottom. Source: British Antarctic Survey and NASA.

likely requirement for international standards to ensure that all interested nations can effectively contribute to the observing system. The failure to undertake such a coordinating effort promptly is likely to lead to the deployment of a complex system with incompatible elements that is both costly and limited in scientific value.

One essential early decision is the nature and scale of the programs where the U.S. intends to take a leadership position, versus those where it intends to engage only in a supporting role. The management challenges will be much the same as those faced in other major global-scale international scientific endeavors except that they are magnified by the nature of the surrounding environment[6].

Basically, any envisioned large-scale system science—whether addressing global change or discovery—mandates the establishment and funding of highly competent program offices as well as a "common framework" for system and project engineering, including the establishment of "technology readiness levels" and performance metrics similar to those employed by the National Aeronautics and Space Administration (NASA), Department of Defense (DoD) and other agencies, and that NSF and DoD currently engage in during their extensive joint annual planning activity.

The age of informal, "as you go" planning has been overtaken by the increased interconnectivity of science and its cost. The USAP should enhance its capability to conduct complex operational planning by adding relevant people skills and analytical support and, where beneficial, establishing program offices for major and long-term efforts.

ACTION 4.1-4. ***USAP and its international partners should develop a strategy for defining components of the continental-scale long-term observing system to ensure that all components of the system are compatible and complementary.***

[6] The U.S. Ice Drilling Program Office's parallel Long Range Science Plan and Long Range Drilling Technology Plan is one example of the sort of planning that will be required for an Antarctic observatory. A similar planning effort is commencing for the Southern Ocean Observing System, but considerably more detail will need to be laid out for this system as well as similar international efforts to ensure that planning, programming, and infrastructure investments can be prioritized and implemented within expected budgetary constraints. Yet another example from a different venue is the multinational program office established to coordinate activities surrounding the International Space Station.

ACTION 4.1-5. ***Pursue development, with international partners as appropriate, of a comprehensive, coordinated, and networked interdisciplinary observing and prediction system that would encompass all the major elements of the Antarctic environment—the atmosphere, terrestrial, marine and subglacial ecosystems, permafrost, ice shelves, ice sheets, subglacial habitats of the interior as well as the ocean and ocean sea ice.***

Key areas of West Antarctica are likely to remain priority destinations for research because of the relatively rapid movement of the West Antarctic Ice Sheet (WAIS) and the concomitant vulnerability of WAIS itself. The glaciers along the Amundsen Sea coast are changing and are currently the fastest moving on the Antarctic continent, with glaciers along the Siple Coast and the Filchner-Ronne Ice Shelf closely following. Work at the Pine Island Glacier and the Whillans Ice Stream to further understand processes in subglacial and sub-ice-shelf environments are important contributions currently underway. The challenge is in delivering and maintaining the equipment needed to carry out research at these more distant locations. Weather and limitations on LC-130 crew time conspire to escalate the challenge. It is possible that a refueling facility coupled with a minor-maintenance facility and crew rest area for the LC-130s in West Antarctica could provide a much more reliable transportation solution for these remote camps; this possibility is discussed in greater detail later in this report.

The new South Pole Telescope and IceCube projects are the most recent examples in Antarctica of research that can begin to answer some of the questions about how the universe began and about its current composition and behavior. Both experiments take advantage of the South Pole environment to carry out measurements that are very difficult to perform in the rest of the world. There are opportunities to expand these research areas by developing an array of telescopes centered on the 2-to-4 mm wavelength region studied with the South Pole Telescope and by using larger volumes of ice compared to IceCube. Currently, a principal constraint for this kind of research is the relative lack of available communications bandwidth from the South Pole. Uniquely among the three USAP year-around research stations, South Pole Station cannot "see" geostationary satellites: their orbits fall below the horizon north of the pole, thus, the station must rely either on specialized polar-orbiting satellites or on aging satellites that have drifted out of geostationary orbits toward the end of their life. The available satellites provide just enough capability to meet today's need, but they will not be able to meet projected growth in research project needs without augmentation. Of even greater concern is the fact that most if not all of these satellites will go out of service over the next decade.

Figure 4.5. Aurora image over South Pole Station, taken with an all-sky imager that is part of a joint research project of Siena College and Nagoya University.

In general, without a significant expansion of available bandwidth to the north and on the continent itself, all future research activities in Antarctica will be limited.

ACTION 4.1-6. ***Increase the available communications bandwidth to Palmer Station, South Pole Station, McMurdo Station, and the field camps in Antarctica.***

To ensure the success of Antarctic research projects as they increase in complexity and extend to larger and even more remote regions of the continent, the level of communication and collaboration between scientists, the support contractors, the Air National Guard (ANG), the helicopter and small fixed-wing service providers, and NSF will need to increase correspondingly. In developing the concept of operations for these more complex projects, the possibility of schedule delays has to be reflected in a clearly defined plan so that as many of the scientific goals of the projects as possible can be achieved during the short Austral summer season. In addition, an overarching risk analysis for each project is needed rather than risk analysis and mitigation of individual components, as is currently practiced. With the present planning approach, the effects of the delay or failure of one component of logistics support does not appear to be propagated in an effective way into the planning of other affected activities, thereby leading to a success-oriented schedule without adequate contingency. Moving from the past model of a "service provider to a customer," toward "closer collaboration among all parties to determine what is essential at the research sites" will minimize the amount of matériel that must be transported to the more remote locations. Of course, projects that can be conducted without support personnel, scientists, or technicians present will greatly ease the demands placed on the logistics system, particularly when serving remote sites.

ACTION 4.1-7. ***Improve the process for developing plans for fielding complex projects, including realistic budgets and schedules that incorporate adequate contingency, a defined risk analysis, and mitigation measures.***

Long-term programs carry long-term support burdens, so should be periodically reevaluated to assure that they continue to be effective and operate efficiently. Other national Antarctic programs have been very successful in transforming their portfolios by ending support for some programs in order to include new approaches, leading to a much broader research program while staying within the same budget profile. For the USAP, this is currently, and should continue in the future to be, accomplished through NSF's merit review system.

4.2. PEOPLE

The total number of people on the continent and on research vessels is a key cost driver because of the infrastructure needed to support their presence in the Antarctic environment. Many individually modest changes can cumulatively represent significant cost reduction opportunities. For example, routine maintenance of field gear needed for the remote camps on the continent may be more economically performed by shipping the material out on the annual resupply vessel and returning it the next year. Instituting modern inventory control techniques using bar code scanners would further reduce the number of people required to manage the materials needed by scientists to carry out their research. Other cost saving could be found by shortening researcher deployments to the minimum necessary duration and instituting a more robust equipment testing protocol.

The staff of the prime support contractor[7], its subcontractors, and personnel supporting rotary- and fixed-wing operations (a total of well over 1000 people, not including shipboard personnel) dominate the USAP population deployed to all Antarctic operating locations. Direct labor costs alone represent approximately 30 percent of total funding to the prime contractor.

Well over half of the prime contractor's full-time personnel deploy to Antarctica for some or all of the summer season, yet some 70 percent of the on-ice workforce is "seasonal" or otherwise not "permanent." Staffing seasonal contractor

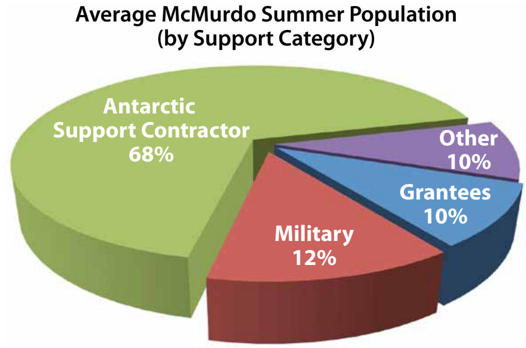


Figure 4.6. Chart illustrating McMurdo Station population by categories.

positions is a continuous, year-long, complex and challenging task, and personnel issues are naturally exacerbated by the challenges of the working and living conditions on the ice, particularly, but not only, during the winter season. Above-normal personnel costs associated with this approach include a lengthy and complicated annual hiring process (involving background checks, yearly medical examinations, and, for winter-over staff, psychological examinations) and a significant number (nominally 15–20 each year) of "difficult-to-hire" positions (due to a combination of the prevailing job market, unique skill requirements and citizenship, for example). An additional complication is the relatively high (up to 50 percent) dropout rate of staff who initially signed up for wintering over. Prospective employees drop out throughout the hiring process, and even occasionally as of the last flight out of South Pole at the end of the summer season. This personnel issue increases the cost of recruiting, conducting medical and psychological screening,

[7] Raytheon Polar Services Company at the time of our visit; the statistics quoted here are for the last few years of operation.

and in some cases transporting and training, replacements. If replacements cannot be found, planned work will not be accomplished.

Employee retention is not unreasonable given the nature of the work—roughly 75 percent for McMurdo WINFLY (winter fly-in), 60 percent for McMurdo and South Pole summer and winter positions, and 80–90 percent for Palmer Station staff. Workforce stability can improve efficiency, but it also can bring its own set of issues, including those of a social and behavioral nature and a lack of innovation, particularly in senior positions. Overall, the Panel found the station and shipboard personnel it met to be generally well skilled and motivated. Nonetheless, the Panel learned of a number of issues that had not previously surfaced to management, implying either a degree of complacency or lack of a fully effective suggestion and review process. A much more effective "suggestion box" system could prove valuable, but only if there is follow through and feedback.

ACTION 4.2-1. ***Establish a "suggestion box" system that encourages the submission of ideas and issues, and ensure that consideration of suggestions is thorough and communicated to the USAP community.***

The sheer number of people required to operate the stations and the intracontinental transportation system, especially at McMurdo, is a primary concern. Inefficiencies attributable to the age, condition, and nature of the facilities and equipment require high staffing levels. These inefficiencies adversely impact working conditions, safety, morale, and welfare. In many cases, they also increase the demand for specialized skills. Turnover of key on-ice staff hampers standardization and the development of a culture focused on supporting field science along with the imperative to operate safely and achieve all reasonable cost savings. Such deficiencies could be ameliorated by new facilities and technology, both hardware and software, in conjunction with process reengineering. Increased communications bandwidth and modern business systems also should enable more tasks to be performed off the ice.

The current change in the prime contractor provides an extraordinary opportunity throughout the program to rethink levels of service, to reemphasize policy objectives such as total-cost consciousness and workplace safety, and to reengineer work processes in parallel with planned business system upgrades. Because labor costs are a very high percentage of the support contractor's funding, devising ways to minimize labor requirements is a potentially important path toward cost savings. It is the Panel's judgment that the overall goal should be a workforce reduction of at least 20 percent at McMurdo, allowing a comparable increase in stability and decrease in cost. Importantly, to reach this level, investments in new infrastructure and other improvements to the supply chain, plus process reengineering and the application of modern business systems, will be required.

ACTION 4.2-2. ***Working with the USAP prime contractor, improve the stability and professionalism of the workforce and reduce the number of support personnel on the ice, with a goal of a 20 percent smaller workforce at McMurdo Station. (This reduction should be achieved*** *through investments in infrastructure and other improvements to the supply chain, plus process reengineering and the application of modern business systems.)*

Similarly, NSF should assess the needed support staffing for field camps on the continent with an eye toward reducing staffing to the minimum level needed. Reducing this population can significantly decrease support costs, making the savings available for the conduct of additional science.

ACTION 4.2-3. ***Ensure that the support population for field camps is streamlined and appropriately matched to the needs of the science activities.***

There is a quite evident lack of understanding of, and concern for, the total costs of an Antarctic research project, and a culture—likely exacerbated by the very strong and very appropriate focus on safety—that generates extremely high levels of support. Because only a limited number of people can be accommodated at each of the stations and on the research ships, maximizing research productivity means limiting time on the ice or at sea to the minimum essential for safely performing the work. The USAP should further develop and promulgate policies and procedures for operations and research that promote a culture of total cost consciousness and workplace safety throughout the entire program and that appropriately matches needs of the science activities to resources provided. Information needs to be made available to all participants in a manner that promotes their participation in cost containment. One way to accomplish this might be to develop a catalog of sorts, such as one uses when shopping at home, detailing the costs of items that are consumed by research and operations personnel on ice to make them more aware of the costs involved in supporting their presence in Antarctica.

ACTION 4.2-4. ***Increase overall awareness of the true cost of resources provided in Antarctica.***

ACTION 4.2-5. ***Foster a culture of efficiency and continuous improvement in all aspects of research and operations in order to reduce the overall footprint of activities and provide greater agility to respond to emerging areas of research. Areas of focus include reinforcing the notion that research supported by the USAP should be composed of activities that can only be performed, or are best performed, in the Antarctic.***

As with the contractor's staff, USAP researchers are an eclectic and diverse mix of experienced personnel and enthusiastic junior scientists, many of them the graduate students or postdocs of the senior principal investigators. The scientists are often accompanied by highly competent technical staff who design, build, maintain, and operate the increasingly sophisticated instrumentation and equipment required for the research conducted in the Antarctic region. The 2011 NRC report states that there is no perceived difficulty in maintaining the pipeline of Antarctic investigators. Nonetheless, we note four "people" issues relating to science that impact logistics and cost.

The first issue, as previously noted, is the balance between on-ice and home-laboratory activity. Although some in situ sample preparation and analysis is generally essential, there is a tendency to want to do analytical work on the ice. This practice increases the time a person is deployed and it demands equipment of ever-increasing sophistication and cost that remains unused most of the year. This is somewhat less of a problem in the Southern Ocean where tightly constrained cruise times dictate work practices, and year-around, 24 x 7 operations are the norm.

The second concern relates to the importance of "new blood" to encourage innovation. Although experience is important, major breakthroughs and novel approaches that open important new paths of inquiry often come with new investigators. The tendency of "old hands" to perpetuate their perceived "legacy rights" to primacy in allocation of limited opportunities and resources can be counterproductive. In many cases, scientists who have not had experience in polar environments, or have not been mentored by those with such experience, find it hard to break into the "club." While there is much information on the Web, a meaningful understanding of the challenges of the polar environment, let alone the peculiarities of the USAP, can be difficult to attain. It requires a concerted effort by NSF to ensure that opportunities for polar science are open to all, and to encourage new participants. Similarly, it takes directed effort to acclimate new participants to Antarctica. The USAP must support the best science, not just the best "geographical" science. Extensive efforts on the part of NSF to broaden and prepare the participant pool are fully warranted. NSF does periodically sponsor new investigator workshops, and should continue this practice.

The third issue has to do with the impact of long-term deployments on the fabric of the research community. Faculty members who spend extended periods on the ice may become less integrated with other members of their university community. Their absence may also impact their ability to build collaborations outside their own areas of expertise or to recruit young scholars from the broader community. Technology that enables faculty to effectively work from their campus instead of being deployed in Antarctica could help alleviate this problem.

The fourth issue is the postulated change in the nature of USAP activity toward a combination of continent-wide, long-term observing systems supported by modeling and integrated communications and data management, and sustained year-around system-scale research, much of it complex and conducted at deep field sites. These trends will require new technology, new modeling, new logistical skills, new equipment and facilities, new and strengthened international partnerships, and new approaches to planning—and some new people with new skills, both on and off the ice and on the ships. Anticipated changes to both science and logistics support will also increase demand for total-cost consciousness and innovativeness on the part of the research community itself.

The USAP is not immune to the changes inherent in evolving approaches to science, technology, and logistics. It is NSF's responsibility to define the policies under which the USAP is conducted and thus to establish the needed culture of total-cost consciousness for support of research. The full range of USAP science support activities—from announcements of opportunity, to proposal review criteria and processes, to length of the Antarctic operating season, to levels of support to scientists and other agencies, to development of interagency and international structures—as well as prudent management of the prime contractor—are all determinants of program efficiency and thus research productivity. In addition, it is NSF's responsibility to have a staff that is adequate in size and capabilities to do so.

The challenges of the prime contractor transition combined with these new approaches to science, technology and logistics, as well as the need to respond to the many recommendations for improvements and cost savings in this report, demand advanced business acumen and planning expertise. Broad and rapid access to external expertise, through a combination of independent contractors and federal and state agencies and their laboratories, is an essential complement to NSF's existing internal capability.

The creation of a small systems engineering/analysis group separate from the prime contractor to perform cost/benefit studies on a routine basis is a top priority. This may be of use for the Arctic as well and could thus report to the Director of the Office of Polar Programs. Although systems expertise as well as management of USAP details provided by the prime contractor (and its subcontractors) are crucial to success, so too are the nature of NSF policies and oversight as well as astute planning and programming and a careful balancing of priorities, incorporating the new infrastructure investments recommended herein.

The need to continue to support wide ranging and increasingly complex research operations safely and efficiently while simultaneously making major repairs and upgrades in a cost-effective manner presents extreme challenges of "multivariate analysis," on timescales ranging from those associated with long-term capital and master planning to annual budget preparation to day-to-day reaction to changing weather conditions.

ACTION 4.2-6. ***Establish a small systems engineering and cost analysis group to conduct high-level cost/benefit analyses independent of the prime contractor, but working openly with the prime contractor.***

An additional and not inconsequential aspect of the "people in Antarctica" topic is outreach to the public, including exploiting the excitement of Antarctic research to impact STEM (science, technology, engineering, and mathematics) education at all levels. This, too, will influence logistical needs. The USAP's demand for funds, even at current levels, necessitates a significant understanding by the public of the importance of Antarctic research for issues of societal importance and "discovery," as well as NSF's commitment to cost containment and efficiency. The price of essential major new infrastructure (for example, icebreaking ships, including a polar research vessel, and communications satellites) whether at NSF or other agencies is certain to exceed anticipated budget levels, placing greater emphasis on the need for broad national support and reductions in the cost of currently planned operations.

Finally, the USAP shares with many other research activities the demand for STEM-competent personnel, and thus is obliged to contribute to education by offering compelling opportunities and motivation to students. The USAP has an unusual opportunity in this regard, one that should not be foregone.

4.3. TECHNOLOGY

Technology plays a very strong role in determining the number and skills required of USAP personnel and its appropriate use can eliminate failure points, reduce personnel requirements, and leverage the contributions of individual support personnel.

Technology can also greatly improve the reach and quality of logistics support. There are dozens of examples, ranging from enabling night landings to providing robotic components for traverses, new machine tools, and even a modern dishwashing system in the McMurdo galley. Many of these efficiencies are well known within the USAP. At issue is the investment strategy—how to balance the funding needed to support ongoing science while remedying deficiencies and preparing for future demands. Technology is only one component of the needed investment—but the lack of it is a significant part of the problem at McMurdo, and to a degree at Palmer Station.

A major concern is that NSF has not established a long-term capital plan and associated capital budget for the USAP. The result has been significant deterioration of the infrastructure and technological currency at both permanent coastal stations, to the point that a major overhaul is now necessary. Although the need for an overhaul is reflected primarily in the condition of facilities, it is equally true for the technology that is used to support activities in Antarctica. Many upgrades should have been accomplished long ago. As was the case with the rebuild of South Pole Station, when field research was reduced in order to ensure sufficient flights were available to deliver construction materials, it may be necessary to reduce scientific activity for a few years in order to undertake the very significant facility, information technology, safety and habitability modernization program that is needed, while simultaneously investing in the new systems and technology required to support long-term observing systems and a broader, year-around reach across and around the continent. Doing so would result in more and better scientific output in the longer term.

For many years NSF has maximized research within its budget constraints while deferring infrastructure and logistics investments. The time has come to make a concerted effort over the next several years to redress the situation to ensure science is not severely hampered in the future.

ACTION 4.3-1. ***Establish a capital plan and capital budget. The investment strategy should emphasize upgrades to essential facilities, logistics and support infrastructure as well as new technology, all aimed at streamlining operations for efficiency and cost-effectiveness. Included is the establishment of long-range master plans for facilities, logistics, support infrastructure, and technology for each of the three major USAP stations.***

Technology enables the pursuit of science as least as much as logistics. This has been particularly apparent in recent decades in the biological sciences, but it is equally important in the other disciplines of Antarctic and Southern Ocean research, particularly for long-term remote observations. An NSF-sponsored workshop on autonomous polar observing systems provided a thorough examination of the challenges and ways forward for the disciplines it considered (primarily Earth geophysics)[8]. Much of what this workshop reported with regard to technological development (especially regarding common needs for communications and power), deployment strategies (for example, integrated or multi-autonomous "Super Sites"), shared logistics, rigorous test and evaluation in polar conditions, and approaches for both technological development and information sharing (such as consortia, cross-disciplinary working groups, conferences, and web-based documentation) is equally applicable to other disciplines, including oceanography in the Southern Ocean.

Figure 4.7. Weather instruments and Global Positioning Systems being placed on uncrevassed ice next to the Pine Island Glacier to allow near continuous observations of the weather conditions and to monitor its movement. This is an example of the programs considered during the NSF-sponsored workshop on "Autonomous Polar Observing Systems" (2010). Source: Cliff Leight.

There are many autonomous systems in place around Antarctica, but they do not constitute the envisioned integrated, continent-wide network that was described earlier. In fact, they often function independently. Upgraded cyberinfrastructure integrated with sensing systems both on and off the ice—for communications, data management, and modeling—must be designed and engineered from a systems perspective, including international compatibility.

Both novel science and research productivity in the USAP depend upon not just good ideas, but also innovative, advanced technologies that have been thoroughly tested and vetted for operations in the extreme Antarctic environment. Similar challenges pertain to Arctic research, and in many cases systems and techniques designed for one pole are equally useful at, or readily modified for, the other. There are well-known venues where scientists interact to exchange ideas and develop collaborations, but there are many fewer such opportunities for the engineers and technologists who develop and operate the equipment that makes the science effort possible. To help ensure that its investments are most effective and efficient, NSF should promote and support science, technology, and logistics planning and sharing mechanisms to include program offices, consortia,

[8] Autonomous Polar Observing Systems Workshop, November 2011, available at http://www.passcal.nmt.edu/content/apos-report-now-available-online.

cross-disciplinary technical working groups, conferences, and web-based documentation of best practices and lessons learned. Such mechanisms should be polar in scope, stress programs where the United States intends to take the international lead and, to the degree practicable, be integrated with similar international planning efforts, in particular, through SCAR. This committee is charged with initiating and fostering development of ideas for high-quality international scientific research in the Antarctic region and on the role of the Antarctic region in the Earth system.

Overall, most of the technologies that can reduce logistical costs and enhance operational support are available within industry or government. The challenges are access, adaptation to USAP needs, assurance of proven readiness for operations in Antarctic conditions, and a willingness to modify traditional procedures. Invention, in the case of logistics support, is generally not the issue. For the support of science, however, invention is at the heart of the matter. An example that greatly impressed the Panel during its Palmer Station visit was the use of gliders and free-drifting profiling floats for directed upper-ocean sampling, yielding orders of magnitude more data than possible from shipboard observations. Most, if not all, of the technologies incorporated into early devices of this type had been available for years. What was lacking was a definitive requirements and funding mechanism to expedite their development. The Panel believes that the creation of such innovative access and sampling technologies, as well as the rapid improvement of "common use" components for power and cyberinfrastructure, can best be spurred through dedicated technology development programs not directly tied to specific individual research projects.

To achieve the degree of system and project engineering expertise needed to cost-effectively support and manage the research called for in the 2011 NRC report, the USAP will need to broaden both its internal capabilities and its access to external expertise. It will also need to rely ever more heavily upon technology developed by other agencies or by industry. This has always been the case with NASA for spacecraft and the military for air support, but is likely to become equally important with regard to the Department of Homeland Security (DHS) for sensing and communications as well as the Department of Energy (DOE) for power technologies. Many current areas of USAP mutual support are governed by law, Presidential Directives, or Memoranda of Agreement, and similar degrees of formality may well enhance additional collaborative development.

Other mechanisms, such as the Interagency Arctic Research Policy Committee that coordinates Arctic research, or the National Science and Technology Council committees that address ocean policy and research, may also prove beneficial for Antarctic and Southern Ocean technology development and sharing. In addition, although there are many differences between the Arctic and Antarctic, there are common technological challenges in sensing, communications, power, and maritime access to important regions in and under sea ice. Although NSF manages the majority of the U.S. research portfolio in both regions, it is not clear that at a national level there is an adequate degree of interaction among related activities focused on the opposite poles.

In parallel with a holistic long-range modernization program for both McMurdo and Palmer Stations and for ship upgrades, means toward effectively achieving science in new ways will need to be pursued.

In conjunction with enhanced participation of polar researchers in NSF's current Major Research Instrumentation program, a dedicated Defense Advanced Research Projects Agency (DARPA)-like polar technology and instrumentation program would yield major dividends—and will likely be required to achieve the science "opportunities" detailed in the 2011 NRC report.

ACTION 4.3-2. ***Continue to sponsor workshops that promote the development of remote sensing equipment that will minimize the number of people on the ice and on research vessels. Such workshops should encourage polar researchers to participate in NSF's Major Research Instrumentation program.***

ACTION 4.3-3. ***Establish a dedicated DARPA-like polar technology development program within NSF and with other agencies. This could include investments in cyberinfrastructure and activities to enable broad observing systems as recommended in the 2011 NRC report.***

People newly involved in the program and new technology need to be "customized" for polar research. Summer schools have proven particularly effective for science training at the collegiate and graduate level, and this practice should be broadened to include polar engineering, technology, and logistics. Similarly, NSF should explore the possibility of expanding the scope and stature of its annual polar technology workshop. The current field safety training program seems to work well to enhance the safety and operational readiness of personnel on their first visit to McMurdo. As research programs become more international, opportunities for similar training for U.S. personnel who deploy with or through the stations of other nations will be increasingly important.

ACTION 4.3-4. ***Foster mechanisms to ensure the readiness and training of scientists, engineers, modelers, and technologists that participate in Antarctic and Southern Ocean research.***

Finally, it is essential to test and evaluate any new technology, whether it be equipment or instrumentation destined for Antarctica prior to deployment, particularly those having to do with encountering harsh environmental conditions. At issue are the degrees of formality for verifying technological readiness and the associated approval processes. Test sites are available at McMurdo for final verification and, for example, at the U.S. Army's Cold Regions Test Center in Alaska and the Cold Regions Research and Engineering Laboratory in New Hampshire, for pre-deployment testing and evaluation.

Researchers are aware of the career-jeopardizing penalties of failed equipment and are highly motivated to ensure that their instrumentation is thoroughly tested. Nevertheless, especially for new USAP participants and new technical approaches, failures do occur, and when they do, the consequences can be severe in terms of loss of productivity and resources. The peer review process can and should add a significant degree of rigor in assuring technological readiness. For logistics and support equipment, including new approaches to items such as shelters, cold weather clothing, power supplies and vehicles, particularly in an era of greater international collaboration, it may be appropriate to consider more formalized approaches to both preparing specifications and validating equipment performance. It is a costly proposition to have equipment deployed to Antarctica fail.

ACTION 4.3-5. ***Ensure that instrumentation to be deployed for operation at remote field sites has passed a thorough pre-deployment testing process, including environmental testing, and has been developed to enable module-level serviceability and remote calibration.***

ACTION 4.3-6. ***Adopt more formal approaches such as successful ones practiced by industry and other agencies for test and evaluation of new systems and technologies and formalize the assessment of technological readiness of new equipment and processes.***

4.4. TRANSPORTATION

4.4.1. ALTERNATIVES TO MCMURDO STATION

McMurdo Station on Ross Island is the operational hub for all continental activities. The current array of logistics and infrastructure at McMurdo is built around the requirement for science and support operations at the South Pole, in the deep field across Antarctica, and in the vicinity of McMurdo, as well as for science support and research laboratories at McMurdo itself. Palmer Station, on the Antarctic Peninsula, is independently supported and resupplied.

The choice of Ross Island as the principal USAP base was historically guided by its proximity to the site chosen by polar explorers, notably the 1910–1913 Scott Expedition. As researchers and logistics experts increasingly learned, the Ross Island location is the best overall site for supporting continental research in Antarctica.

Table 4.1. Scientific Attributes of McMurdo Station and Nearby Region

	KEY ADVANTAGES	LIMITATIONS
Dry Valleys	Proximity (helicopter accessible); Vast array of valuable research topics and sites available	Distance requires intermediate refueling camp for helicopters
Sea Ice and Glacial Ice Shelf	Proximity (easy access by light vehicle or helicopter) to largest ice shelf; Persistence	None
Ocean Biology and Chemistry (McMurdo Sound)	Proximity (easy access through sea ice for divers, fishing); Persistent ice cover for stable research platform	Persistent ice cover limits water access and biological diversity
Penguins	Several major rookeries nearby; Several species frequent region; Extent and persistence of sea ice allows natural and long-term observation of controlled populations	Emperor and Adélie species
Seals	Several species summer in McMurdo Sound; Persistence of sea ice allows natural and long-term observation of controlled populations	Weddell species
Whales	Several species frequent McMurdo Sound	Orca and Minki species
Volcanology	Active (Mt. Erebus) and extinct volcanoes within easy helicopter range	None
Long-Duration, High-Altitude Ballooning	Good latitude; Good launch site characteristics	None
Glaciology	Proximity (easy helo access to glaciers in the northern Transantarctic Mountains, icebergs, and snowfields and ice shelf features)	Ice streams are distant
Geospace & Upper Atmosphere	Highest geomagnetic latitude; Conjugacy to sites in northern Canada	None
Gateway to Interior Field Sites	Good accessibility to significant portions of East and West Antarctica, all of the Ross Ice Shelf, and nearly all of the Transantarctic Mountains	Much of the region from 115°W longitude (clockwise) to 115°E not easily accessible with current capabilities
Gateway to South Pole	Three hour flying connection; Trail established for overland traverse	None

If McMurdo Station existed only to support itself, its present location arguably might not be optimal. However, McMurdo exists primarily to support Antarctic science over much of the continent. Even if the station existed only to support local-area research, its present location would still be desirable due to the wide range of scientific interests in the region.

Because the science and related support activity is essentially expeditionary, and because expeditionary activities in turn require a pyramid-like broad base of support, it is clear that what is needed is in essence a town, providing all the necessities to a population scaled roughly in proportion to the number of researchers supported in the field (including South Pole Station). Even with paying increasing attention to moving non-critical activities off-continent, a substantial presence is still required to support science on the continent.

Due to the relatively large number of persons involved in the support pyramid, and the need for moving some cargo by air, if at all possible there should be reasonable access to a location for landing wheeled aircraft originating outside Antarctica, such as C-17 and commercial passenger aircraft from New Zealand, Australia, South Africa, or South America. Considering the volume of cargo and fuel that is required to support science in Antarctica—and the cost savings associated with transportation by sea as compared with air, the location should be accessible to large, ice-strengthened ships that are capable of making these deliveries.

Access to the continental interior—for deep field research and access to the South Pole Station—should also be afforded by the USAP's logistics hub. For decades this access has been dominated by the LC-130 aircraft and, more recently, by traverses. Thus, the location must

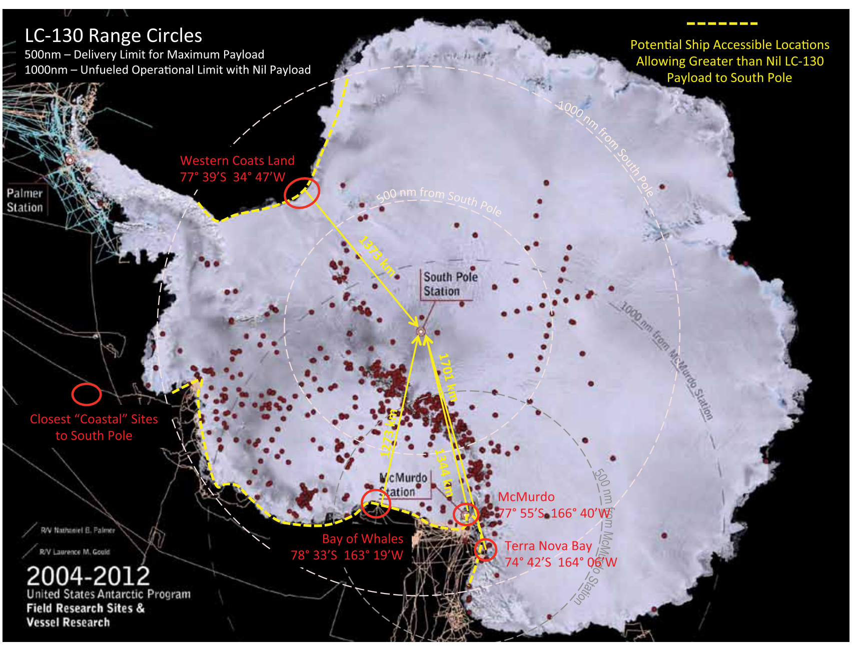


Figure 4.8. Map of Antarctica showing LC-130 range circles, potential ship-accessible locations capable of supporting South Pole Station (in terms of aircraft range), and closest coastal sites offering support of South Pole Station.

offer a skiway for the LC-130 (and the smaller fixed-wing aircraft that are also used) and research sites of interest should be within the operating range of the aircraft. For the traverse, reasonable terrain, routing, and proximity to research sites and stations is required.

The Panel conducted a search for a location with these characteristics using aerial photography, maps, in situ observations, and other sources to determine if such locations exist.

No reasonable alternative to McMurdo was found that would permit transshipping (sea, air, and land), or that would justify abandoning the investments made in fixed plant at McMurdo. There is no other location on the Antarctic continent offering the USAP the advantages of the McMurdo area: a deepwater port—which is also the closest such port to the South Pole—accessible in the summer via an icebreaker (56 years of successful deliveries); runways capable of handling large aircraft, whether on skis or on wheels; developed infrastructure for research

Table 4.2. Comparison of Logistical Factors Influencing Choice of Ross Island as the Present Location of Resupply and Support for USAP Continental Research and Related Activities

	MCMURDO	BAY OF WHALES	TERRA NOVA BAY	WESTERN COATS LAND
Harbor for 9-m Draft Ship	Yes; Winter Quarters Bay	No; Ice Shelf Edge	No	No; Ice Shelf Edge
Direct Ship to Shore Off-Load	Yes	Yes	No	Yes
Vertical Offset for Ship Off-Load	Land at Sea Level	15–50 m	N/A	40 m
Location for Wheeled Runway(s)	Yes; Sea Ice and Glacial Ice Shelf	No; Skiway	Yes; Active Glacier (reached only by helo)	No; Skiway
Length of Season for Wheeled Runway(s)	All year	N/A	Oct–Nov and Feb	N/A
Distance to South Pole (air)	1340 km	1270 km	1700 km	1370 km
Dates of Sea Ice Minimum	15 Jan – 15 Mar	11 Dec – 26 Feb	26 Dec – 10 Mar	10 Jan – 10 Mar
Sea Ice Extent at Minimum (typical)	10 nm	0 nm	0 nm	30 to >100 nm
Icebreaker Required for Access (typical)	Yes	Yes	Yes	Yes
Ice Free Land for Infrastructure	~1.5 mi^2	None	Some	None
Level Surfaces for Infrastructure	~0.75 mi^2	Unlimited; On Snow	Limited	Unlimited; On Snow
Stability of Infrastructure Site	High	Low	High	Moderate
Surface Access to Interior Antarctica	Easy; Via land to Ross Ice Shelf	Easy; Directly across Ross Ice Shelf	Difficult; Across active glaciers and through mountain ranges	Easy; Directly across Filchner Ice Shelf

support, including storage for 11 million gallons of fuel and an advanced laboratory; and access to the Ross Ice Shelf that enables efficient traverse operations to much of the Antarctic interior. In addition, McMurdo is an ideal location from which to provide support for NASA's satellite links and long-duration balloon program as well as the polar space programs of the National Oceanic and Atmospheric Administration (NOAA) and DoD[9].

ACTION 4.4-1. ***Continue the use of McMurdo, South Pole, and Palmer Stations as the primary U.S. science and logistics hubs on the continent.***

As discussed in the remainder of this section, multimodal blending of each transportation resource at key locations can maximize cargo movement and minimize cost by exploiting the relative strengths of each, providing a range of options now and into the future.

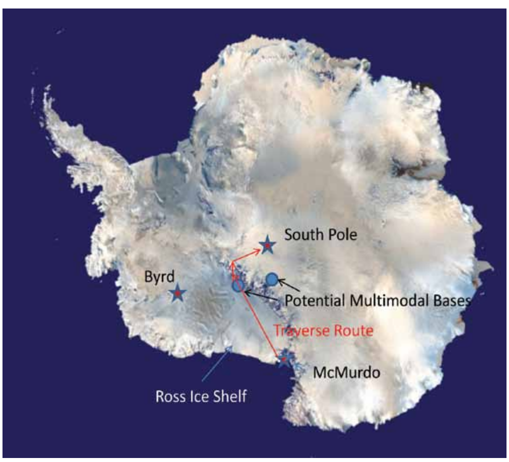


Figure 4.9. Map of Antarctica illustrating potential locations for bases in a multimodal transportation system.

4.4.2. AIR AND LAND

4.4.2.1. Traverse Operations

Operations during the early years of Antarctic exploration were highly dependent on overland traverse because large ski-equipped aircraft that could operate in the interior had not yet been developed. Most of the early interior stations were constructed using traverse technology or, in the case of South Pole Station, airdrop. During the mid-1960s, development of the LC-130 and the capability it offered for remote transportation virtually eliminated the need to make deliveries by traverse, and the capability gradually faded away. Recognizing the potential single-point failure represented by total reliance on the LC-130, for the past ten years the USAP has been gradually redeveloping the capability to traverse fuel and cargo between McMurdo Station and locations in Antarctica's interior, relearning old techniques and combining them with new technology.

The primary focus of traverse operations has been the route between McMurdo and South Pole Stations. The Ross Ice Shelf provides a nearly level route as far as 84°S, or about two-thirds of the distance to be traveled. After a climb up the Leverett Glacier to the Antarctic Plateau, the remainder of the trip is also nearly level. Currently, each "swing" of the traverse requires a crew of ten, and the one-way transit from McMurdo to South Pole takes 30 days. The

[9] In Appendix VI, the Panel provides the results of an evaluation of alternative sites for USAP support operations now carried out at McMurdo Station, confirming the present McMurdo site as the best available alternative, particularly given the investment, albeit aged, that it represents.

vehicles are operated for 12 hours each day, with 12 hours allocated for equipment maintenance and crew rest.

Crevasse detection, modern vehicles, sleds, and other equipment have made traverse operations much safer and more efficient. The USAP currently fields two traverse trips per year to the South Pole. The capital investment for traverse equipment is large, but it is only a fraction of the real cost of air support. That said, the only way to take full advantage of the investment is to increase the daily use rate. The Panel believes, consistent with the success of recent traverse operations, that NSF can achieve significant benefits in four major areas that should be analyzed in more detail.

First, examine routings to reduce time, wear and tear on equipment, and risk. Traverse equipment should be tailored to mission set. In other words, it may be more cost-effective to use different equipment for different parts of the routing. Equipment that is tailored for relatively smooth portions of the route (Ross Ice Shelf and Plateau) might be different from equipment needed for the climb up the Leverett Glacier. Similarly, equipment used for the transit to hubs might be different from that used on spokes to field camps. Matching equipment to conditions could pay significant dividends.

Second, increase equipment utilization rates. Currently, a round trip to the South Pole from McMurdo takes about 45 days. This is primarily because operations are limited to 12-hours per day, driven mainly by crew limitations. By using the Global Positioning System (GPS), manned "mother vehicles" can be coupled to unmanned

Figure 4.10. Photos illustrating traverse equipment. Source: USAP photo archives.

"follower" vehicles using robotics and automatic operations, and significant reductions could eventually be made to the crew size per traverse operation while also increasing safety. This would significantly reduce the logistics burden overall and allow smaller and better crew rest facilities. A small traverse crew, augmented with robotic capabilities on all or most tractors, would permit up to 20-hour utilization rates that by itself would almost double current capability using existing equipment.

Third, use multimodal operations. Linking the traverse with ski-equipped aircraft operations shows significant promise for reducing the cost of field support. For instance, traverse operations across the Ross Ice Shelf followed by the use of LC-130 flights to the South Pole would make the traverse more efficient by obviating the need for the traverse to make the difficult climb up to the Antarctic Plateau, thereby increasing system through-put and reducing wear and tear on traverse equipment. The LC-130s could even double-shuttle to the South Pole, carrying additional payload. This might also allow stockpiling cargo and fuel using the traverse before the period when flying is feasible and then surging LC-130 operations to more efficiently move cargo and fuel to the South Pole itself.

In the reverse, using the multimodal approach in an air-to-land configuration could aid science by delivering matériel to a forward supply point via the LC-130 aircraft and then using the traverse to deliver that material to field camps. By flying from McMurdo to this depot instead of all the way to the South Pole, the LC-130s could deliver an additional 10,000 pounds of fuel while saving over $20,000 per flight in fuel burned and flight-hour cost savings. A new camp at this depot could store fuel as well, serving as an intermediate hub for smaller aircraft and as an alternate LC-130 airfield to be used in the event of adverse weather. This approach could reduce LC-130 missions supporting South Pole by more than half and would reduce the per gallon cost of fuel delivered by as much as one-third.

NSF may find that the flight-hour cost and fuel savings generated by either of these alternatives could fund the traverse operation and a new camp at the transfer point. The USAP has used the South Pole and other waypoints as lesser hubs for field support, but they have not been developed as intermodal way stations. In addition to the stated benefits, either of these approaches would reduce the cost of cargo and fuel deliveries and decrease LC-130 air-miles for South Pole deliveries, thereby making additional flights available for direct science support.

Fourth, modify the maintenance support concept. Development of a new traverse equipment maintenance program could increase availability. The concept could include more refined periodic maintenance at McMurdo, or use of leases to enable the equipment to be exchanged for rebuilt hardware on a periodic basis.

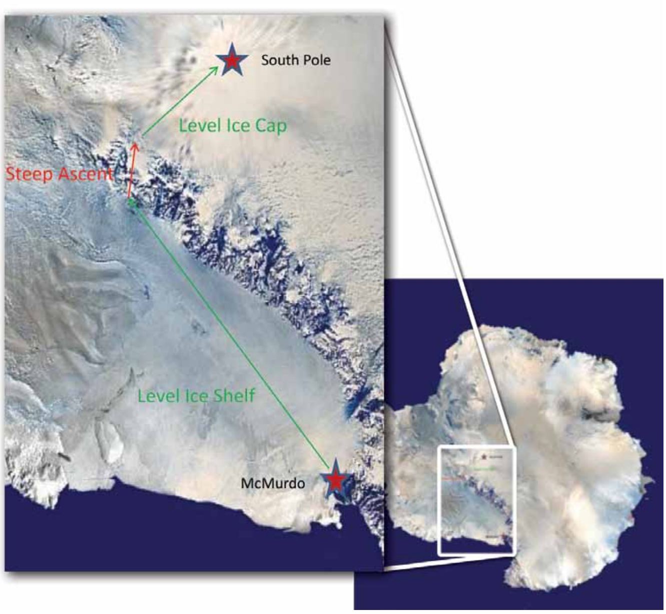


Figure 4.11. Detail of an Antarctic map illustrating geography along the traverse route. The multimodal transportation concept determines the best methods for transporting cargo in areas of level terrain versus areas of steep topography.

ACTION 4.4-2. ***Invest in robotics and automation to improve the efficiency of the delivery of cargo and fuel via overland traverse, particularly between McMurdo and South Pole stations.***

4.4.2.2. C-17 and LC-130

DoD provides C-17 and LC-130 support to the USAP each year through a Memorandum of Agreement with NSF. Each year, approximately 70 C-17 missions fly between Christchurch and McMurdo Station and approximately 400 LC-130 missions fly to multiple destinations throughout the interior of Antarctica delivering people, cargo, and fuel. Depending on range and the availability of alternate airfields, the C-17 is approximately four times more efficient than the LC-130 in terms of cargo delivered, and more than twice as efficient on a cost per pound basis. Transporting cargo via LC-130 costs $5.25 per pound, whereas via the C-17 it costs $2.37 per pound. The C-17 is, however, limited to wheeled-operations and therefore can only fly to McMurdo and provide an occasional airdrop to the interior.

The LC-130 has the unique ability to land reasonably large payloads throughout the continent on its skis and is therefore a critical component of the system enabling scientific exploration. Unfortunately, this same ski system creates inefficiencies: it is heavy, requires specialized maintenance, and slows the aircraft due to added aerodynamic drag. Although much faster than traverse operations, the LC-130's operating costs make it very inefficient for routine airlift to developed stations such as the South Pole. Its forte remains with science logistics support to distant locations with minimally developed infrastructure—a demand that is expected to increase significantly as the character of Antarctic science evolves.

The C-17 has revolutionized the way in which expeditionary sites, such as those in the Antarctic, are resupplied. It is designed to deliver

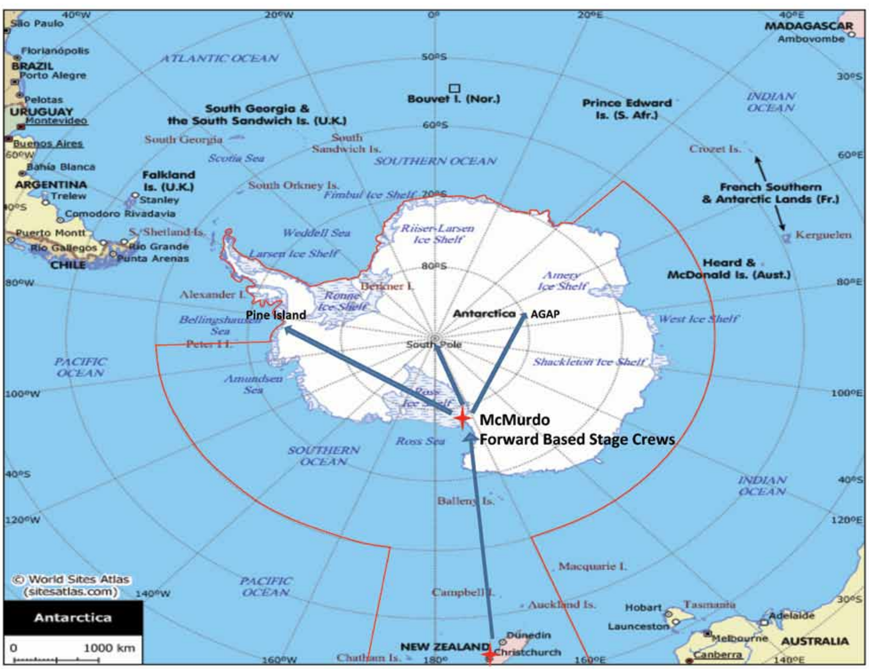


Figure 4.12. Southern Hemisphere map illustrating air routes from New Zealand to Antarctica and onward.

people and equipment to small, austere airfields and rapidly off-load and onload with minimum external support. Also, because of its size, the C-17 can carry much larger equipment, including containers, thereby simplifying cargo handling. In particular, it would be more effective than the current LC-130 operation at delivering fuel to the South Pole and performing large retrograde operations. The USAP, working with its DoD partners, has a significant opportunity to identify concepts of operations that maximize use of dedicated C-17s and refocus LC-130 operations to missions that exploit its unique capabilities. In order to do this, it would be necessary to construct and maintain a wheeled-capable runway and taxiway at the South Pole (discussed in detail later in this section).

ACTION 4.4-3. ***Work with DoD and ANG to maximize use of dedicated C-17s and thereby refocus most LC-130 operations to support field activities.***

4.4.2.3. Airdrop

NSF has the opportunity to take full advantage of new airdrop operations developed by DoD for routine and emergency resupply of forward field camps and multimodal hubs in the Antarctic. Airdrops are one of the most effective tools for periodic resupply of forward operating bases where terrain and adverse weather make ground resupply too costly. Such considerations relate to Antarctic resupply efforts.

The C-17 and LC-130 are both ideally suited for airdrop missions and the crews operating them almost all have the benefit of this experience. Low-altitude, low-cost, pre-packaged parachutes have dramatically reduced the complexity of these operations. GPS-guided precision airdrop capability also provides an important all-weather backup that would increase the dependability of service.

The LC-130s and C-17s have used parachute delivery across the Antarctic and have blended these operations with traverse support, but the use of airdrops currently is not part of the routine logistics support plan. This proven capability is therefore underutilized for remote field delivery. Airdrop eliminates the considerable expense of a runway or a ski-way, and also avoids the penalty of reduced cargo-carrying capacity that is associated with landing the LC-130 in remote areas without groomed surfaces. Significantly heavier cargo loads can be delivered by airdrop while eliminating landing stress and fatigue on the aircraft.

The airdrop equipment itself is nonetheless expensive at $100,000 each, and a C-17 flight to and from the South Pole would cost $60,000. However, a single C-17 airdrop could deliver the equivalent of four LC-130 loads to the deep field which would cost $168,000. The savings are slight, but new, lower cost, disposable parachutes in wide use by DoD could further reduce costs. These chutes could eventually be burned on site in a future waste-to-energy program, eliminating the expense associated with return and repacking. In addition, it may

Figure 4.13. Airdrop from a C-17.
Source: U.S. Air Force.

still be more cost-effective to use airdrops for high-altitude or hard-to-reach deep field sites. Complementary use of conventional C-17 and LC-130 flights with a robust airdrop program would improve the utilization rate of both aircraft while accelerating the flow of fuel and cargo to remote camps.

ACTION 4.4-4. ***Consider more widespread use of airdrops for resupply operations, particularly for South Pole Station and deep field camps.***

4.4.2.4. LC-130 Fleet

NSF owns four of the LC-130 aircraft that are operated and maintained by the ANG (four additional NSF-owned aircraft are in storage), and six are owned by the ANG. The ten-aircraft fleet is used in support of both Arctic and Antarctic research programs.

For at least the past decade, the USAP has mounted a program of approximately 400 flights per season, deploying seven LC-130 aircraft to the Antarctic theater. A significant number of the flights each year were used to shuttle fuel, cargo, and passengers to South Pole Station, and they were vital to the successful completion of the projects to modernize the station, install the IceCube Neutrino Observatory, and erect the 10-meter South Pole Telescope. Now that these major projects are complete, and with the advent of the overland traverse—and the potential improvements to it outlined herein—NSF is in a position to reduce the number of flights each year from approximately 400 per season to 300. This action, together with reducing the number of aircraft deployed from seven to five, could save just over $7 million per year in flying hour, fuel, personnel, and travel costs.

Figure 4.14. NSF-owned LC-130 aircraft operating in Antarctica. Source: Robyn Waserman.

If as a result of reduced flying hours the LC-130 fleet could be reduced by four aircraft, additional savings could be realized. If the NSF aircraft were the ones retired, additional costs could be avoided, including Programmed Depot Maintenance (PDM) that must be performed on each aircraft every 69 months. At $4 million per PDM, this represents average annualized savings of nearly $2 million per year. NSF would then also avoid the cost of upgrading its aircraft to the eight-bladed propeller system, currently estimated to cost $8 million total for the four aircraft. Thus, if the four NSF aircraft were retired, there would be recurring savings of $2 million per year and a one-time cost avoidance of $8 million.

While the Panel does not attempt to estimate the savings that might accrue from reducing the fixed cost of operations at the ANG, where NSF supports approximately 220 full-time personnel and all incremental costs, the Panel certainly encourages NSF to do so. If, for example, a reduction in just two crews were possible, the annual savings would be approximately $1.5 million. Additional savings could be gained if the reduced flight operations enabled other organizations, such as the U.S. Navy contractor providing air traffic control and weather forecasting, to reduce operations below the current

24 x 7. Less significant, but nonetheless real, savings could also be realized in food, travel, and other ancillary support costs, regardless of which aircraft were retired.

As mentioned earlier, NSF should explore whether one of the remaining aircraft should be modified for use as a platform for research. A 2005 workshop report, *Scientific Opportunities for a Long-Range Aircraft for Research in Antarctica*[10], articulated the potential value that a modified LC-130 could bring to the Antarctic science enterprise. The 2011 NRC report made similar observations. The research that could be facilitated includes in situ observations of the atmosphere and ocean as well as remote sensing for solid Earth sciences, glaciology, and ocean sciences. A ski-equipped aircraft was found to be a requirement because of the long-range operations needed to survey areas of interest—typically 800–1000 miles (1300–1600 kilometers from established stations—and because of the small number of existing landing sites for wheeled aircraft. A further requirement was for development and use of science payloads that integrate multiple sensors and that could deploy drop-sondes for in situ atmospheric observations or similar sensors for in situ oceanographic observations. An LC-130 would meet all these requirements and would be capable of using existing instruments developed by the National Center for Atmospheric Research for use in other, smaller, NSF-sponsored science aircraft.

NSF investment in a long-range science aircraft would have ancillary benefits to a future, more efficient, USAP. The long-range capability, coupled with the advanced sensors and data acquisition systems available today, would mean that acquisition of data sets could be accomplished when operating directly from McMurdo or from other nations' established stations. This avoids setting up remote camps deep in the interior that would be needed to support short-range aircraft attempting this kind of work. For example, if the multinational "Antarctica's Gamburtsev Province" project to explore the history of the East Antarctic Ice Sheet and lithospheric structure of the region had been supported with a long-range aerogeophysical aircraft instead of with two remote camps and two small aircraft, support planners conservatively estimate that about $6 million in logistics costs would have been saved in one field season.

The cost to complete the science modifications of an LC-130 so that it could complete a Gamburtsev-like project is estimated to be approximately $5 million. When considering other costs that could be avoided by use of this airborne facility in appropriate circumstances, the payback is nearly immediate. There would also likely be considerable interest on the part of other national Antarctic programs in this capability on a cost-reimbursable basis, allowing NSF to increase the breadth of its partnerships and amortize the cost of ownership of the research aircraft.

ACTION 4.4-5. ***Reduce the flying hour program and the LC-130 fleet by 40 percent, and modify one of the remaining aircraft as an airborne science platform to both reduce costs and expand science opportunities continent wide.***

[10] Available at http://bprc.osu.edu/PolarMet/lara/lara_report.pdf.

4.4.2.5. Airships

DoD is developing hybrid airships for long-duration surveillance, and technology that could enable lighter-than-air aircraft delivery of heavy or outsize payloads to remote locations. Even given the extreme environment in Antarctica (including strong winds), new technology and concepts of operation could allow safe and efficient use of airships for some missions.

Although production models are likely many years in the future, airships may someday be a viable component of the USAP's multimodal transportation system, offering unique research and support opportunities, such as rapid deployment of scientific equipment and field camps in a cost-effective manner. Given the terrain and challenges of traverse operations in the Antarctic, airships may be an ideal asset for shuttling material across the ice shelf for staging of onward movement by traverse or fixed-wing aircraft. They could be particularly useful in moving heavy/bulky commodities such as fuel. They could also serve as a platform for remote aerogeophysics, allowing further exploration of the continent—for example, high-intensity remote sensing over a large area of the Antarctic from relatively low altitudes could advance ice sheet monitoring and geophysics. As this new technology evolves, NSF should explore the possibilities and opportunities it offers.

Figure 4.15. Polar airship concept illustration. Source: Institute of the North.

The USAP has a 20-plus year history of supporting lighter-than-air operations in Antarctica through long-duration ballooning, and additional expertise to support such operations may be available through other government agencies. NSF could benefit from monitoring DoD activities in lighter-than-air technology.

ACTION 4.4-6. ***Continue to explore lighter-than-air hybrid airship technology for possible Antarctic use.***

4.4.2.6. Runways

The traditional concept of operations at McMurdo has been to operate three airfields.

1. An annual Sea Ice Runway, located a few miles from McMurdo, operating from October to December and supporting all aircraft types.

2. The Pegasus Runway on the glacial ice of the McMurdo Ice Shelf with a thin compacted "white ice" pavement, for landing wheeled or ski-equipped aircraft (on the skiway) from early December through February. This runway is located 19 miles (30 kilometers) from McMurdo and its port, necessitating an extensive ground transportation link.

3. The Williams Field Skiway, located on the Ross Ice Shelf approximately nine miles (15 kilometers) from McMurdo, operating from early December through February for ski-equipped aircraft only.

In 2008, the USAP began to shift all fixed-wing operations to the Pegasus Runway in a proof of concept project to consolidate all runway operations. Although the Sea Ice Runway continues to be used, Williams Field is no longer used for aircraft operations.

Consolidating operations provides clear efficiencies, but combining them at Pegasus has posed several challenges. First, the site is far from McMurdo, making ground transportation to and from the site arduous, especially since the condition of snow roads can be unpredictable. When a portion of the McMurdo Ice Shelf recently broke free, it was necessary to relocate the snow road to Pegasus, further increasing the travel distance. Additional vehicles have been purchased to support transportation to the site, but the distance still represents a significant disadvantage. Another disadvantage is the requirement to pipe fuel for aircraft operations to the Pegasus site.

The distance from McMurdo to Pegasus is more than double that to Williams Field where the LC-130s traditionally operated. The fuel line requires frequent maintenance, as well as supplemental pumping at a half-way point. Under present practices, the line is installed and removed each year. Given these challenges, the Panel concludes that the USAP should consider reactivating Williams Field as the primary site of aircraft operations for ski-equipped aircraft. This would allow some consolidation by avoiding the need to build the Sea Ice Runway every year and focuses resources on

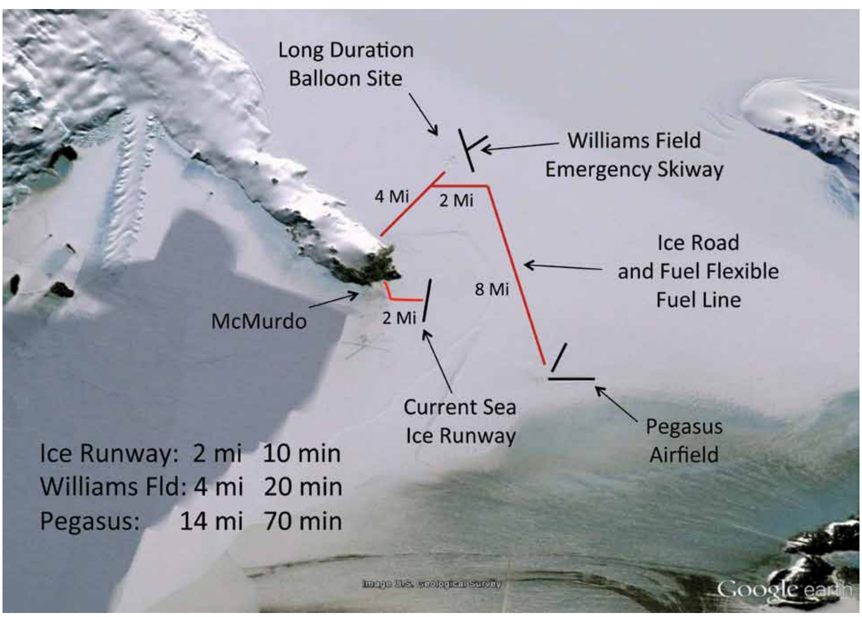


Figure 4.16. McMurdo-area diagram showing the three runway facilities used by the USAP, and the ground transit times to each.

Figure 4.17. NASA's Long-Duration Balloon facilities at Williams Field, near McMurdo Station. Source: Robyn Waserman.

more permanent infrastructure such as compacted roads for improved transportation and improvements in material handling, fire fighting and fuel supply, all of which would help optimize air operations[11]. Compacting the runway and taxiways would allow more efficient LC-130 operation and also reduce wear and tear on skis while providing an alternate runway in the McMurdo area.

Importantly, a Pegasus Runway/Williams Field combination also reduces the single-point failure now present when the Sea Ice Runway becomes unusable and air operations move to Pegasus Runway. Given that McMurdo Station is the major support facility for the USAP, this in itself may justify the investment in activating Williams Field.

ACTION 4.4-7. ***Make the Pegasus Runway more permanent, including support facilities, fire rescue, air traffic control, and fuel support. Examine the possibility of retaining Williams Field for LC-130 operations to eliminate the need to construct the Sea Ice Runway each year and to provide an alternate runway in the McMurdo Area, eliminating the single point failure represented by the Pegasus Runway. In addition, compact roads to the runways and at Williams Field to reduce wear and tear on skis and the aircraft.***

4.4.2.7. Potential Ice Runway at South Pole

In the 1960s and 1970s, the USAP used snow-milling to construct load-bearing snow infrastructure (for example, the foundation for the South Pole Dome). Unlike the current use of drags and wheel compaction, snow-milling uses high-speed rotating devices to pulverize and mix several inches of surface snow that is then smoothed and allowed to set into a hardened surface. Milling breaks the bonds of the snow crystals, which then reform into a strong and uniform surface.

Advances in ice engineering and snow milling technology may be applicable to the South Pole, making it possible to compact the surface at the station to the hardness required for C-17 wheeled landings. Currently, only ski-equipped aircraft land at South Pole Station. Developing the hardened surface would take up to three years at an estimated cost of approximately $4 million. Even so, a compacted runway at the South Pole for wheeled operations could be a true game changer. A C-17 could deliver outsized payloads (the LC-130 and the traverse cannot). Further, passengers and cargo could move directly between New Zealand and the South Pole, stopping in McMurdo only to fuel the aircraft. On the return flight, the C-17 could retrograde waste and cargo more efficiently. With this concept of operations in mind, there may also be opportunities to redesign the

[11] Compacted roadways could increase speeds for some vehicles by up to 40 percent, reducing the time it takes to travel to the airfields and also the amount of specially designed equipment that is currently required.

cargo packaging and transportation system beginning in the United States, before it ever reaches Antarctica.

As stated, the C-17 is generally capable of delivering in one trip the equivalent of four LC-130 loads. If there were an associated reduction in LC-130 flights, an action that would also extend the service life of the LC-130s by reducing the annual flight hours, 30 such C-17 flights would save approximately $2 million and the investment in the runway would be quickly recovered.

ACTION 4.4-8. ***Construct a compacted snow runway at South Pole Station that is capable of supporting C-17 operations to allow heavy airlift from McMurdo Station or direct resupply of South Pole Station from Christchurch when conditions warrant.***

4.4.2.8. LC-130 Modernization

The average age of the ten LC-130 aircraft supporting polar operations is 30 years. At the current use rate, the fleet should last 15–20 more years without major (perhaps cost prohibitive) wing repair. Fleet replacement of the ten aircraft using the relatively new C-130J is estimated to cost nearly $1 billion, including ski modifications, spare engines, propellers, and other parts.

Given the relatively short service life remaining on the LC-130s compared to acquisition of replacement aircraft, the USAP should work with its DoD partners to plan and program for the follow-on LC-130J aircraft[12].

Figure 4.18. (top) A USAP LC-130 aircraft using assisted takeoff. Source: Charles Kaminski. (bottom) An LC-130 with eight-bladed propellers. Source: USAP photo archives.

Two unfunded initiatives to increase the capabilities of the LC-130 exist that could be particularly beneficial to the USAP. These initiatives have the potential to extend the service life of the LC-130 aircraft. They include adopting the eight-bladed propeller (which yields an eight percent fuel savings) and using the Rolls Royce Advanced Engine Technology (ADVENT) (yielding a ten percent fuel savings). Both modifications would extend the range of the aircraft and/or increase the cargo weight delivered by reducing the amount of fuel that the aircraft needs for each flight. The eight-bladed propeller also brings additional efficiencies by allowing heavier cargo loads when operating in deep snow or from fields at high elevations by reducing the need for Assisted Take Off bottles. The current inventory of 1950s-era bottles will be depleted in approximately five years and replacement bottles are virtually cost prohibitive—each bottle costs over $20,000, and

[12] The Australian Antarctic Program has plans to purchase and modify a C-130J prototype with a removable ski system. The USAP is monitoring this initiative and may itself be able to field a modernized ski-equipped LC-130.

eight are needed for each take off. The propeller and engine modifications are not inexpensive, but the real savings come not only from fuel not used but also from extended life for the airframe and repair and replacement of the components, which can be done in the field with no specialized equipment.

In an effort to reduce the crevasse hazard to LC-130 ski landings, DoD has developed, and is in the final stages of deploying, a crevasse detection radar that fits onto the side of an LC-130. Using the Special Airborne Mission Installation and Response System (SABIR), this radar will attach to any of the LC-130 aircraft. Although not as capable as the dedicated airborne platform that was discussed earlier is envisioned to be, the success of this development has been recognized by the USAP as a valuable asset for scientific research in both polar regions. A parallel project is now under development to field several remote-sensing instruments, including a science radar version of the crevasse detection radar called the "Ice Pod." Given the same basic hardware and interchangeable components, the system can be rapidly modified for surface, subsurface, and deep penetrating radar for use on the polar icecaps. In essence, a new mission has evolved that will allow the LC-130 fleet to spread across the continent, reaching locations that are inaccessible to smaller, shorter-range aircraft. Another benefit of this system is that it does not preclude using the cargo compartment for moving supplies while directly engaged in supporting science.

ACTION 4.4-9. ***Modernize the LC-130s with eight-bladed propellers, ADVENT engine modification, SABIR, and crevasse detection radar, and begin building a transition plan to the LC-130J.***

4.4.3. SEA

Both U.S. coastal stations in Antarctica—McMurdo Station on Ross Island in the Ross Sea at 77.88°S, 166.73°E, and Palmer Station on Anvers Island west of the Antarctic Peninsula at 64.77°S, 64.08°W—are most economically resupplied by sea. As discussed above, resupply of South Pole Station is accomplished by air and land from McMurdo, and McMurdo is also the single critical point for support of the vast majority of other U.S. operations on the continent[13]. Although personnel and a significant amount of cargo are transported between Christchurch and McMurdo via the U.S. Air Force, ANG and, occasionally, other nations'

Figure 4.19. Military Sealift Command tanker *Paul Buck* at McMurdo Station (right), with U.S. Coast Guard Cutter *Polar Star* alongside (left). The Russian icebreaker *Krasin* (right) and the USAP RVIB *Nathaniel B. Palmer* (left) are in the background. Source: Brien Barnett.

[13] McMurdo is likewise critical to the support and operations of New Zealand's Scott Base, located almost adjacent to McMurdo on Ross Island. It is an important gateway for access to the new French and Italian Concordia Station, and for Italy's Zuchelli Station in Terra Nova Bay, some 230 miles (370 kilometers) to the north. It also offers opportunities for future collaboration with South Korea's new Jang Bogo Station, also in Terra Nova Bay.

aircraft, both the volume and the mix of matériel required to support operations on the continent (and the lack of suitable air facilities at Palmer Station) make resupply by sea the only feasible means for sustaining U.S. presence and operations in Antarctica.

4.4.3.1. McMurdo Station and Resupply

The traditional resupply strategy for McMurdo involves a single annual visit, usually in late January[14], by two Military Sealift Command (MSC)-chartered ships—a tanker for fuel and a freighter for cargo—supported by a medium or heavy icebreaker (in years of heavy ice, a second icebreaker is available as a backup, either on site or in the United States, to assist the primary icebreaker if it becomes necessary due to ice conditions or mechanical failure).

The track of the fuel tanker is constrained by the need to obtain USAP-specific cold-weather fuel (AN-8) from either Greece or Australia, where the only two refineries manufacturing this fuel are located. The specialty nature of this item makes it very difficult for the USAP (or DoD) to gain commercial leverage. It would be prudent to find a fuel that is more readily available or to increase the number of refineries capable of producing the specialty fuel. The Panel assumes that the scale of the DoD purchase allows best-in-class pricing, but this should be benchmarked against other large fuel consumers using similar types of fuels (most likely airlines) to assure that the USAP is benefiting from the best-in-class pricing which it deserves. In addition, it is noteworthy that DoD charges a $700,000 per year administrative fee for its services on behalf of the USAP.

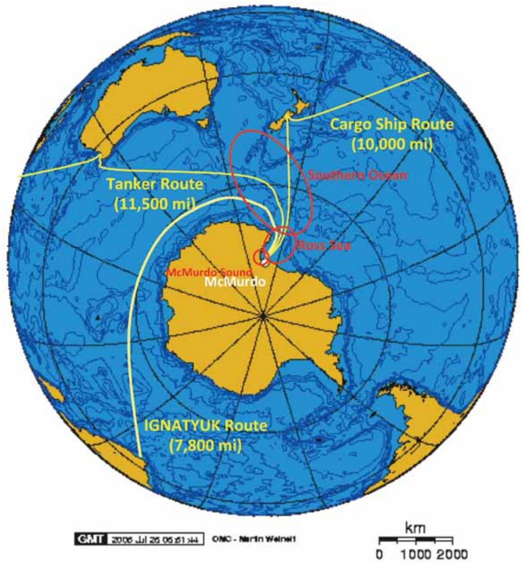


Figure 4.21. USAP resupply chain sea routes.

Figure 4.20. Military Sealift Command cargo ship *American Tern* unloading onto the ice pier at McMurdo Station. Source: Ralph Maestas.

ACTION 4.4-10. ***Seek alternate cold weather fuels or otherwise develop alternate sources for AN-8 in order to reduce the refining costs associated with procuring this particular blend of fuel and the transportation costs involved in picking it up from these refineries.***

[14] A 2009 analysis of ice conditions indicated that the annual resupply is scheduled to commence near the beginning of the lowest risk period, appropriately providing for contingency delays before ice and risk increase sharply in mid- to late February.

With respect to the cargo vessel, USAP cargo is staged at Port Hueneme, with additional matériel from New Zealand loaded at Christchurch's Port Lyttelton as the vessel transits south. Waste and other cargo from the continent are generally returned by the vessel to the United States, although time sensitive or otherwise critical items can and do get shipped to the United States from New Zealand.

Although the MSC reports no difficulties in annually acquiring the services of ice-strengthened tankers and freighters now or for the foreseeable future, the modernization of Port Lyttelton and the Christchurch International Airport that is currently in the planning stages may necessitate changes to USAP facilities and operations there. This also offers an opportunity to expand the use of Christchurch as a multimodal logistics hub for support of McMurdo Station to enhance sea (and air) aspects of Antarctic resupply. One possibility would be to use commercial ships to transport USAP cargo between Port Hueneme and Port Lyttelton throughout the year instead of via the single, dedicated, chartered vessel from Port Hueneme. The cargo thus staged could be moved to McMurdo by an MSC-chartered vessel from New Zealand, minimizing the length of the charter that currently costs $65,000 per day. Alternatively, the cargo could be moved by smaller vessels undertaking shorter and perhaps more frequent runs between Christchurch and McMurdo, thereby reducing costs and increasing flexibility. Further, as noted by the captain of the 2011/12 cargo vessel, changing conditions in the Arctic are spurring rapid advances in polar logistics in that region that should be of value to the USAP. For example, there are systems and techniques that could reduce on- and off-load time and effort, such as "roll on-roll off" capabilities built into modern cargo vessels that greatly facilitate the loading and unloading process. Also, new classes of icebreakers are being constructed that have the ability to carry cargo and/or fuel, and access to such ships as an augmentation to the annual break-in could enable multiple trips between New Zealand and the continent during the resupply period.

ACTION 4.4-11. ***Continue to examine options to support and improve the delivery and retrograde of cargo to and from McMurdo Station. For example, work with DoD and MSC and in consultation with the appropriate New Zealand***

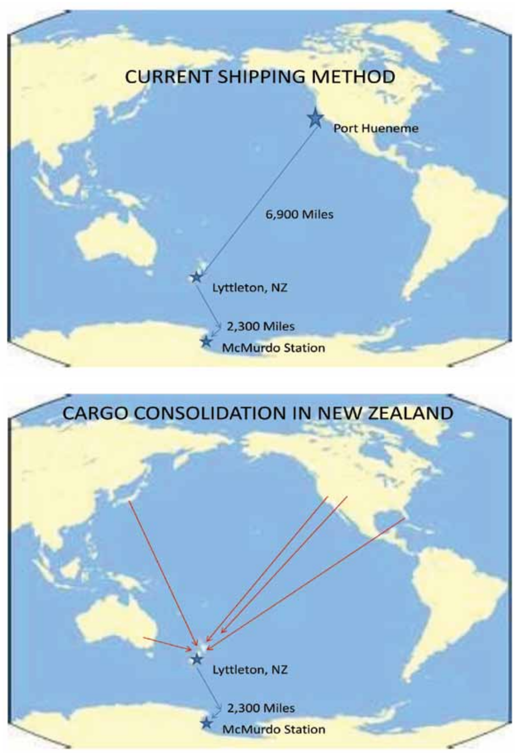


Figure 4.22. Maps of the Pacific Ocean with schematics of the current shipping method versus a methodology focusing on cargo consolidation in New Zealand.

authorities to explore the possibility of incorporating the use of commercial vessels to move cargo throughout the year from Port Hueneme to USAP staging facilities in Christchurch and also the use of vessels sourced from New Zealand to deliver cargo to McMurdo.

The most significant issues for McMurdo Station resupply are off-loading locations and ice conditions in the local area (moderate concerns), and long-term assured access to the services of a U.S.-controlled icebreaker for the break-in (a major concern).

Off-loading cargo and fuel at McMurdo is typically accomplished across an "ice pier." It is made more difficult when the ice leading to the pier itself is sufficiently thick, having grown over multiple years, or when (as happened in 2011/12) warm winter conditions prevent construction of a sufficiently strong ice pier. Illustrating the former case, in one year when the U.S. Coast Guard (USCG) could not break a channel to the pier for the fuel tanker due to the severe ice conditions, it became necessary to off-load fuel across some six miles of sea ice using hoses[15]. It has not yet been necessary to off-load cargo across such distances. Illustrating the latter case, the lack of an ice pier in 2011/12 required use of a portable modular causeway provided by the U.S. Army and brought to Antarctica on the cargo ship. Although this method was effective, it was also expensive and it reduced the cargo-carrying capacity of the vessel in both directions.

In general, there appear to be workable solutions to most conditions that can be envisioned without the need for major reinvestment or modification of the basic strategy for McMurdo resupply. Thus, the Panel considers that the fundamental strategy of a single annual cargo resupply/retrograde and fuel delivery mission—supplemented by air support and buttressed against failure by recent increases in fuel storage capacity and decreases in fuel usage—is appropriate and adequate when balancing risk and cost[16].

However, the USAP could not operate effectively or for very long without the services of an icebreaker capable of breaking a channel to McMurdo Station and escorting the resupply vessels to the pier (whether it be ice or portable) and this represents a significant single-point failure mode.

[15] These and a wide range of other resupply issues were thoroughly examined in the NSF Office of Polar Programs Advisory Committee's August 2005 *Report of the Subcommittee on U.S. Antarctic Program Resupply*. A follow-on December 2006 assessment of potential ship off-load sites in the McMurdo area concluded that it is reasonable to conduct sea ice fuel off-load at distances up to three miles (five kilometers) from the station, but that sea ice off-load of cargo is too high risk. This study did identify tentative locations on the Ross Ice Shelf for cargo off-load, with the provision that such sites should be no higher than 23 feet (seven meters).

[16] NSF recently conducted an analysis of biennial, as opposed to annual, resupply. The analysis notes this should be feasible if warehouse and waste management upgrades are properly designed, and that "the most significant impact appears to be on the science program, with delivery to the ice of large science project equipment and the timely return of sensitive or high volume field samples presenting the greatest challenges." The analysis found that the investment could be quickly recaptured, and a switch made in roughly four years pending an aggressive schedule of warehouse renewal. It does state that extensive additional analysis of this option will be required. The Panel notes that many of the upgrades needed for a biennial resupply option are encompassed within the scope of our recommendations; however, lacking the details of a full analysis including the anticipated impact on the types of new science (and associated logistics) suggested by the 2011 NRC report and Chapter 5 of this study, it is premature to support this option.

Figure 4.23. The ice pier at McMurdo Station, February 2011. Source: James Swift.

The McMurdo break-in was historically accomplished first by U.S. Navy and then by USCG icebreakers. Since the 2004/05 Austral summer, due to reliability concerns and other operational considerations regarding the USCG polar class vessels, the USAP has had to charter icebreakers from other nations such as Russia and Sweden. Initially, these vessels were backups to deployed USCG vessels. Subsequently, they were used in the primary role with the USCG icebreakers in standby. During the last two years, foreign icebreakers have been the only ones used for the McMurdo break-in.

The U.S. inventory of icebreakers relevant to McMurdo resupply operations is effectively limited to three USCG ships—the medium icebreaker *Healy* and two polar class icebreakers, *Polar Sea* and the *Polar Star*[17].

Healy, commissioned in 2000, participated in the McMurdo break-in mission in 2002/03. *Healy* is more ice-capable, albeit less maneuverable, than the Russian *Vladimir Ignatyuk* that successfully conducted the 2011/12 break-in under the very light ice conditions that prevailed prior to the arrival of Iceberg B15 in the McMurdo Sound area and again over the past two years. The *Healy* does not possess either the power or the maneuverability required for unassisted break-in operations in heavy, multiyear ice. In addition, *Healy* is typically fully engaged in Arctic science operations for its entire annual operating schedule (approximately 185 days per year) and is expected to be committed to such duties indefinitely into the future. *Healy* could, at least in principle, be made available as a backup vessel to assist another vessel with the break-in under exigency situations, or, if deemed in the national interest and other options are unavailable, to conduct the break-in at McMurdo under light ice conditions (much as it did for a fuel delivery to Nome, Alaska, in early 2012). The relevant studies assume that the *Healy* will eventually undergo a service life extension that would permit it to remain in operation for the foreseeable future.

Figure 4.24. Unloading cargo in February 2012 from the Military Sealift Command cargo ship *Green Wave* via the portable modular causeway system supplied and operated by the U.S. Army 331st Transportation Company. Source: William Henriksen.

[17] The USAP's *Palmer* is a dedicated scientific research vessel, fully committed to Southern Ocean research, and in greatest demand during the Austral summer when resupply occurs. Its moderate icebreaking capabilities render it unsuitable for the break in mission.

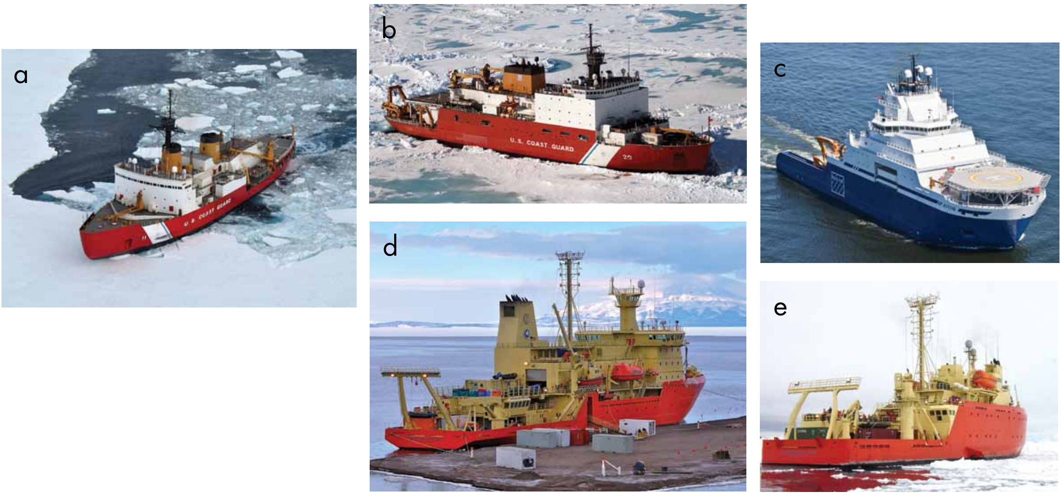


Figure 4.25. U.S. icebreakers (a) USCGC *Polar Sea*, (b) USCGC *Healy*, (c) Shell icebreaker *Aiviq*, (d) RVIB *Nathaniel B. Palmer*, and (e) ASRV *Laurence M. Gould*. Sources: (a, b) U.S. Coast Guard, (c) Edison-Chouest Offshore for Shell, (d) James Swift, (e) Jeffrey Kietzmann.

Polar Sea, commissioned in 1978, is in "commissioned, inactive" status and has been incapable of operating since May 2010, when it experienced an unexpected catastrophic failure of five of its recently refurbished engines. It is not decided whether the *Polar Sea* will return to active status.

Polar Star, commissioned in 1976, is undergoing a $60 million service life extension that should provide an additional seven to ten years of operating life. *Polar Star* would not be available for operational icebreaking services until 2013/14 at the earliest, and is unlikely to be operational much past the 2020/21 season.

At present, and perhaps again in the future, the USAP is in the position of being principally or totally reliant upon foreign sources for icebreaking support for the annual resupply. Additionally, it is not clear that the Swedish and Russian icebreakers used in recent years will be available in the future. This approach to resupply of U.S. operations in Antarctica is unsatisfactory in the long term. The lack of a U.S. capability to conduct the McMurdo break-in severely jeopardizes the U.S. commitment to its stated policies regarding the Antarctic Continent. As soon as possible, the break-in should again be supported by icebreaking services reliably controlled by the U.S. government, preferably an icebreaker owned and operated by the USCG.

Given U.S. national polar policies and the resultant commitment to operations in the Arctic and the Antarctic[18], a number of studies have examined the need for U.S. icebreakers and various approaches to modernization of the fleet[19].

[18] NSPD-66/HSPD-25 of January 9, 2009, for the Arctic and PDD/NSC-26 of June 9, 1994, for the Antarctic.

[19] Several studies particularly informed the Panel's findings with respect to the USAP's icebreaking needs, including a 2005 report by NSF's Office of Polar Programs Advisory Committee (*Report of the Subcommittee on U.S. Antarctic Program Resupply*), a 2006 report by the National Research Council (*Polar Icebreakers in a Changing World: An Assessment of U.S. Needs*), and other reports on USCG missions and requirements. The latest of these was the 2011 Congressional Research Service report *Coast Guard Polar Icebreaker Modernization: Background, Issues, and Options for Congress*.

Although there is not yet a national consensus on the size and characteristics of the appropriate U.S. fleet of icebreakers, initial funding for the definition and development of a new icebreaker to be owned and operated by the USCG is in the President's FY 2013 budget request to Congress.

ACTION 4.4-12. *Follow through on pending action in the President's FY 2013 Budget Request for the USCG to initiate the design of a new icebreaker, giving due consideration to a design that addresses the USAP's needs, including for example the potential ability to conduct science from the icebreaker itself.*

In summary, the Panel notes the following with regard to McMurdo resupply:

1. The United States will continue to conduct operations at and from McMurdo Station for the foreseeable future.
2. McMurdo resupply (and retrograde) should normally be conducted annually.

Figure 4.26. Russian icebreaker *Vladimir Ignyatuk* aside the McMurdo ice pier. Source: USAP photo archives.

3. The resupply operation requires the support of at least one icebreaker, of a class suitable for the prevailing ice conditions.
4. It is in the U.S. national interest that McMurdo break-in and resupply be provided by a U.S.-flag vessel owned, controlled, and scheduled by a U.S. government entity.
5. Presidential Memorandum 6646 of February 5, 1982, affirming NSF's responsibility for budgeting and managing the entire U.S. national program in Antarctica, tasks the Departments of Defense and [Homeland Security] to provide the logistics support requested by NSF[20]. Thus, NSF both can and should request the support of the USCG (on a cost-reimbursable basis)—assuming a capable USCG icebreaker is available.
6. USCG *Polar Star*, upon completion of its retrofit, and a new USCG icebreaker, if and when constructed, should support the annual break-in to McMurdo Station as part of its primary mission requirements.

The Panel further notes that it is prudent for NSF, with support from other federal agencies that have polar ship construction and operations experience, and with oversight from the Department of State, Office of Management and Budget (OMB) and the Office of Science and Technology Policy (OSTP), to thoroughly examine, and prepare to exercise, a range of other options for icebreaking support of the annual break-in, both as a stop-gap measure and as a contingency against future inability of the USCG to carry out the mission. Among such options discussed by the Panel are the following:

[20] See Section 4.11 for a more thorough analysis and discussion of Presidential Memorandum 6646 and other governing directives for U.S. Antarctic operations.

1. NSF has successfully managed to charter foreign flag icebreaking vessels to support the break-in for several years and it is not unreasonable to expect that one or more such ships could be similarly chartered in the future.

2. A U.S. government commitment to enhance the national icebreaker fleet could generate U.S. commercial interest in constructing appropriate vessels to be operated in support of the USAP via a lease, government-owned/contractor-operated, or other arrangement.

3. There may exist opportunities for securing an icebreaker from other nations on a quid pro quo or joint venture basis. South Korea is constructing its new year-around Jang Bogo Station in Terra Nova Bay and has indicated an interest in cooperative logistics arrangements with the United States at McMurdo Station. Australia is planning a new resupply/science support vessel for Antarctica. Russia is planning to reopen its Russkaya Station in the near future, and will support it with the new light icebreaker *Akademik Treshnikov* (launched in 2011). Partnership with Australia, such as the opportunity to homeport a ship in Hobart to significantly reduce transit times, or a combination of Australia and France in this regard, could be particularly beneficial because of other mutual interests between our nations.

4. Should NSF acquire a Polar Research Vessel (PRV) possessing the characteristics specified in the science mission requirements, it should be able to support the break-in under conditions similar to those under which *Healy* is capable of operating. The Panel recognizes that redirection of a PRV for break-in duty would make it unavailable for and adversely impact Southern Ocean research.

The Panel stresses, however, that we strongly believe that it is in the U.S. national interest that support of the annual resupply break-in

Figure 4.27. Examples of non-U.S. icebreakers: (a) *Agulhas II* (South Africa), (b) *Araon* (South Korea), (c) *Oden* (Sweden), and (d) *Krasin* (Russia). Sources: (a) Engineering News (online); (b) Dongmin Jin; (c) Dave Bresnahan; (d) Mike Usher.

to McMurdo Station be performed by a USCG owned and operated icebreaker whenever such a vessel is available.

Finally, the Panel notes that NSF's interest in icebreakers goes well beyond the McMurdo break-in, and includes research access to ice-covered waters in the Southern Ocean and polar Arctic. The possibility also exists that any new icebreaker could itself have an inherent capability to support science. Therefore, NSF should be a party to deliberations at the national level with DoD, DHS, the Department of State, OSTP and OMB on the size, composition, and operating profiles of the national fleet of icebreakers and other polar-capable ships to ensure that the nation's icebreaker and ice-capable fleet is fully adequate to support not just the McMurdo break-in but all national missions in both polar regions.

ACTION 4.4-13. ***In collaboration with DoD, DHS and the Department of State, and with oversight from OSTP and OMB, ensure reliable, long-term access to icebreaking services for resupply of McMurdo and South Pole stations.***

4.4.3.2. Palmer Station and Antarctic Peninsula Region

Since 1998, the at-sea component of resupply and the majority of personnel transfers between Punta Arenas, Chile, and Palmer Station have been performed by the purpose-built, ice-strengthened *Gould*[21]. The contract for this vessel was recently extended to July 2015, with further yearly options for an additional five years. *Gould*, with a range of 12,000 miles (nearly 20,000 kilometers) and a 75-day endurance, also performs a number of research cruises in the Antarctic Peninsula region[22]. The *Gould* is fully capable of supporting year-around oceanographic research in the peninsula area, although her resupply and personnel transportation tasks have traditionally kept her in the vicinity of the Punta Arenas to Palmer Station route most of the year. The *Gould* spends considerable time at the Palmer pier, on some occasions providing additional berthing for researchers, and supporting field camps along the peninsula. The combined functions of personnel transport, resupply and research have proven generally satisfactory, although there are a number of promising alternative options[23].

As the United States will presumably continue to maintain a station and to conduct significant amounts of sea-based research in the rapidly changing Antarctic Peninsula region far beyond the expiration of the *Gould's* current charter, the USAP should now select and act upon one or more of the available options and plan for the ultimate replacement of the *Gould*.

ACTION 4.4-14. ***Collaborate within NSF and with the University-National Oceanographic Laboratory System and other interested federal agencies to develop science mission requirements for Antarctic Peninsula marine***

[21] The *Gould* carries the American Bureau of Shipping (ABS) classification "ABS A1."
[22] See www.usap.gov/usapgov/vesselScienceAndOperations/documents/lmg_history.pdf for the *Gould's* cruise history.
[23] *Re-supply and Science Support Evaluation of Palmer Station and the Antarctic Peninsula Region*, Martin, Ottway, van Hemmen & Dolan, Inc, Final Report April 26, 2010.

Table 4.3. Summary U.S. and Foreign Icebreakers

SHIP NAME	COUNTRY	ICE BREAKING (M @ KTS)	PROPULSION POWER (HP)	PROPULSION TYPE*	DISPLACEMENT (TON)	YEAR IN SERVICE
50 Let Pobedy	Russia	2.8 @ 3	75,000	N	25,800	2007
Yamal	Russia	2.8 @ 3	75,000	N	25,800	1993
Rossiya	Russia	2.8 @ 3	75,000	N	23,625	1985
Sovietskiy Soyuz	Russia	2.8 @ 3	75,000	N	23,625	1990
Xue Long	China	1.2 @ 2	17,700	NA	21,200	1993
Yermak	Russia	1.8 @ 2	36,000	DE	20,241	1974
Taymyr	Russia	2.0 @ 2	47,600	N	20,000	1989
Vaygach	Russia	2.0 @ 2	47,600	N	20,000	1990
Krasin	Russia	1.8 @ 2	41,000	DE	20,000	1976
Admiral Makarov	Russia	1.8 @ 2	36,000	DE	20,000	1975
Shirase	Japan	1.5 @ 2	30,000	DE	17,600	1982
Polarstern	Germany	1.0 @ 5.5	20,000	DE	17,300	1982
Healy	USA	1.4 @ 3	30,000	DE	16,400	1999
Akademik Federov	Russia	1.3 @ 2	18,800	DE	16,000	1987
Kapitan Sorokin	Russia	1.4 @ 2	22,000	DE	15,000	1977
Kapitan Dranitsyn	Russia	1.4 @ 2	22,000	DE	15,000	1980
Kapitan Nikolayev	Russia	1.4 @ 2	22,000	DE	15,000	1978
Kapitan Khlebnikov	Russia	1.4 @ 2	22,000	DE	15,000	1981
Almirante Irizar	Argentina	1.2 @ 2	16,000	DE	14,899	1978
Polar Star	USA	1.8 @ 3	18,000/60,000	DE/GT	13,400	1974
Oden	Sweden	1.9 @ 3	23,200	DE	13,042	1989
Agulhas II	South Africa	1.0 @ 5	11,700	DE	11,700	2011
Louis St. Laurent	Canada	1.2 @ 3	30,000	DE	11,400	1993
James Clark Ross	England	0.8 @ 2	8,500	DE	7,700	1990
Kigoria	Russia	NA	17,400	DE	7,200	1979
Vladimir Ignatyuk	Russia	1.2 @ 3	23,200	DE	7,007	1983
Terry Fox	Canada	1.2 @ 3	23,200	DE	7,007	1983
Araon	Korea	1.0 @ 3	13,400	DE	6,950	2010
Nathaniel B. Palmer	USA	0.9 @ 3	12,700	DE	6,640	1992
Aurora Australis	Australia	1.2 @ 2.5	12,000	DE	6,574	1990
KV *Svalbard*	Norway	NA	13,410	DE	6,500	2002
Almirante Oscar Veil	Chile	NA	15,525	GT	6,500	1969
Fennica	Finland	0.8 @ 9.5	20,000	DE	6,370	1993
Nordica	Finland	0.8 @ 9.5	20,000	DE	6,370	1994
Botnika	Finland	0.8 @ 8	13,000	DE	6,370	1998
Aiviq	USA	1.0 @ 5	21,800	DE	5,100	2012
Aura II	Finland	1.0 @ 1.5	4,850	DE	3,350	2012
Austrolabe	France	NA	6,200	DE	1,700	NA

* N = nuclear; D = Diesel; DE = diesel electric; GT = gas turbine; NA = not available

operations in the post-2020 time frame to address sea support after the* Gould *is no longer suitable or available.

The principal conclusion reached by the Panel following its visit to Palmer Station and the *Gould* is that there are significant, comparatively low-cost opportunities for increasing the use and scientific output of Palmer Station via improved sea support. However, Palmer Station is over 40 years old and is in need of significant infrastructure upgrades[24], the most pressing of which is stabilization of the existing pier—or, preferably, replacement with an improved off-load platform.

Studies of Palmer Station have addressed the high-priority need to replace the existing, badly degraded pier, and have suggested a phased approach for other essential or desirable station upgrades. Virtually all of the options evaluated in these studies entail improving access to the station by blasting or otherwise removing the hazardous rock shelves and underwater pinnacles near the pier. These hazards make docking conditions for the *Gould* difficult and altogether preclude access for larger vessels such as the *Palmer*.

In addition to replacing the pier, the Panel believes the USAP should consider options to improve the sea-based resupply system. For example, barges could serve simultaneously as off-load platforms and fuel storage facilities. Providing shore power to the *Gould* or other ships, or ship power to the shore station[25], could also reduce costs and improve maintenance flexibility. Solutions to the pier/off-loading platform problem should simultaneously address improvements to the adjacent boathouse and associated small-boat handling, maintenance, and safety discussed below.

Figure 4.28. ARSV *Laurence M. Gould* at the Palmer Station pier. Source: Craig Dorman.

Six- and ten-passenger Zodiac boats are used to support diving, oceanography, and land-access operations in close proximity to Palmer Station. The Zodiacs are tied up adjacent to the boathouse near the pier and are accessed by clambering across the steep, rocky, and frequently icy, shoreline. The boats must be lifted from the water each evening during some periods of the year because leopard seals chew on them. These boating conditions present both a safety hazard and a logistics burden, and the limitations of the Zodiacs severely restrict the range and type of science operations in the area around the station. These first-order problems require immediate rectification.

[24] *Palmer Station Major Systems Study*. RSA Engineering, Inc., January 5, 2011.

[25] The *Gould* has 3700 kW main generators. The ship's load at the pier is approximately 450 kW and Palmer Station's is approximately 150 kW. When tied up at the station, the ship could easily provide power to the station as well as herself with a single generator. It may also be worthwhile to investigate options for providing shore power to the *Gould* in Punta Arenas, enabling her to go "cold iron" when tied up for extensive periods instead of remaining fully crewed and operational.

Two relatively modest additions to the USAP ship and boat fleet could significantly enhance science operations and safety near Palmer Station. First, augment the Zodiac fleet with at least two (one for work, the second as a rescue standby) Rigid-Hull Inflatable Boats (RIBs). RIBs are commercially available in a wide range of sizes and could significantly extend the range and safety of both water- and land-based research around the station. Research productivity at Palmer Station would be significantly enhanced if present restrictions on ship access and work in local waters could be reduced. Second, assign a regional or coastal class research vessel to Palmer Station during the Austral summer months for both research and some aspects of resupply and personnel transfer[26]. This action would release the *Gould* for a broader range of oceanographic research operations during the summer and she could then revert to combined support/research operations during the winter.

Figure 4.29. The Blue Ribbon Panel inspecting the Palmer Station pier. Source: Craig Dorman.

Figure 4.30. Zodiac boat launch facility at Palmer Station. Source: Craig Dorman.

In 2012/13, the USAP plans to experiment with this second option by assigning the University-National Oceanographic Laboratory System (UNOLS) research vessel *Point Sur*, operated by Moss Landing Marine Laboratories, to Palmer Station. If this arrangement proves satisfactory and there are both adequate funds and sufficient research interest, it may be feasible to use UNOLS research vessels in this manner on a more routine basis, or to make collaborative arrangements with neighboring international stations for comparable support. This action and others that further strengthen collaboration between the Office of Polar Programs, which supports the USAP and its two ships, and the Division of Ocean Sciences, which supports most other NSF oceanographic research, could foster broader participation of the national oceanographic community in Southern Ocean research.

ACTION 4.4-15. ***Retrofit the Palmer Station off-load platform to include sufficient draft to and at the platform to accommodate a range***

[26] Using the classification system of the University-National Oceanographic Laboratory System (see http://www.unols.org), nominally a vessel of approximately 125–150 feet (38–46 meters) length, similar to R/V *Hero*, which supported Palmer Station from 1968–1984.

of resupply and research vessels, improve small boat access, and introduce RIBs into the Palmer Station boating fleet.

ACTION 4.4-16. ***In consultation with the NSF Division of Ocean Sciences, and other marine research agencies as appropriate, assign a regional or coastal class research vessel to Palmer Station during the Austral summer.***

Many nations operate stations in the Antarctic Peninsula region, raising the possibility of employing commercial or other nations' ships for personnel transfer and resupply, offsetting some or all of *Gould's* transportation duties and thus freeing the ship to engage in more research activities.

As noted, the *Gould* is the primary means used to get research and support personnel to and from Palmer Station. The transit from Punta Arenas across the Drake Passage and then along the peninsula to the station takes at least four days, limiting the number of researchers who can reach Palmer Station each year (a number that is further restricted by berthing limits onboard and at the station) and increasing significantly the ratio of time spent on logistics to research time for science teams. It would appear that a relatively simple modification to the logistics chain could enhance the pursuit of science and reduce costs. This would entail private charter, or possibly DoD, flights from Punta Arenas to either the Chilean base on King George Island or the U.K. base at Rothera, followed by a one-day sea voyage to Palmer Station. The

Figure 4.31. Example of a Rigid-Hull Inflatable Boat. The USAP version would likely have an enclosed wheelhouse, given the prevailing temperature and weather conditions in the vicinity of Palmer Station. Source: Tim McGovern.

Panel followed this route and, even with a day's weather delay, the time required to transit to Palmer Station was significantly reduced.

The *Gould's* captain noted that the ship would burn 40,000 fewer gallons of fuel—approximately $140,000 at today's cost—for this round trip compared to the voyage to and from Punta Arenas, nearly offsetting the $190,000 cost of a charter flight. With the potential to sell some seats on these flights to the Chilean or U.K. programs, the cost of the charter could be completely offset by the amount saved in fuel. This is just one example of the many options that should be examined for collaboration with other nations that maintain stations in the peninsula area. A study of the Palmer resupply system also examined several other options for shared sea-based resupply, personnel transfer, and science in the area[27].

[27] Op cit footnote 23. Routine, direct air support of Palmer Station is not currently a viable option for a range of operational, safety, and environmental reasons.

There may also exist the possibility of transferring personnel through collaborations with the cruise ships that routinely operate in the area and seek to visit the station.

ACTION 4.4-17. ***Commence discussions with counterparts in Chile and the U.K. regarding collaborative logistics and ocean-based research operations in the Antarctic Peninsula region, including personnel transfer to U.S. research sites in the peninsula via King George Island or Rothera Station.***

In summary, recent and potential developments in transportation infrastructure provide the USAP with many opportunities to improve the productivity and efficiency of its broad transportation system. Focus should be put on matching the best transportation assets to the mission and conditions in order to optimize the overall enterprise. Given the challenges of providing logistics support in the Antarctic, optimizing the use of transportation assets, and the assets themselves in the case of new developments, is essential. The most dramatic improvements will be realized through the use of a true enterprise approach, taking best advantage of all transportation modes—air, land, and sea. This approach requires much improved connectivity among transportation modes and, most importantly, command and control that can direct multimodal operations rapidly and effectively in a changing environment. As a practical matter, to take full advantage of multimodal operations, the ability to use containers and transfer equipment among transportation modes is critical. Containers that can be easily transferred between large and small traverse operations, and between land and air, will pay significant dividends by reducing the time and number of people involved. Given today's advances in transportation support, none of these prerequisites are overly difficult to put in place, and the benefits far outweigh the cost. The result will increase the resources available for the pursuit of science.

4.5. SUPPLY CHAIN

Except for its local access to air, water and ice (for breathing, drinking, runways, wharves, and more), the U.S. program in the Antarctic could be a space station: everything else it uses has to come from far away—mainly the United States. External factors affect the schedule for cargo acquisition and shipment, including the annual cycles for Congressional appropriation of funds, science proposal evaluation and award, the duration of a research award (multi-year awards enable forward surface shipment for subsequent seasons), and the Antarctic seasonal extremes of sea ice, cold, and darkness. Still other factors that affect supply operations include the lengthy supply-line procurement lead times and the availability of appropriate aircraft and vessels for shipment.

The supply chain, both intercontinental and within Antarctica, is intermodal and mixes government, chartered, and commercial transport. In comparison to other supply systems, an atypical factor for the Antarctic is that most aircraft flights and outdoor operations are limited to five months of the year or less, and economical ship/icebreaker access to McMurdo is limited to approximately an 18-day period each year. Palmer Station, requiring a small fraction of the USAP's total cargo, lacks air transport but has year-around ship access. Palmer's distance to a commercial port (Punta Arenas, Chile) is less than 1000 miles (1610 kilometers) compared to more than twice that distance between McMurdo and Christchurch.

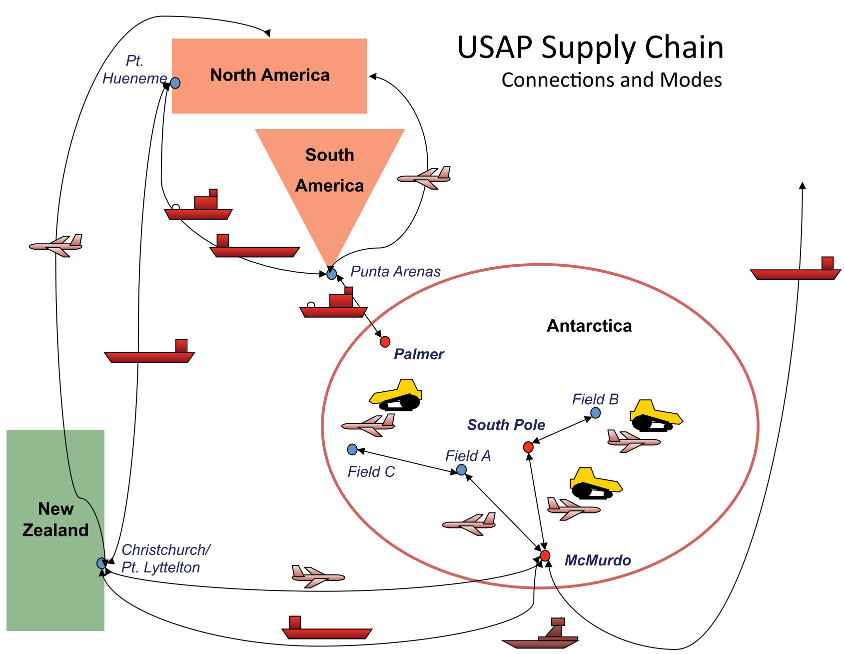


Figure 4.32. Illustration of the USAP supply chain.

a

Location	Aircraft	Dates of Typical Operation	Limit to Operations
McMurdo	C-17	Late Aug; 1 Oct – Late Feb	Daylight
	LC-130	Late Oct – Late Feb	Tasking in Interior
	Small Fixed-Wing	Mid Nov – Mid Feb	Tasking in Interior
	Helicopter	Early Oct – Early Feb	Tasking
South Pole	LC-130	Early Nov – Mid Feb	Temperature
	Small Fixed-Wing	Late Oct – Late Feb	Tasking
Deep Field Camps	LC-130	Early Nov – Mid Feb	Temperature
	Small Fixed-Wing	Mid Nov – Mid Feb	Tasking
	Helicopter	Mid Oct – Mid Feb	Tasking

b

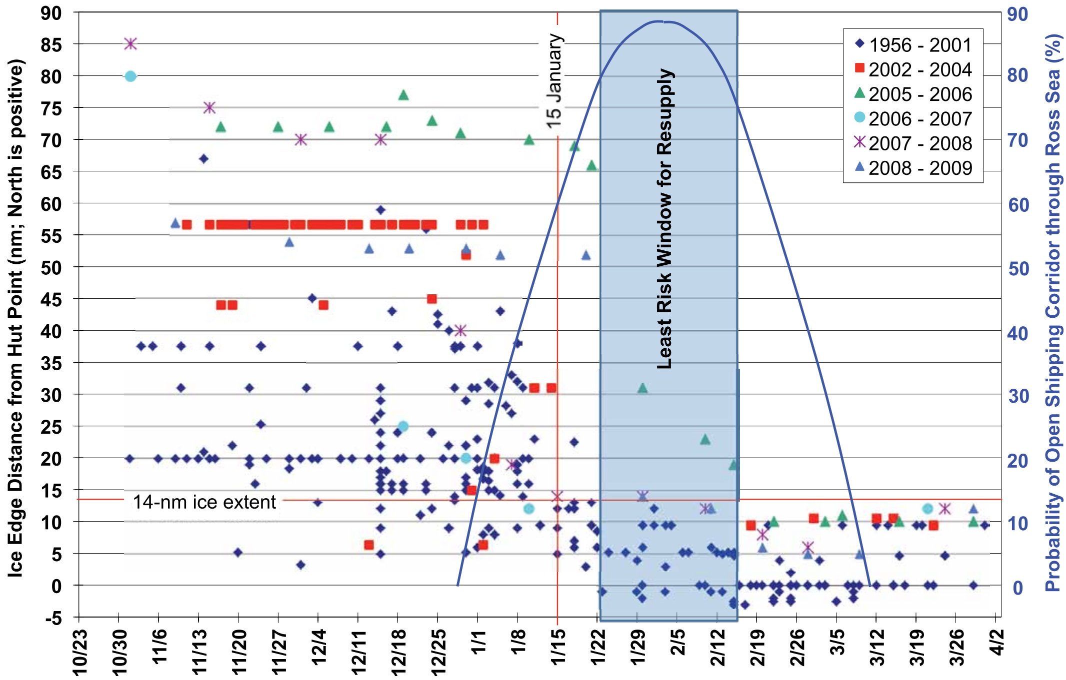


Figure 4.33. Illustrations of resupply windows for (a) aircraft and (b) ships. (b) also shows long-term ice-edge-to-McMurdo distance data, month by month, along with calculated probability of open-sea transit through the Ross Sea north of McMurdo Sound.

Material enters the USAP supply chain from three main sources: grantees (equipment specific to their projects), military support organizations (internal supplies), and—the largest fraction—the support contractor (program-wide needs). Passengers are subject to constraints, not the least of which is station capacity.

The USAP warehouse at Port Hueneme is the marshaling and packaging facility for most USAP cargo leaving or entering the United States. The facility handles some 40 million pounds (more than 18 million kilograms) each year. Full-time employees of the support contractor are supplemented by personnel from the DoD packaging facility and by others during ship calls.

At Port Hueneme, items headed for the Antarctic are repackaged as necessary to comply with Antarctic Treaty regulations (for example, no plastic "peanuts" allowed) and to withstand transport across the tropics and into the cold. Items received at Port Hueneme from the Antarctic include sorted hazardous and non-hazardous waste, worn equipment and scientific cargo such as ice cores, all of which the facility forwards to U.S. destinations.

McMurdo receives more than 11 million pounds of cargo a year, more than 60 percent of it on a single ship with icebreaker escort during the January-February sea ice minimum. The backload is also substantial: the ship in recent years has retrograded more tonnage than it delivered, ranging from waste not permitted to remain in Antarctica to scientific samples—that are in some cases irreplaceable.

The delivery modes and delivered amounts do not vary much from year to year, except during periods of heavy construction, when southbound cargo volumes can increase significantly. Storage of cargo in Antarctica is principally at McMurdo as the continental hub, although each station stores at least several

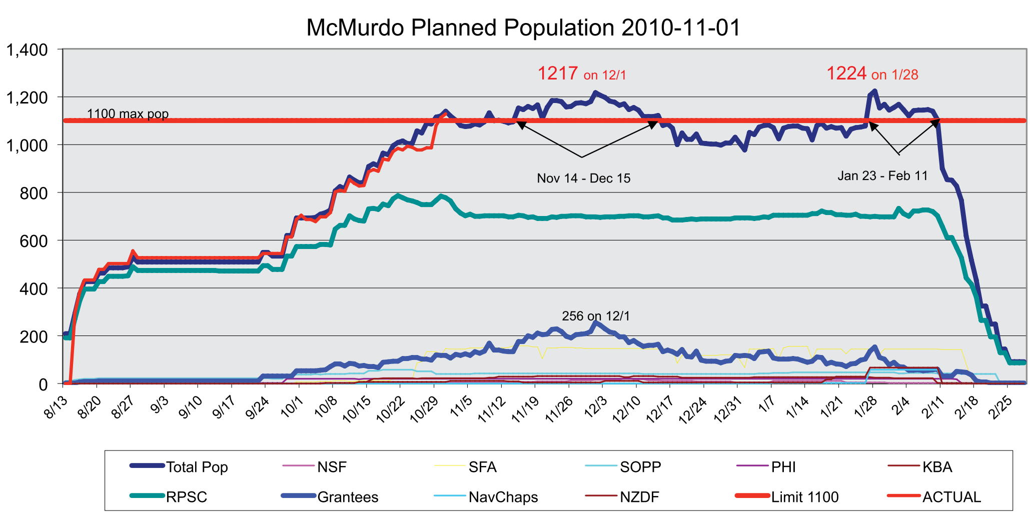


Figure 4.34. Chart illustrating how McMurdo Station planned population varies over a summer season, showing that some cannot arrive until others leave due to station capacity issues.

Figure 4.35. USAP cargo packing facility at Port Hueneme. Source: USAP Port Hueneme Archives.

months' worth of resources for its own use. At McMurdo, storage is widely dispersed, with no consolidated warehouse.

Automated functions associated with the supply stream use software systems called MAPCON for maintenance planning and control, CTS (Cargo Tracking System) for cargo tracking, PTS (Passenger Tracking System) for personnel tracking, and Power 1000 (P-1000) for procurements. These "legacy" software systems were custom-developed for the USAP years ago and date back to the early 1990s. They are sorely in need of replacement. In addition to a lack of compatibility with modern inventory technology and material management systems, the software is becoming unsupportable. The new contractor will at least initially be forced to adopt these systems.

In general, USAP supply chain operations can be characterized as "willing people doing their best" (Edward Deming), but with seriously out-of-date systems, facilities, and processes. It is evident that there has not been any substantial investment in supply chain systems and infrastructure for a considerable period of time. It is also apparent that best practices common in the private sector are not in use in the program. Operating standards fall short of those at well-run companies, and there are a number of situations where best practices from a safety or efficiency standpoint are not being followed.

In general, and especially at McMurdo Station, there is no clear plan for development and optimization of facilities. Expansion largely has been determined by the annual availability of funds and has thus resulted in substantial inefficiencies that lead to increased personnel requirements and substantially higher overall costs. The lack of investment and lack of

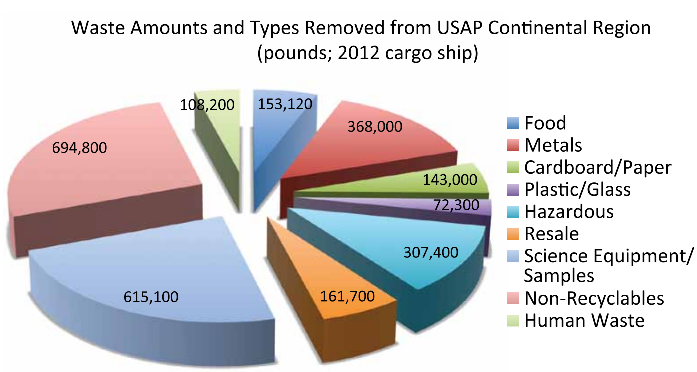


Figure 4.36. Illustration showing type of cargo shipped from McMurdo Station in early 2012.

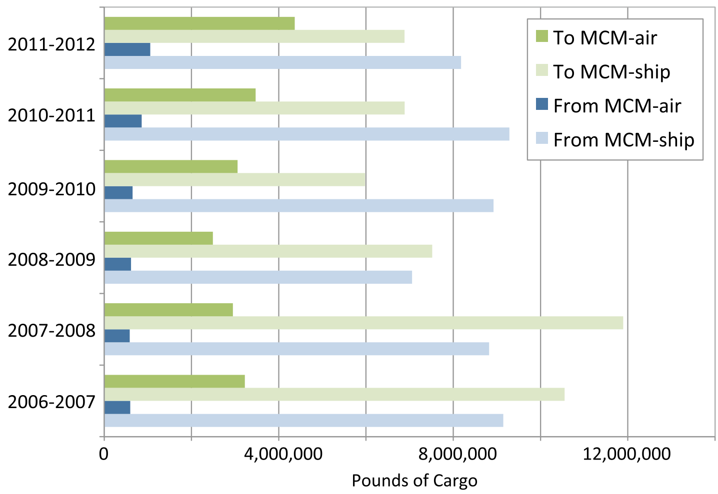


Figure 4.37. Chart illustrating year-to-year variations in cargo shipped to and from McMurdo Station by air and by sea from 2006–2012.

planning has also resulted in facilities—housing and recreational—that fall short of what should be expected at a national research facility.

The remainder of this section of the report addresses maintenance, warehousing and storage, purchasing, and inventory aspects of the USAP supply chain.

4.5.1. MAINTENANCE

Maintenance activities occur in numerous places throughout the Antarctic program, including McMurdo, South Pole, and Palmer Stations. There is also maintenance activity at the Christchurch, New Zealand, complex and some limited maintenance of scientific equipment at the USAP warehouses in Punta Arenas, Chile.

4.5.1.1 Christchurch, New Zealand

In Christchurch, maintenance activities consist principally of aircraft-oriented work. There is a hangar in USAP-leased spaces for storage of LC-130 spares, including engines, propellers, and skis. The ANG personnel in Christchurch during the operating season perform routine maintenance on the aircraft. Air New Zealand also has a substantial aircraft maintenance facility located at the Christchurch International Airport. This commercial repair facility performs unscheduled and depot-level maintenance—such as engine, communications, and structural repairs—that is beyond the ability of the small ANG maintenance contingent. The Air New Zealand facility also performs maintenance on the C-17 aircraft when they are based in Christchurch. No other substantial aircraft maintenance activities are performed in Christchurch.

4.5.1.2 McMurdo Station

McMurdo, as the largest and most complex facility on the Antarctic Continent, is where the bulk of maintenance activities for the USAP take place. In general, maintenance facilities throughout McMurdo Station are out-of-date, poorly maintained, and below acceptable standards of safety and appearance. Separately, the overall site itself is disorganized with substantial amounts of material stored apparently randomly across the site.

One of these activities is vehicle maintenance. The vehicle maintenance shop at McMurdo consists of eight bays in which routine maintenance can be performed on the variety of vehicles in use at the site, including bulldozers, graders, tractors, lift trucks, trucks and vans, and shuttles. The facility is under-sized. The work is made much more challenging by the variety and age of the vehicles to be serviced. Many of the vehicles date from the 1950s, and there are a number of situations (not limited to maintenance alone) where spare parts are no longer commercially available. Maintenance of such vehicles requires a skilled cadre of mechanics and machinists who may also be called upon to fabricate parts that can no longer be purchased or scavenged—thereby reducing productivity and increasing costs. With the exception of a new fleet of vans, it is the Panel's view that the vehicle fleet at McMurdo Station is woefully out-of-date and is a liability to the USAP, especially when combined with other inefficiencies in the existing infrastructure.

Figure 4.38. Vehicle maintenance facility at McMurdo. Source: Peter Rejcek.

Figure 4.39. Aerial photo of McMurdo vehicle maintenance facility (large building) surrounded by storage area for vehicles and materials, shops, and small warehouses. Source: Joe Harrigan.

Starting with vehicles and vehicle maintenance, a planned program of modernization across the entire fleet is urgently required. The USAP should investigate the opportunity for a collaborative arrangement with a major heavy equipment manufacturer (Caterpillar is an example of a possible choice because much of the equipment at the site was built by that company) as a way to reduce the cost of replacing and maintaining the vehicle fleet. In addition, the vehicle maintenance facility, while structurally sound, needs to be expanded by at least two and ideally four additional service bays. There is room directly adjacent to the facility to accommodate this expansion, so it should be a relatively straightforward proposition. In addition, the doors on the vehicle bays are out-of-date and, because poorly insulated, substantial heat is lost from this facility. New highly insulated and tightly fitting doors would improve the integrity of the maintenance facility.

ACTION 4.5-1. ***Develop and implement a vehicle modernization plan, possibly in conjunction with a major vehicle manufacturer.***

ACTION 4.5-2. ***Expand the vehicle maintenance facility at McMurdo, adding four bays and replacing the existing bay doors with insulated models.***

A second category is facilities maintenance and construction, which includes carpentry, electrical, plumbing, pipefitting, and metal work. Each craft is located in its own building, which is relatively distant from the others. The buildings are old and in uniformly poor repair. The equipment used for maintenance is generally out-of-date.

One place where investment is needed is the machine shop. Recruiting skilled machinists has become a substantial challenge because almost all milling machines used commercially today are computer-controlled, whereas the McMurdo machines are not. One machinist with whom the Panel spoke took pride in the fact that he was one of the few people who still had the skills to operate these machines—but this is obviously a risky situation. Secondly, the fact that the maintenance facilities are physically dispersed makes communication and sharing of skills and materials between the sites inconvenient in the summer and difficult in the winter when snow, cold, and ice create an additional challenge.

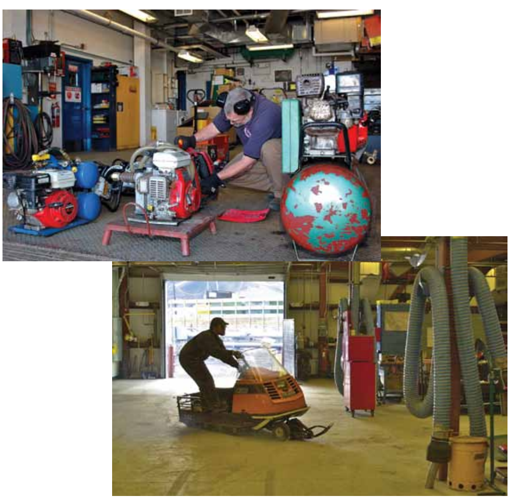


Figure 4.40. Repair shops for generators and snowmobiles at McMurdo. Source: Peter Rejcek (top) and Kris Kuenning (bottom).

Figure 4.41. Helicopter maintenance facility at McMurdo. Source: USAP Archives.

The existing collection of dilapidated and widely distributed sites for carpentry, electrical, plumbing, pipefitting, and metal work should be consolidated into a unified maintenance facility. Given that none of the existing maintenance facilities are worthy of retention, this new facility should be designed as part of the overall facilities master plan. The design should include sufficient inside (but unheated) storage for routine usage items such as lumber, piping, and metal in order to facilitate access during the difficult winter months. As a part of this consolidation work, a complete inventory of existing tools and machinery in use in these facilities should also be performed with an eye toward upgrading to current technologies. There should be a complete study of equipment needs as part of the overall planning effort.

Maintenance performed at the site also addresses the support equipment provided for scientists in the field, such as tents, sleeping bags, sleds, and snowmobiles. The employees working in this area appear to be doing a remarkable job with what they are provided, but it also appears that there is an unnecessarily large variety of equipment and that this diversity puts pressure on staffing, space, repairs, and inventory cost. In addition, the facility is undersized for the work involved. Over time, this operation should be moved to a more appropriate location, but in the short-term this area is workable.

Most communication equipment is maintained at the McMurdo site. Again, this is an area that is woefully out-of-date, thereby degrading the efficiency and productivity of maintenance activities. Maintenance employees told the Panel of having to shop for parts on eBay because no manufacturer supports or maintains some of the items currently in routine use at McMurdo. Again, the employees seem to do a good job keeping most of the equipment in operation; however, the cost of doing so is substantial.

Figure 4.42. Air National Guard crew maintaining an LC-130 at the McMurdo airstrip, air temperature –7°F (22°C), winds 17 miles per hour (15 knots). Source: USAF Air National Guard.

Finally, some aircraft maintenance is performed at McMurdo. The helicopter operations contractor performs maintenance and stores spare parts in a warehouse and hangar at the helicopter pad. The hangar, while needing some improvements (for example, new floors, upgraded lighting, and a coat of paint), seems adequate for the task.

ANG personnel also perform some maintenance on the LC-130s at McMurdo. This is accomplished outside at the airstrip and seems to be well managed and sufficient for the operation. Finally, there is maintenance of the equipment that supports the aircraft. Aerospace Ground Equipment such as generators and heaters are maintained and repaired by the Antarctic Support Contractor (ASC). These operations appear to be adequate as well.

ACTION 4.5-3. ***Provide a single consolidated facilities maintenance building to house carpentry, electrical, plumbing, pipefitting, and metal work at McMurdo Station.***

4.5.1.3 South Pole

Maintenance activities are also performed at the South Pole, but on a much more limited basis than at McMurdo. South Pole maintenance activity consists primarily of vehicle maintenance, which is performed in a two-bay repair area. There is also a dedicated snowmobile maintenance facility at the station. Some minor facility and communication equipment maintenance is also performed. Reflecting the relative newness of the station, these activities appear to be appropriately up-to-date and well organized. However, there is an opportunity to expand the vehicle maintenance facility that is now too

Figure 4.43. South Pole Station vehicle maintenance facility. Source: Josh Landis.

small for the work at hand from the current two to four bays. The remaining maintenance facilities and operations at South Pole Station appear to be well managed and well maintained.

4.5.1.4 Palmer Station

Palmer Station, the smallest of the U.S. permanent Antarctic sites, has much the same maintenance tasks as those at South Pole Station. In addition, Palmer Station has a boat maintenance facility where the majority of maintenance work needed at that site is performed. Station personnel are challenged to keep an aging fleet of Zodiac boats in safe operational working order for science and rescue operations. Other activities at Palmer Station include routine maintenance, modernization, and repair of the laboratory and housing buildings that date from the station's establishment. A preliminary study has been conducted that could serve as a reasonable master plan for phased modernization of the maintenance, hazardous materials handling, and personnel safety at Palmer Station[28].

4.5.2. WAREHOUSING/STORAGE

Warehousing and storage activities are performed at all permanent locations in the Antarctic program. With the exception of South Pole Station, the warehouse facilities are out-of-date, in poor repair, too small and not conducive to efficient operations. As a result, they are costly and lead to low productivity across all of the operation, particularly in Christchurch and at McMurdo.

4.5.2.1 Christchurch

USAP activities are located within two separate complexes. The buildings in the aviation complex are USAP-owned, situated on land leased from the Christchurch International Airport. The complex of administration and other buildings, also leased, is located immediately outside the boundaries of the airfield. Staging and palletizing are performed in an outdoor storage yard. This bonded area requires no New Zealand customs clearance for throughput of items to Antarctica rendering this yard, from a customs standpoint, a highly efficient operation. Because

Figure 4.44. Blue Ribbon Panel members and NSF staff visit the Palmer Station boat maintenance facility. Source: Craig Dorman.

[28] Op cit footnote 23.

it is outdoors, however, it can be very inefficient in periods of rain or cold. There is also a combined warehouse and distribution center for the Extreme Cold Weather (ECW) clothing used by all personnel in Antarctica. This facility is in reasonable condition, well laid out, and appears adequate for its purpose. There is a large and underutilized 1950s-era aircraft hanger that is, in part, used as a warehouse for LC-130 parts and supplies. The exterior cladding of the hangar is in poor condition and it is not insulated, although the basic structure appears to be sound. Finally, there is an empty warehouse that is small, but offers the opportunity for some utilization improvement. The ECW warehouse and the empty warehouse are colocated with the USAP Administration Building and are not directly on the airfield; the LC-130 parts hangar and the palletizing yard are on the airfield proper. Longer term, the airport authority has indicated a desire to expand. Should this occur, it is likely that USAP activities at the airport will be relocated, providing an opportunity to consolidate USAP administration, warehousing, and aviation support functions in Christchurch at a single location.

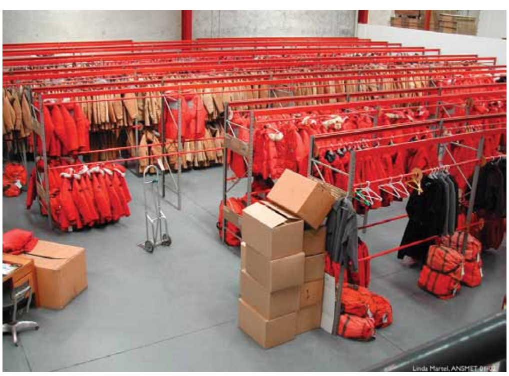


Figure 4.45. Extreme Cold Weather clothing warehouse in Christchurch. Source: Linda Martel.

Figure 4.46. Cargo staging area in Christchurch. Source: Christchurch Photo Library.

At Christchurch, the first order of business in the warehouse and storage area is to work with the airport authority on the development of its new master plan to assure that USAP needs are included. A key aspect of this input should be fully identifying the economic benefit of the USAP's Christchurch activities to the local community and to ensure that this benefit is considered in the eventual relocation.

ACTION 4.5-4. ***Work with Christchurch International Airport and Lyttelton Port of Christchurch to assure that USAP needs are considered in the master plans now being produced by New Zealand.***

Between now and the re-siting of the USAP facilities, there should be no permanent construction activities unless these facilities would continue to be used by the USAP at its new location. In the interim, there is a substantial opportunity to better utilize the existing hangar at Christchurch. One option would be simply to use this facility more effectively by optimizing the layout. Another, more radical, idea would be to move the building to McMurdo Station and, once a highly insulated roof and siding, cement floor and racking system were added, using it as part of the warehousing plan for McMurdo. Other than that, the Panel recommends no short-term investments at Christchurch.

4.5.2.2 McMurdo Station

At McMurdo Station, total storage is 680,000 square feet (63,200 square meters) for materials and supplies. The vast majority of this storage is outside, either in racks, on pallets, or in shipping containers. Consistent with the relatively haphazard growth at this site, storage is not well organized for efficiency. Only slightly over 100,000 square feet (9300 square meters) of warehousing space is enclosed, and it is contained in 22 separate buildings spread across the site.

Without exception, the warehouse facilities are out-of-date and, in some cases, effectively unusable. The Panel visited one warehouse where some areas of the flooring would not support the weight of the lift truck, and it was said to be not unusual for lift trucks to break through floors while pulling items out of storage. Materials are stored in ways that professional warehousing operations would consider both inefficient and unsafe. Employees climb on top of multiple layers of pallets to retrieve materials. Warehouse conditions are often dirty and not up-to-date from an electrical or safety

Figure 4.47. Photo of McMurdo Station showing the diversity and geographic spread of USAP warehouses (circles). Source: George Blaisdell.

standpoint. Modernizing these facilities will require one of the larger investments among the productivity and safety improvements identified in this report. The need for improved efficiency will grow as year-around activity becomes more the norm. Given the cost effectiveness of ship versus air transportation and the need to provide for contingencies in the event that ships cannot reach McMurdo, inventory levels will, by necessity, increase.

At McMurdo Station, there needs to be a complete reexamination of the site's warehousing, storage, and logistics flow. The site will require 300,000–400,000 square feet (28,000–37,000 square meters) of inside warehouse storage space. It should be in a single consolidated site with proper racking and, where appropriate, temperature control. (The site requires a freezer storage unit and an above-freezing storage unit in addition to unheated warehouse space, the latter of which should take up the majority of the space.) Consolidating into a single unit would allow demolition of eleven outdated and inefficient warehouses plus five former fuel storage tanks now being used for material storage. Separately, a single warehouse would improve the flow of materials; today, materials are moved numerous times between their initial arrival and final disposition. Each of these moves represents a loss that leads to the need for additional people, versus a more optimized and streamlined design. In addition, the vast majority of the current storage space is outside so that staff must look for materials in the snow, often spending hours to do so.

Figure 4.48. Example of unsuitable warehouse at McMurdo Station. In this warehouse, the forklift cannot be driven in some areas because breakthroughs and other floor damage have occurred. Source: USAP photo archives.

ACTION 4.5-5. ***Consolidate warehousing and storage at McMurdo Station into a single inside facility, totaling an estimated 300,000-400,000 square feet, and minimize outside storage; in the interim, correct deficiencies in flooring so that they no longer represent safety risks to personnel needing to work in the warehouses.***

ACTION 4.5-6. ***Reevaluate on-site transportation and personnel "touches" to streamline product flow, especially at McMurdo Station.***

NSF should fully explore the construction of a new high-density storage warehouse with a high-insulation factor. A high-density shelving system installed in a two-story storage building would cost approximately $11 million. Savings would include approximately 175,000 gallons of fuel per year (approximately $600,000 annually at today's cost per gallon), an estimated 275,000 kilowatt hours per year in lights, furnace fans, and miscellaneous electrical consumption ($55,000 annually at $.20/kW); reductions in parts and labor; and an unknown value for the avoidance of future life-cycle costs. In addition, the quality of service will improve as inventory accuracy dramatically improves.

Fuel storage capacity is 11 million gallons, equal to about two years' supply under normal usage. McMurdo has one fuel tank that serves as a backup should there be a problem with another of the tanks. This is a prudent safety precaution. Considering that fuel is delivered only once per year and that no deliveries are possible during the winter months, the system seems to be appropriately configured and generally well managed. Proper maintenance of this facility is critical, but in terms of existing infrastructure, no substantial new investment is required here.

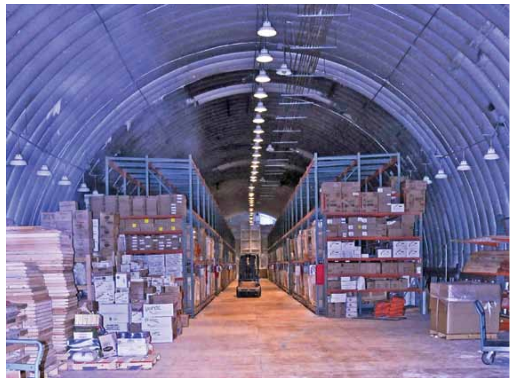


Figure 4.49. Covered storage at South Pole Station. Source: Craig Dorman.

4.5.2.3 South Pole

At the South Pole, warehousing is much less complex because of the lesser volume involved. Fuel storage capacity is 500,000 gallons. There are also storage areas for operating supplies and food. A substantial amount of the materials stored at the station are redundant and should be removed. Even so, the site requires additional capacity to store the remaining materials. This requirement should be studied as a part of the overall master planning. As with McMurdo Station, substantial quantities of materials are stored outside, and dealing with these materials is even more challenging than at McMurdo given the weather extremes.

4.5.2.4 Palmer Station

At Palmer Station, there are a variety of small storage areas that would benefit substantially from consolidation and removal of materials no longer being used. There is also the opportunity to obtain supplies more frequently by using research and, perhaps, cruise vessels. Hazardous materials are processed and stored in containers located near the entry to Palmer Station. In many cases, there is not adequate ventilation, lighting, or emergency plumbing for safe and efficient hazardous waste processing. The Panel advises consolidating all of the hazardous material operations in one area farther away from the main facility.

ACTION 4.5-7. ***Consolidate hazardous materials at Palmer Station into a building that is properly constructed and located away from the station.***

4.5.2.5 Port Hueneme

Storage at Port Hueneme is primarily used for in-transit goods that are assembled in California for deployment on the annual supply ship to McMurdo. Storage capacity appears to be sufficient and the activity seems to run smoothly.

4.5.3. PURCHASING

From a USAP standpoint, purchasing activities are relatively straightforward, with two major blocks of sourcing activity. The principal one is fuel, which is purchased in three grades: unleaded gasoline, JP5 (fuel that is burned for power generation and in all vehicles), and AN-8 (fuel used in aircraft and at South Pole Station). Except for vessel fuel, which is purchased on the open market, fuel for aircraft and ground operations is purchased as a part of an overall procurement through DoD.

The remaining sourcing activity concerns all other materials associated with USAP activities. This spend pool is primarily managed by the ASC. It was difficult to assess the effectiveness of the contractor's purchasing effort and it is not clear, given the transition in contractors, how changes in this area might lead to reduced costs and efficiencies. To start, it will be important to understand the purchasing methodology used by the new contractor. This understanding should include an assessment of whether appropriate incentives are in place to drive lower acquisition costs for materials and supplies in a manner that benefits the USAP. Given that the contract was only recently awarded, the Panel did not have the opportunity to develop this understanding, but it is a key leverage point that should be central to the USAP's improvement efforts.

4.5.4. INVENTORY

Essentially all USAP inventory is at McMurdo Station. There are small amounts of inventory at the staging area in Christchurch, as well as at Palmer and South Pole Stations, but they consist largely of food and fuel supplies.

Methods of delivery to Antarctica dramatically influence overall inventory levels. Because of the cost difference between ocean freight and air freight, it makes sense to deliver via ship even with the higher inventory levels sea transport entails, especially given that no delivery is possible for six months out of the year.

The economic value of the overall material and supply inventory totals $60 million. Inventory inaccuracy is about $1 million dollars per year—a very high number. Most of the inventory inaccuracy appears to be due to the amount of inventory stored in open, unsecured areas. A contributing factor is the antiquated, difficult-to-use inventory management software that is unreliable and requires extensive manual intervention. No bar code readers or other productivity-enhancing technology are used at most sites except for the small warehouse in McMurdo that manages the food supplies being sent into the field with scientists—put in place on the initiative of the staff working in this area. In general, there is little standardization and the resulting complexity drives excessive levels of inventory. Finally, the inventory statements do not document the very large quantities of scrap materials that are present throughout the system. They consist not only of food and human waste that must be transported back to the United States, but also large quantities of scrap wood, cardboard, paper, metal cans, and remnant construction materials.

The Panel recommends an aggressive program of simplification and standardization—there are simply too many unnecessary options in the system today, all of which require inventory (and staffing) to maintain. This complexity extends across the entire spectrum of activities, from vehicles, to tents and sleeping bags, to electrical components, to food. An aggressive standardization program will reduce inventory—and costs.

Separately, the inventory management system, MAPCON, is in urgent need of replacement with a commercially available system that can be supported by outside vendors. Any system chosen should be one that is widely used in industry today. This would allow the private sector to drive improvements in the system and allow the USAP to benefit from the private sector focus. Use of modern productivity-enhancing technologies like bar code scanners or radio frequency identification chips where appropriate should also be implemented. Given the importance of improving productivity and reducing headcount to the overall cost of McMurdo Station operations, there must be a very clear focus on productivity-enhancing investments. This is an area where the technology is already well established and the risks are low. As will be discussed, the ASC will be implementing new commercial software to replace the legacy logistics management software systems.

ACTION 4.5-8. ***Replace the government-owned MAPCON materials management system with a modern, commercially available, inventory management system.***

At South Pole Station, the LC-130s and traverses from McMurdo Station provide supplies and food to the site. They also remove the excess construction materials first to McMurdo Station and then on to the United States. There is limited opportunity for inventory reduction. As discussed earlier, cost savings involve optimizing the traverse and using C-17s at South Pole. Either or both could provide an opportunity to lower inventory levels at South Pole Station. Short of these actions, the Panel had no major recommendations in this area for the South Pole Station.

Figure 4.50. (a) Consolidated waste, in this case baling cardboard waste, at McMurdo Station for shipment off continent. (b) South Pole waste materials are returned to McMurdo Station, in the case shown via the return trip of the traverse. (c) Processing metal waste at McMurdo Station. Sources: (a) Lisa Harding; (b) Paul Thur; (c) USAP photo archives.

At Palmer Station, frequent year-around supply obviates the need for extensive on-site warehousing. The Palmer supply chain is constrained by the three-mode mission of resupply, personnel transport and research, all performed by a single vessel, the *Gould*. The supply chain's dependence on the vessel needs to be reevaluated well prior to the scheduled end of the *Gould*'s current charter in 2020.

At Christchurch, other than parts and supplies for the LC-130s and the ECW clothing issued to all USAP participants, there is essentially no inventory stored there. Christchurch serves largely as a transshipment point, with materials arriving at the airport and loaded onto the C-17s for delivery to McMurdo Station.

In summary, in order to create an efficient, effective and low-cost supply chain to support future research activities in Antarctica, major elements of the existing operation need to be dramatically redesigned and upgraded. The primary focus of this work should be on simplification and cost reduction. Central to the cost reduction effort must be a very clear focus on organizational productivity, with a goal of substantial reduction in headcount required at McMurdo Station (and to a lesser extent at South Pole Station) to support the scientific operations in place today and envisioned for the future. As previously noted, over time, with proper investment and training, the Panel estimates that a 20 percent reduction in support staff should be achievable. This reduction will not come simply by reducing headcounts, but through a major effort to improve systems, reduce the need for multiple handling steps for materials throughout the system, and simplify the organization and every aspect of the operation, particularly at McMurdo Station. This work must be based on a holistic master plan for the site that not only includes an assessment of facility requirements, but also a complete redesign of logistics flows, information systems, housing, recreational, and support facilities. In addition, there needs to be a separate assessment of the best ways to provide for investment in routine maintenance and repair and a method to upgrade the overall daily operating standards at the operating sites. Absent these improvements, any short-term investment coming from the Panel's work will simply deteriorate over time back to the current unacceptable level.

ACTION 4.5-9. ***Develop a multifactor life-cycle planning and implementation process to better organize, implement, and prioritize supply chain projects.***

4.6. ENERGY AND UTILITIES

The provision of energy in Antarctica affords a major opportunity for the USAP to reduce costs and become a demonstration site for carbon-free energy. There has been commendable progress, and there are already some excellent projects underway that deserve to be pursued more boldly. The Panel believes that the USAP should establish a goal of supplying 100 percent of the nontransportation energy requirement for the Antarctic summer by renewable energy sources over the mid-term (five years) and by zero-carbon-generating energy sources over the longer term (15–20 years). As has been discussed, it is apparent that many USAP participants are not fully aware of the true cost of energy. Improving transparency in this regard will undoubtedly promote savings.

The USAP has undertaken a number of energy-related studies. The status of these studies and associated recommendations are unclear. Using its current experiences, and with the improvements noted below, the USAP should develop an energy master plan for implementing mid- and long-term goals. Additionally, the USAP should clarify the role of the individual working in this area and ensure that the energy manager has the requisite authority and responsibility to implement the program.

At McMurdo Station, there are both short- and long-term opportunities to reduce energy costs. In the short term, most buildings are under-insulated and not sufficiently weather-tight. Consistent with the development of a master plan for the site, there should be an assessment of return on investment for insulating or re-insulating individual buildings. It has been determined that the 14 buildings at McMurdo with the poorest insulation consume 50 percent of the fuel used for heat. The return on investment from improving the insulation in seven of the buildings would be realized in fewer than ten years. For the remainder, the payback period extends past the anticipated life of the building.

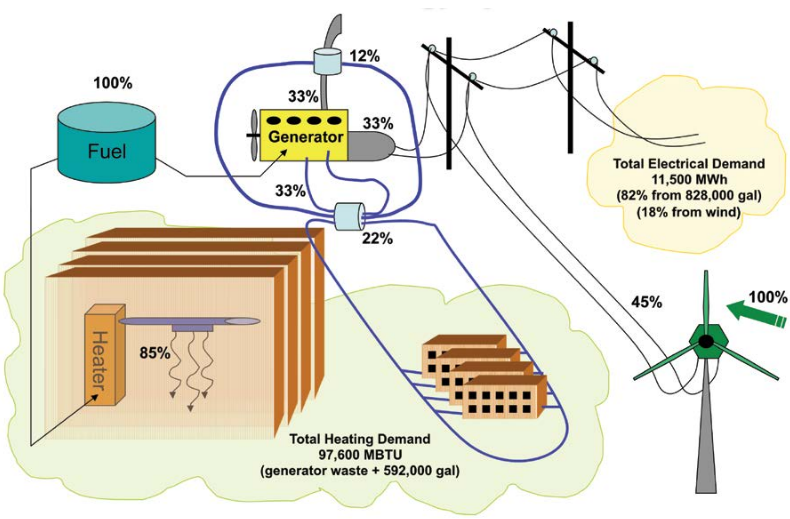


Figure 4.51. Illustration of energy production scheme at McMurdo Station.

Figure 4.52. Wind turbines at McMurdo Station. Source: Craig Dorman.

ACTION 4.6-1. ***Develop a priority list for improving the insulation of buildings and implement an appropriate plan that includes the previously identified seven buildings with the poorest energy efficiency that are expected to remain in use.***

Over the mid-term, there are a number of activities that could lower costs at McMurdo and improve the environmental footprint of this important link in the Antarctic logistics chain. The site, in cooperation with New Zealand's Scott Base located directly adjacent to McMurdo Station, currently operates three-330 kilowatt wind turbines. The New Zealand Antarctic Programme provided the capital investment in the turbines, while the USAP funded site preparation and connectivity to its power plant. In addition to providing essentially all the electric energy required for Scott Base, these turbines provide about 20–30 percent of McMurdo's electric energy requirements. For the USAP, this equates to annual savings of approximately 118,000 gallons of fuel. The Panel's judgment is that additional wind turbines would be an appropriate investment to reduce costs and improve the environmental impact at McMurdo Station. The Panel's calculations in this regard assume that New Zealand again provides the capital investment.

ACTION 4.6-2. ***Together with the New Zealand Antarctic Programme, develop a plan to expand the highly successful Ross Island wind turbine project to achieve the maximum practicable wind energy penetration for the unified McMurdo-Scott Base power grid.***

The 350,000 pounds (159,000 kilograms) of scrap wood generated annually at McMurdo is accompanied by waste paper, cardboard, and burnable food and human waste. All of these substances are stored until they are eventually transported to the United States via the outbound cargo ship. These materials are a renewable fuel that could reduce—or ideally eliminate—the need for oil-driven generators. Substantial advances have been made in the clean conversion of wood-based waste materials into energy, and they should be adopted at McMurdo. A preliminary study of using this renewable fuel as a clean heat and electricity source in modern burners was completed in 2009, with attractive economics—for an initial investment of $400,000, annual savings of $100,000 would be generated. Technology has progressed over the past three years such that the investment might be even more attractive.

ACTION 4.6-3. ***Together with DOE, determine the feasibility and cost of converting the waste wood, paper, and cardboard into building heat and electricity at McMurdo Station and substantially reduce the amounts that must be transported off-continent.***

With the exception of some very creative solar applications for remote field operations and the extensive renewable system in place at the Black Island Telecommunications Facility, there was no significant evidence of solar investment at any of the fixed stations. Given that for six months of the year there is a substantial amount of sunlight, this seems like a missed opportunity and the Panel recommends that an assessment of solar opportunities be included in the overall energy study for McMurdo.

ACTION 4.6-4. ***Develop a plan to maximize solar generation of heat and electricity at all sites, including both fixed-base and field locations.***

Longer-term, the Panel also recommends that an updated geothermal study be performed. An assessment should be made, possibly in collaboration with New Zealand which has extensive geothermal capability, to determine whether geothermal energy production could be viable at McMurdo and whether such development would be considered allowable under the Antarctic Treaty.

ACTION 4.6-5. ***Together with New Zealand, reexamine geothermal opportunities for producing heat and electricity at McMurdo Station.***

The Panel believes that by combining the use of waste wood, additional wind power generation, better insulation of some existing facilities, and solar and possibly geothermal energy production, McMurdo could become completely energy independent, with the exception of transportation requirements. These actions would likely create major cost savings and provide the opportunity for an exciting demonstration project in the sustainability arena.

At South Pole Station, essentially all energy needs are currently met by fuel oil generators and waste heat recovery. NSF has started discussions with DOE's National Renewable Energy Laboratory (NREL) regarding the feasibility of introducing alternative energy technology at South Pole Station. Use of alternative energy will not only reduce fuel consumption (a goal in and of itself), but will also be beneficial to the environment itself and to the atmospheric research that requires a clean environment.

South Pole "summer camp," initially associated with construction of South Pole Station, the 10-meter telescope, and the IceCube Neutrino Observatory, typically housed 100 people over and above those housed in the station. The original design for South Pole Station was for 150 residents, which should be the target population for annual planning. If it becomes necessary to once again exceed the design occupancy on a short-term basis, the USAP has a project plan to provide energy-efficient supplementary

Figure 4.53. Wood chips at McMurdo Station, a potential source of renewable fuel. Source: USAP photo archives.

Figure 4.54. Solar-powered remote instrument on the Mt. Erebus volcano. Source: Peter Rejcek.

accommodations powered and heated by solar energy sources to save the 13,000 gallons of fuel per year needed to operate the former summer camp. At the purchase price of fuel, savings would be $46,000, but when considering the average cost to deliver that fuel, the savings rise to $350,000. These estimates do not include personnel savings that would be associated with 100 fewer people at the station nor the labor savings associated with opening, maintaining, and later winterizing the camp each summer; these reductions are anticipated from changes in the ASC's concept of operations. Although South Pole Station has a very low wind regime, wind energy may also be applicable to this site and should be included in the overall energy assessment, again with an eye toward elimination of fuel oil as an operating energy source.

The USAP also has a design for a solar garage at South Pole Station. The garage could be procured for $25,000, and is estimated to save 8,000 gallons of fuel per year. In addition, the solar garage may also alleviate the vehicle maintenance work space shortage identified above and may be relevant to other stations and sites through the USAP.

ACTION 4.6-6. ***Introduce the solar garage concept at South Pole Station and other locations where similar operating and environmental conditions prevail.***

At Palmer Station, traditional fuel oil generators produce needed power and heat. Opportunities exist for wind and solar energy production, and it is likely that the use of fuel oil as an energy source can be considerably reduced.

It is likely that modernization of the vehicle fleet will result in the use of substantially less energy than today. Separately, a well-designed master plan for the site will reduce the overall amount of vehicle travel because of the implementation of site efficiencies, again reducing energy use. The USAP has undertaken some early work to introduce electric vehicles at McMurdo, and this should continue.

One of the largest sources of fuel use is the resupply of South Pole Station from McMurdo Station by LC-130s. The key opportunity here is to reduce the amount of LC-130 use between these two locations. Recommendations in this regard appear earlier in this report.

Efficiencies in energy production and use provide major opportunities for the USAP, not only in reducing costs but also in demonstrating NSF's commitment to the viability and advisability of renewable and ultimately carbon-free energy.

4.7. COMMUNICATIONS AND INFORMATION TECHNOLOGY

Communications and Information Technology (C&IT) is a relatively new, yet indispensable, component of the USAP infrastructure. Supply chain and deployment management, medical services and scientific research support (and so-called morale services), all depend heavily upon C&IT. Communications are severely challenged at latitudes of 81° where the line of sight to the satellites are blocked by Earth's horizon.

4.7.1. EXAMPLES OF C&IT DEMANDS WITHIN THE USAP

The examples that follow highlight the growing demand for and the required diversity of the C&IT portfolio in support of USAP science and operations.

4.7.1.1. Antarctic Astrophysics and Geospace Sciences

The South Pole, with its high elevation and very low air temperatures, is a unique place to carry out essential and cutting-edge research in particle astrophysics and astronomy. A large array of computers at South Pole Station preprocess and compress IceCube Neutrino Observatory data. These data are transferred daily to the University of Wisconsin-Madison (~100 GB/day), along with instrument control, technical support, and remote maintenance exchanges (~5 GB/day). The availability of near-real-time data transfer permits distribution of alerts of significant transient events so that the research community can immediately compare IceCube data to signals

Figure 4.55. The South Pole Telescope back-lit by an aurora. Source: Don Hartill.

Figure 4.56. POLENET seismic sensor site in Antarctica. Source USAP photo archives.

from space- and ground-based detectors around the globe. Minutes make the difference between capturing the event and missing it. Similarly, the South Pole Telescope requires a mix of reliable daily bulk data transfer (~60 GB/day) and real-time telescope control and maintenance (~5 GB/day). Planned upgrades will increase the daily data rate to 80 GB/day and, in future years, to 200 GB/day.

4.7.1.2. Automatic Remote Observations

Antarctica hosts remote instrumentation used for both operations and research. Automatic Weather Stations (AWS) provide meteorological observations that are critical for developing weather forecasts for USAP aircraft operations, and provide the scientific record of Antarctic weather that is crucial to international operational weather forecasters' computer models and to the study of climate change and other Antarctic phenomena. Satellite communications provided by polar low Earth orbiting satellites provide the essential communications link from the isolated weather stations scattered across the Antarctic continent.

The continent-wide array of automated Polar Earth Observing Network (POLENET) stations includes locations equipped with seismic detectors. On June 1, 2012, at 0501 hours GMT, a rare seismic event occurred in Marie Byrd Land. This event was captured and transmitted in real time by seismic sensors participating in the Incorporated Research Institutions for Seismology Global Seismographic Network, allowing the data to be introduced in global real-time data sets for epicenter and magnitude determination, among other parameters. The real-time capture and transmission via satellite enabled immediate analysis of a rare event that is likely to lead to follow-on investigations.

The AWS and POLENET rely on two different satellite systems—the international, government-hosted system ARGOS-2 ("ARGOS" is not an acronym, but rather the chosen name for the system) for the former and Iridium for the latter. Researchers supporting POLENET and other remote instruments anticipate improvements in design to include reliability and power generation/usage during the Austral winter when solar energy is unavailable. These innovations are expected to enable increased data relay throughout the year, eliminating the need for annual physical site visits for the sole purpose of data recovery, and extending the site visitation frequency from annually to biannually or longer. The savings in field logistics (aircraft support, staff), when coupled with the added benefits of data fusion with real-time global feeds, will afford a significant return on investment and scientific value. Ultimately, the innovations will also increase the demand for transmission of data out of Antarctica.

4.7.1.3. Supply Chain Management

Supply chain management relies on three major software database applications that were introduced during the 1990s. The software and associated databases are sustained at the ASC facilities in Colorado, at the logistics hubs in California, New Zealand and Chile, and in Antarctica. The present operation requires each location to be a full data center operation with server equipment, network file storage, and telecommunications links—and require full-service, on-site C&IT support staff. When changing business processes cannot be easily supported by the existing applications, C&IT analysts and developers must develop customized applications.

With the award of the ASC in late 2011, the USAP is now looking forward to replacing the legacy, heavily customized software with leading commercial-off-the-shelf applications. However, the need to exchange supply chain data and manage supply chain processes between all USAP operating locations will continue. Thus, the role and importance of C&IT to supply chain management will not diminish, but its focus will shift.

4.7.1.4. Telemedicine

NSF provides small-clinic medical services to USAP personnel at all three Antarctic stations, staffed mainly to address routine out-patient issues and emergency medical services. Critical care patients are stabilized for medical evacuation from Antarctica. However, there are occasions, such as during the Austral winter, when evacuation is not possible. To help address these gaps, NSF introduced telemedicine, providing a means for on-site medical personnel to consult with U.S.-based experts in any field of medicine and to transmit x-rays and other diagnostic information. The telemedicine capability was instrumental, for example, when the winter-over physician at South Pole Station self-diagnosed breast cancer and began working with NSF and U.S. physicians for a detailed diagnosis and treatment plan, using a proof-of-concept high speed satellite link developed for science data transmission and Internet service. A USAP physician later analyzed program data and found that, during 2002–2004, ultrasound imaging enabled by the telemedicine capability made intercontinental medical evacuation unnecessary in one-quarter of potential cases. The USAP telemedicine program is now available at all three Antarctic stations.

4.7.2. IMPLEMENTATION OF USAP C&IT

The C&IT portfolio is extensive, providing technical services, communications, information systems and governance. The C&IT budget portfolio is divided into categories that serve to demonstrate the nature of the various technical systems, services, applications, and management requirements. Of the approximately $28 million annual budget, sustainment expenditures dominate at 49 percent, with 12 percent dedicated to the direct support of science, and 18 percent to governance activities such as policy and strategy, and information security and assurance. This latter category consumes more of the operating budget each year as regulatory requirements increase.

The implementation of C&IT requires expert suppliers and a skilled workforce to sustain, refresh, and evolve services and infrastructure. C&IT services supporting the USAP are obtained largely from the ASC. The performance and success of the USAP C&IT services is directly proportional to the skills and expertise of the contracted personnel.

There are additional, noncontractor-supplied personnel supporting USAP C&IT services, such as the Space and Naval Warfare Systems Command (SPAWAR), providing project management office support to NSF. It should be noted that NSF now has only a single individual who is responsible for oversight of the entire USAP C&IT enterprise. The complexity of the C&IT enterprise, the short turnover time of its

USAP C&IT LINES OF FUNCTION

Technical Services

- Systems Architecture
- Hardware/Software Engineering
- Systems Design
- Integration, Test, & Installation
- O&M
- General Electronics Bench Repair
- Systems Lifecycle Planning

Communications

- Fixed Satellite Service
- Land and Maritime Mobile Satellite Service
- Radio – Long Haul
- Radio – Land Mobile
- Radiotelephone
- Local/Long Distance Telephone
- Campus Telephone Exchange
- Wide Area Data Networks
- WiFi Access
- Internet Service
- Audio/Visual Production and Service
- Video Conferencing
- Cable Television

Information Systems

- Campus Local Area Network
- Data Centers
- Intranet and Extranet/Web Portals
- Desktop Computing, Seat Management
- Office Automation Software
- Enterprise E-mail
- Data Relay Services
- Enterprise Mission Information Systems
  - Supply Chain
  - Maintenance Mgmt
  - Medical
  - Deployment
  - Science Support Planning
  - Collaboration

Governance

- Policy & Guidance
- Capital Investment Planning
- Enterprise Architecture
- Information Assurance
- Electromagnetic Spectrum Management
- Project Management
- Inter-Agency Agreement Management

Figure 4.57. USAP C&IT lines of function.

technology underpinnings, and the essential nature of C&IT services require significant time and expertise to oversee. Another complexity is the use of a seasonal workforce that is largely temporary, complicating configuration management and other key processes needed to sustain a modern C&IT enterprise. A single person at the NSF program office level is not sufficient to cover all of the issues and provide the technical, operational, and managerial oversight of the large supplier/contractor support base. A strong case can be made for providing additional NSF staff resources to meet the workload and also to assure continuity of operations.

ACTION 4.7-1. ***Augment the NSF Program Office for C&IT to accommodate its growing responsibilities.***

4.7.3. SUMMARY OF KEY C&IT ISSUES

Several issues threaten the USAP's ability to provide its basic C&IT functions, especially with the volume and quality of service that is now the normal expectation.

4.7.3.1. Future Science Requirements

Future USAP science requirements will place increased demand on satellite communications. An NSF-funded workshop in June 2011 projected future communication and data transmission needs through the end of the decade[29]. The projected requirements are staggering, and many are not supportable with the present USAP satellite communications capability. In fact, they outstrip current capacity by 100–600 percent. While some economies may be achievable through improvements in experiment design, there remains a significant gap between capability and requirements. The results of this

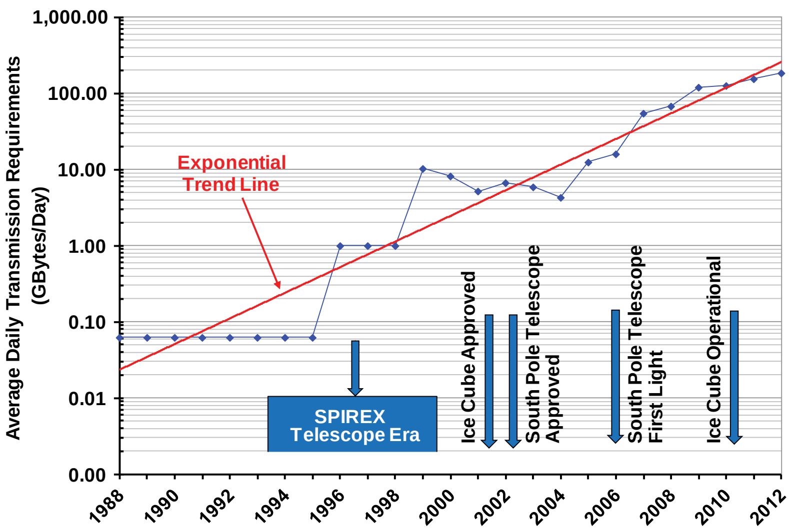


Figure 4.58. Historical trend of South Pole science data daily transmission volumes. Note that the vertical axis is logarithmic; the straight line relationship would be an exponential curve if the vertical axis scale were instead linear.

[29] Available at http://www.usap.gov/conferencesCommitteesAndWorkshops/contentHandler.cfm?id=2684.

workshop and others have yet to be synthesized into an overall plan for the conduct of the C&IT program, but it is clear that the USAP must take steps to increase its ability to support the C&IT needs of future science.

ACTION 4.7-2. ***Develop and implement a new architecture for C&IT that is consistent with future program needs, including the provision of increased bandwidth.***

4.7.3.2. Satellite Communications

Communications-equipped satellites are the only means available to implement modern high-speed digital communications to the Antarctic Continent and ships at sea. Conventional geo-synchronous satellites, stationed directly over Earth's equator, have limited coverage of the polar regions, with all coverage ending at 81°N and 81°S. McMurdo is at 78°S, but South Pole Station is at 90°S and beyond reach.

It is possible, and current practice, to overcome this limitation for South Pole Station by using satellites that have drifted out of their intended orbit over time. Assuming that the satellite continues to function, it can continue to provide telecommunications services, although the quality and the daily contact time varies by satellite, depending upon the degree of inclination of the satellite's orbit. The maximum contact is approximately 7.5 hours/day, while the minimum useful contact is approximately 3 hours/day.

The USAP has marshaled an eclectic collection of aged satellites to provide operational broadband Internet and high-speed data transfer services for South Pole Station. The Tracking and Data Relay Satellites (TDRS) are the first generation of NASA's space data system launched in the 1980s. The 34-year-old Geostationary Operational Environmental Satellite (GOES)-3, the only satellite directly owned by NSF, began life as one of the first generation of 1970s-era operational weather satellites managed by

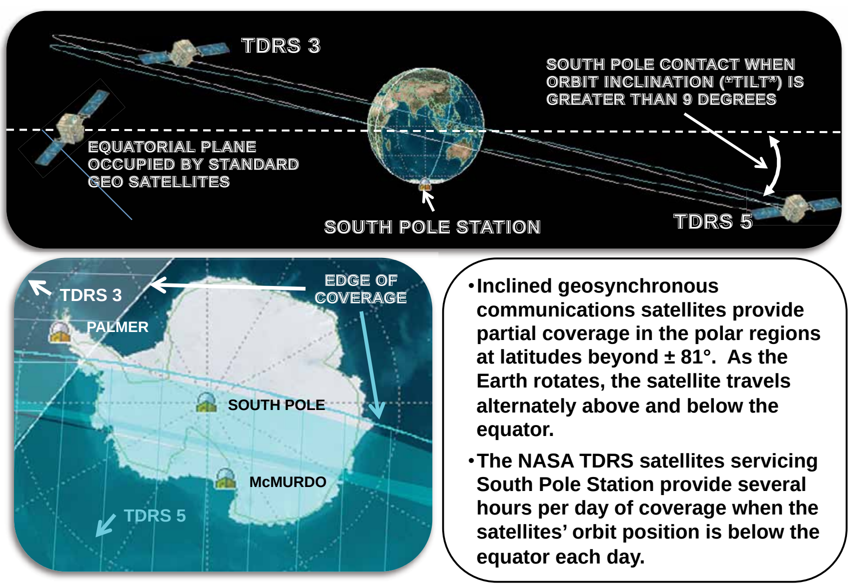


Figure 4.59. Schematic showing how inclined geosynchronous orbit satellites such as NASA's Tracking and Data Relay Satellites (TDRS) extend coverage into the deep Antarctic interior.

NOAA. Skynet-4C is an aged military communications satellite formerly owned by the United Kingdom Ministry of Defense that has been outsourced to commercial operators.

NSF continually works to identify potential candidate satellites to ensure a steady supply of communications resources. Viable and available satellites are rare, requiring a confluence of factors (economics of operations, international space debris mitigation conventions, U.S. national and commercial space policy) and acceptance of risk incurred by dependence on aged satellite systems far beyond their design life. NSF has already experienced the loss of two of these inclined-orbit satellites—NASA's TDRS 1 and Intelsat's MARISAT 2—due to age far beyond the design requirements and the need for the operator to move satellites to "graveyard orbits" to prevent space debris hazards. New (to USAP uses) satellites are occasionally found—NSF recently initiated discussions with DoD to explore the feasibility of repurposing the Defense Satellite Communications System (DSCS)-3B12 satellite for NSF use. Two additional Skynet satellites and three additional DSCS satellites may also be viable options.

In order to address the risk of reduced or no access to aged, out-of-planned-orbit satellites in an era of rapidly increasing research data transmission requirements, NSF issued a Request For Information (RFI) to the commercial satellite industry for solution concepts for all Antarctic communications requirements, with emphasis on South Pole Station. The RFI included an NSF initiative to test the interest of the industry in government-industry partnerships. NSF received 19 distinct solutions, with a broad cross-section of industry representation, ranging from well-known and established satellite builders and systems operators to entrepreneurial start-ups. Nearly all solutions proposed new satellite construction and dedicated launch vehicles. Solutions that were capable of meeting all of NSF's requirements predictably carried the highest cost. The lowest-cost solution was a variant of the method currently employed by NSF—the repurposing of aged inclined satellites.

The current strategy for managing the ebb and flow of inclined geosynchronous satellites supporting South Pole Station is predicated upon a successful agreement with DoD to retain legacy DSCS satellites as they approach the end of their mission lives. Antenna needs of some other candidate satellites could require a new 9-meter antenna at South Pole Station (estimated to cost $7 million or more to construct) if current data rates are to be sustained. NSF is considering a new Earth station complex of smaller, 2.4- to 4-meter, antennas that require less costly infrastructure and facilities. However, the smaller antenna size would also restrict the data rates available.

ACTION 4.7-3. ***Complete the ongoing assessment of alternatives for future South Pole bulk date transfer service and baseline an approach that does not depend on the TDRS system or GOES satellites. Consider both satellite and terrestrial capabilities, including a "New Start" (new satellite program) option that would provide high reliability and long-term capability.***

4.7.3.3. IRIDIUM Mobile Satellite Communications

USAP field activities in the deep Antarctic interior are almost totally reliant on the Iridium mobile satellite communications system, the only commercial system with true global coverage. NSF receives steeply discounted Iridium service rates from the DoD Defense Information Systems Agency. This satellite system has been key to current successes for both automated field instrumentation used by scientists and for reliable operational communications to supplement legacy high-frequency, or HF, radio communications.

The Iridium system is used to link South Pole Station to the USAP's main hub in Colorado, providing gap-filling network communications during the extensive times when broadband satellites are not visible. A bank of twelve single-channel Iridium data modems has been fashioned into a link that combines the 2.4 kb/s rate of each individual modem into an effective single channel of 28 kb/s—approximately equivalent to dial-up modems of the late 1980s. The resulting email traffic to/from South Pole Station has overcome former long delays in communications, a major benefit for both science and operations. IceCube uses the Iridium link for real-time instant messaging. A real-time seismic data feed is also supported by this link, contributing seismic sensor data in real time to the global Comprehensive Test Ban Treaty Organization monitoring network. (The Organization placed such importance on receiving real-time data from the South Pole sensor that it cofunded the development of the Iridium link system.) Lower data rate versions of this same design have been developed for the South Pole traverse and large deep field camps, facilitating operations and logistical support from McMurdo.

Iridium is actively working to implement a follow-on constellation of satellites (named IridiumNEXT), scheduled for service circa 2017, with the potential to provide even more capability. It is not known if DoD will execute a discounted rate contract for this future service. If not, it may be very expensive for NSF to support the projected needs of the deep field science program, let alone its current requirements.

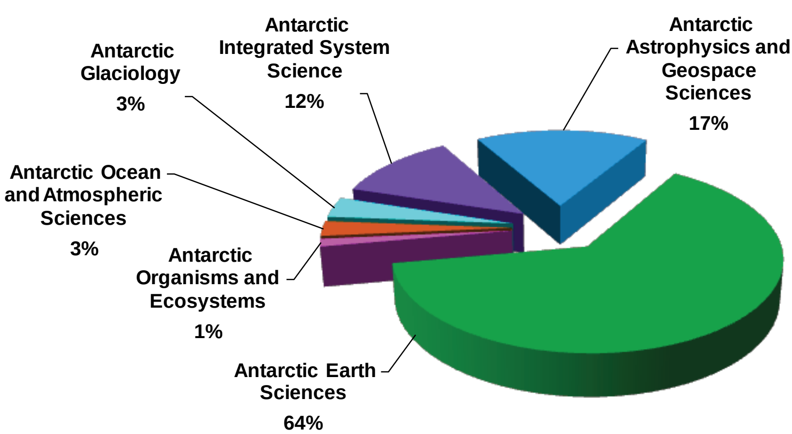


Figure 4.60. FY 2011 Iridium air time science usage.

ACTION 4.7-4. ***Identify those science projects that can benefit from real-time experimental data delivery to the United States and other off-ice sites and establish new Service Level Agreements that reduce the demand for scientists to be on-site in Antarctica.***

Figure 4.61. Black Island Telecommunications Facility. Source: Steve Martaindale.

4.7.3.4. McMurdo Station Communications and the Black Island Telecommunications Facility

At McMurdo Station there is a region blind to viewing key satellites. The primary off-continent satellite communications services supporting McMurdo Station are thus provided from the Black Island Telecommunications Facility (BITF). This facility is 22 miles (35 kilometers) from McMurdo and offers the necessary clear horizon for viewing geosynchronous communications satellites.

The BITF had its beginnings in the mid-1980s when an existing single-voice channel Inmarsat land Earth station was relocated from McMurdo in order to see a satellite blocked by Mt. Erebus. Over the years, continuous improvements, additions, and changes have been conducted at the facility as its core mission of telecommunications has grown. Preventative and corrective maintenance, systems replacement, and other upgrades are conducted during the Austral summer when helicopter service is available. During the Austral winter, the facility is largely unattended. C&IT technicians in McMurdo remotely monitor the health and status of the satellite communications and facility systems, and local weather conditions. Black Island receives the brunt of damaging storms and high winds that occur year-around due to the regional topography.

Recent technical assessments of the radomes protecting the antennas indicate that they have reached their nominal 20-year design life and are recommended for replacement.

The BITF power system is essentially a large uninterruptable power system using 288 lead-acid deep-cycle batteries. Recent maintenance inspections revealed that the usable life of the batteries has been reached. The cost of replacement batteries is estimated at $250,000. Failure to replace the batteries in time could result in a loss of McMurdo Station off-continent primary communications. Recent innovations in the battery industry indicate there are newer technologies available that could provide longer service lifetimes and represent a lower total cost of ownership. These so-called “lead-carbon” technologies should be explored during the anticipated battery replacement effort.

The winds from a storm in May 2012 incapacitated three of the four wind turbines used for power generation at the BITF. The turbines cannot be repaired until the Austral summer. Unfortunately, these turbines are no longer in production and, while the ASC has been able to secure all remaining parts available and has sufficient spares to support approximately three to four more years of operation, searches of the marketplace have not uncovered viable alternatives for the power, physical size, and ruggedness needed to withstand the rigors of the Black Island climate. The ASC is working with NREL for alternatives. NREL in turn is seeking to establish a joint venture with private sector entrepreneurs to restart production of these turbines, while incorporating design improvements gleaned over years of use at Black Island. Solutions must be found soon if the BITF is not to revert to diesel power during the Austral winter.

With the introduction of a collaboration among NSF, NOAA/Joint Polar Satellite System (JPSS), and NASA for operational weather satellite data acquisition in McMurdo for rapid return to worldwide weather processing centers, there are multiple players who now have a stake in the BITF and its satellite communications link. NOAA invested significant funding over the past several years to refurbish the NSF-owned satellite Earth stations in preparation for the higher data rates that are required for the composite daily traffic flow of the USAP and these other stakeholders. Based on an initial introduction facilitated by NSF, NOAA and its contractors worked with the Australian satellite operator SingTel-Optus to modify a commercial communications satellite that was still under construction to make it capable of supporting the data rates needed from the existing Earth station antennas. This modification provided the innovation needed to break through the bandwidth barrier that plagued McMurdo in the past.

A continuing partnership is being sustained. NSF hosts NOAA/JPSS telecommunications equipment in the McMurdo data center, provides the microwave telecommunications link to the BITF, provides and sustains the upgraded satellite Earth stations, operates and maintains the BITF facility, and participates jointly with NOAA for trouble reporting, troubleshooting, fault resolution, and service restoration activities. NOAA/JPSS serves as a telecommunications services provider by supplying the "pipe" that is transmitted over the Earth station, the lease for the satellite transponder, the primary and backup teleport in Australia, and return of the pipe to the United States via its global leased network from AT&T.

The BITF also hosts the primary HF radio communications receiving system that supports air-ground communications for USAP flight operations. The BITF provides a television receive-only satellite downlink to recover Armed Forces Network live television broadcast feeds, distributed over a cable television distribution system, with radio feeds broadcast over the local radio station.

ACTION 4.7-5. ***Assess the risk posture of the Black Island facility and develop and implement a plan to modernize it over the next five years.***

4.7.3.5 Obsolescence of Major C&IT Systems

Beyond the future requirements for connectivity and bandwidth, a more immediate problem is obsolescence of essential systems, some far beyond end of life. There are both software and hardware elements that are becoming difficult to maintain and for which vendors no longer provide support, creating a high risk of failure. Examples cited previously include supply chain software and the BITF. The McMurdo private branch exchange for telephone service was also found to be at the end of its service life and in need of replacement. In addition, the outside wire/cable plant at McMurdo Station has architectural, capacity, business continuity and potential security deficiencies, and there is a similar situation at Palmer Station. Much of the facility infrastructure (such as power systems and building features) were not designed with consideration of C&IT needs. An effective disaster recovery plan and capability should be developed now and a more structured and systematic life cycle process put into place to address hardware/software aging, capacity, and performance issues.

ACTION 4.7-6. ***Identify all legacy elements of the C&IT program that represent serious risk to the mission and develop and implement a plan to mitigate those risks.***

4.7.4. INFORMATION ASSURANCE/SECURITY

Management of information security (or, more broadly, information assurance) is a significant consideration for the USAP C&IT program. The news media is now filled with stories about hacking. Because the USAP C&IT environment is connected to the Internet, it faces similar risks and has experienced hacking events, "spyware," computer viruses, and the like. As required by federal laws, guidance and standards, NSF has improved the USAP C&IT information security posture, and in the process has expended significant energy, time, and funds. The USAP is responsible for safeguarding sensitive information contained in participants' medical records, in mission systems such as aeronautical communications, in control systems for satellite Earth stations, and in computing systems embedded in essential communications systems such as the McMurdo HF radio system.

4.8. HUMAN CARE

Because of the remote location and demanding environment of the Antarctic Continent and surrounding seas, the well-being and morale of all who work in the USAP are high priorities. Among the issues that affect people working there are housing conditions in the field and on stations and ships, food supply, the availability of recreational opportunities, establishment of a safe and pleasant working environment, access to appropriate medical care, and the provision of ECW clothing and personal protective equipment.

The challenges of working in Antarctica's environment are severe at any time, but they impact scientists and support personnel differently depending on the season, location, and activities being undertaken. Continuous attention to human needs assures fewer accidents, a safer and healthier Antarctic experience, and continuation of the overall long-term success of the science and of the U.S. contribution to the objectives of the Antarctic Treaty. Addressing the issues of "human care" for all USAP participants requires a range of strategies. For example, different factors can affect the health of those working at sea level at McMurdo Station compared with those working at high elevations at the South Pole or at some deep field sites, or at sea. There are also diverse safety issues (ocean survival versus laboratory safety versus ice survival), differing access to medical and health care, and contrasts in risk levels for different types of jobs, durations, seasons, and locations depending on whether a person is located in the field or at a station. Housing requirements differ according to these same factors and by the number of people needing to be housed. For example, housing in the field may be required for small teams of two to five scientists with no on-site contractor support, or for larger projects that include 50 or more researchers with contractor support.

4.8.1. HOUSING

Living space and sleeping arrangements significantly contribute to well-being, but each permanent U.S. station differs in the character of its accommodations and in the requirements of its community[30]. Most, if not all, locations operate 24 x 7. In all cases, lack of sleep and privacy can seriously affect morale and health and safety, and reducing the population density at permanent research stations could have a very positive effect on human welfare. As a result, it is important to provide an environment where restful sleep can take place irrespective of what else is going on. Scientists at McMurdo, South Pole, or Palmer Stations can be in transit status (en route to the field, to another permanent station, or to and from vessels), or based on station for longer periods, including the winter-over period. Dorm rooms are used primarily for sleeping and their schedules are highly variable, dictated by their laboratory and field work. For contractor

[30] For personnel in field camps and onboard ships, accommodations are limited. Field camps range from small tents to larger semi-permanent structures, with varying degrees of comfort. Investigator-run camps rely on shared cooking and cleaning duties, while at the larger field camps, contractor personnel provide food service and medical care. Shipboard accommodations tend toward spartan, with small, shared cabins and in-suite restroom facilities, frequently with unreliable toilets.

Figure 4.62. (top) Housing for the summer-only population at South Pole Station ("summer camp") in Jamesway buildings. Source: USAP photo archives. (bottom) Inside a dorm room in the Elevated Station at Amundsen-Scott South Pole Station. Credit: Calee Allen.

staff housed for the summer or winter at one of the three permanent stations, dorm rooms are a place for relaxation, recreation, and entertainment as well as sleep.

At Palmer Station, there are cramped dorm rooms with bunk beds and limited toilet and shower facilities. Palmer Station participants are housed in two locations. One is in the "Bio Building," where a third floor housing area is located above the ground floor laboratories and the second floor administrative offices and galley. The other is in the "GWR Building," which houses a garage, warehouse, and the power plant. Both of these locations present potential risks to personnel, with significant concerns for fire safety.

ACTION 4.8-1. ***As part of the master plan for Palmer Station, consider health and usability issues, including upgrading or replacing housing and baths as needed.***

McMurdo Station has overcrowded sleeping quarters that affect sleeping, privacy, and health. Because of the differences in job requirements, work schedules and operations at McMurdo, options might include designating separate dorms for support staff with different but standard work schedules, and scientists with highly variable work schedules. Additional consideration might be given to providing single rooms or fewer roommates as the population changes, allowing personnel to move to less crowded rooms. This would require the use of modern hotel software or a similar mechanism.

ACTION 4.8-2. ***Consider a dedicated dorm for those with similar work schedules, such as those working at night at McMurdo Station and researchers, aided by commercially available software to more efficiently and effectively manage housing and minimize the number of residents per room.***

Housing in the new South Pole Station is modern and relatively comfortable. However, as discussed previously, the demand for bed space at the station requires daily management attention to population issues. In addition, when used, the "summer camp" used for population overflow is an energy-intensive proposition.

Figure 4.63. Double cabin on ARSV *Laurence M. Gould*. Source: Craig Dorman.

4.8.2. FOOD

The quality of food can profoundly affect morale and health. The Panel found that, overall, food quality, quantity and options at all stations, field camps, and ships are generally healthy. Fresh vegetables and fruits are highly valued by all participants. McMurdo and South Pole Stations have small greenhouses that provide the community with some fresh vegetables (as well as a source of recreation and light during the long winter), but vegetarian options are few and, at all stations, certain foods can be depleted before the end of a season. At all USAP locations, food quality and quantity vary from year to year depending on the food order made the previous year and the capabilities of the kitchen staff. Comments made to the Panel reinforced the observation that effort devoted to hiring and retaining highly qualified and motivated kitchen staff is a good investment.

Real and perceived shortcomings have led people to bring their own food, which is an inefficient means of solving the problem and may result in food waste not being dealt with in an appropriate manner. Assuring a sufficient amount and variety of food, options for various food preferences and requirements, and a supply of fresh (when at all feasible) fruits and vegetables are imperative for health and morale. The nutritional content of meals is generally not displayed—but should be—for those who wish to choose food based on nutritional value.

ACTION 4.8-3. ***While the Panel commends the ongoing efforts to provide freshly prepared foods at the stations and on ships, the USAP is encouraged to emphasize the provision of a variety of fresh vegetables and fruits to those deployed and the hiring of highly competent, motivated galley staff.***

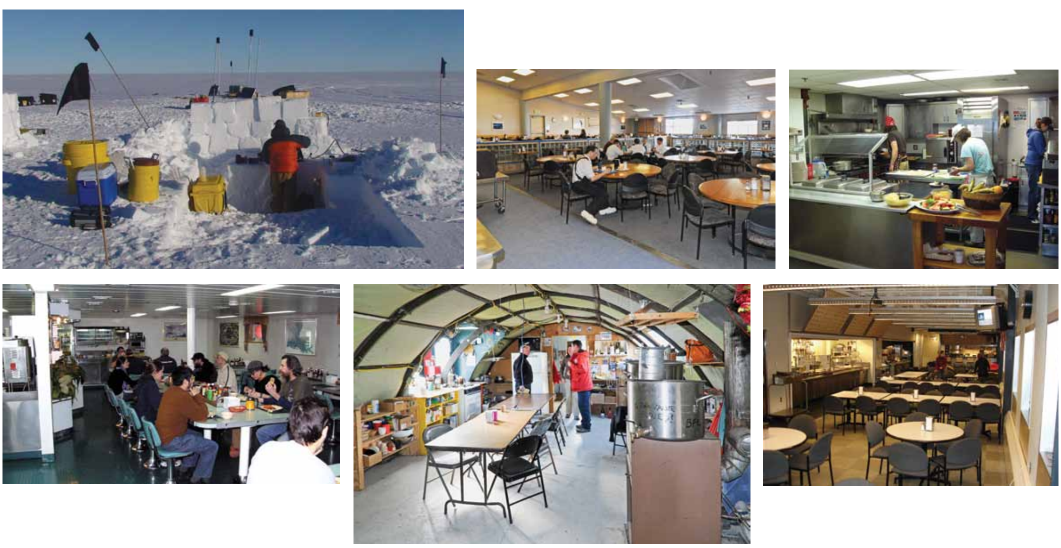


Figure 4.64. Food preparation and dining areas at USAP stations and ships. Sources (clockwise from top left): David Holland; Craig Dorman; James Swift; Brien Barnett; Craig Dorman; James Swift.

The Panel recognizes that the food production system at the permanent stations cannot be duplicated at field camps, but newly developed food alternatives may reduce transportation and cooking requirements while providing nutritious and tasty meals, and should be explored.

ACTION 4.8-4. ***Investigate means to reduce the time, personnel and energy required for food preparation at remote field camps, such as by utilizing modern prepared foods requiring reduced energy in their preparation, similar to those used in military operations.***

4.8.3. RECREATION AND MORALE

Recreational activities help to improve morale and health and can positively impact work quality and efficiency. Morale, in turn, is enhanced by the sense of community that exists among scientists and support staff, and can be particularly strong and important at the smaller stations and during the winter when the population decreases.

All permanent stations and both research vessels (*Palmer* and *Gould*) have some cardio-exercise and weight equipment. At McMurdo Station there is a centralized cardio-exercise facility, a weight room and a gym for basketball, volleyball, and exercise classes. There are a variety of recreational classes and activities, such as yoga, knitting, painting, chess, card games, and band practice that are distributed in many buildings across McMurdo. Some of them take place in dorm lounges, which can negatively impact personal space in the dorms. A centralized facility for classes, recreation, and meetings was listed as a priority in a recent survey of more than 900 members of the McMurdo community. Including many options for activities at each station and on the ships can also help to build a sense of community.

ACTION 4.8-5. ***Upgrade or build a centralized recreation building at McMurdo, or make recreation a principal function of a centralized multipurpose facility.***

Figure 4.65. Recreation facilities at (a) McMurdo Station and (b) on RVIB *Nathaniel B. Palmer*. Sources: (a) Craig Dorman and (b) James Swift.

Communication can also help to build a shared sense of community among deployed personnel—NSF, contractors, military, and research teams alike. Communication tools to be used would differ by station and on the research vessels, but include suggestion boxes, staff meetings, announcements regarding items of general interest to those deployed, newspapers, blogs, and closed-circuit televised information services.

In the United States, wi-fi technology and the Internet are now considered essential for communication and entertainment, as well as for real-time data collection, transfer, and analysis. However, as previously described, that degree of connectivity does not exist in Antarctica, and likely cannot for some time. Nonetheless, both science and support personnel at McMurdo Station noted the need for and benefits of enhanced communications capabilities—within the station and from the stations to the United States.

ACTION 4.8-6. ***Investigate and establish practices that would improve communications between the various colocated deployed teams at all Antarctic sites—including NSF personnel, contractor support staff, military personnel, and scientists—and thus promote increased overall awareness and appreciation of ongoing activities, interests, and priorities.***

4.8.4. SAFETY AND HEALTH

Maintaining personnel safety and health is a major challenge in the Antarctic. Activities span operating heavy equipment, flying over trackless and hostile terrain, mountaineering, and scuba diving under the ice. Nonetheless, the USAP has a generally good record of maintaining the health and safety of participants, particularly when considering the remoteness of the continent and extreme working conditions.

4.8.4.1. Safety and Risk Management

Direction, integration, and oversight of all safety activities associated with the USAP are the responsibility of NSF. Day-to-day execution of safety programs is the responsibility of the support contractor that operates and maintains the infrastructure for research in the Antarctic region. Safety responsibilities also extend to participating military organizations, other government institutions, and subcontractors. Safety is, in effect, the responsibility of all participants in USAP activities. This is a significant challenge that requires constant attention. Safety is both a precursor to and an enabler of operational success. The impacts of the environment, the higher cost of replacing lost or damaged property, the limitations in the rapid provision of advanced medical care, and the hazards imposed on rescuers in Antarctica make the risks associated with virtually all endeavors higher than they would be for similar operations in the United States.

Safety issues regarding facilities and equipment, transportation, supply chain (maintenance, warehousing), energy and utilities, communications, and human care are identified or alluded to elsewhere in this chapter. Members of the Panel identified safety issues during site visits to McMurdo, South Pole, and Palmer Stations. The findings and associated recommended implementing actions discussed in this section address strategic, high-level safety issues and the most significant issues identified from site visits.

There is no single overarching safety framework that encompasses all aspects of safety related to the broad spectrum of activities that take place in Antarctica and the Southern Ocean. Facility operations, occupational health and safety, transportation, and personal safety are addressed under the terms of the support contract. The contractor provides safety directives and executes safety-related activities that conform to Occupational Health and Safety Administration (OSHA) standards (for example, respiratory protection, hearing conservation, confined space safety), except in cases where not feasible due to environmental or logistical considerations. NSF also directs conformance with other U.S. regulations or industry standards.

Military operations in support of the USAP are conducted under the safety guidelines for the Service involved (Air Force, Coast Guard, Navy, and Army). Certain activities, such as aircraft rescue and firefighting, require the contractor to conform to DoD requirements. As a result, when assessing the value and risk of research, especially research conducted at remote locations, diving operations, small boat operations and research involving heavy equipment, it is challenging to create and sustain a process that ensures safety and creates accountability for compliance involving all players. Nonetheless, this is a necessity.

The mixed contractor-research population (largely at McMurdo Station but extant at all locations) creates a challenge in uniformly enforcing safety standards, communicating risk, and developing and sustaining a "safety culture" that focuses first on individual behavior and responsibility. Overall, the safety record, as reflected in the statistics provided, is much better than one would anticipate based on a cursory inspection.

While there has not been a recent catastrophic event that has resulted in death, multiple injuries or extensive physical damage, the current distributed assignment of safety responsibilities does not represent a comprehensive and sustainable safety management system (SMS). An SMS is a systematic approach to safety that has been incorporated by numerous international regulatory bodies such as the International Labor Organization, International Civil Aviation Organization, and the International Maritime Organization. A review of this approach is currently underway in the USAP and the Panel encourages this activity to continue. Further, corporations operating in challenging environments have developed safety practices that could be adapted by the USAP. In general, the appearance is that these commercial organizations place greater emphasis on safety than does the USAP.

The perception, assessment, and acceptance of risk associated with research activities vary with the individual or organization involved and their respective responsibilities for outcomes related to research and research support. One of the most discussed safety topics in the Panel's deliberations involved the tension between safety systems and oversight on the one hand, and individual responsibility and autonomy on the other. The research community has varying degrees of risk acceptance as it relates to the goals of their research and the value of the science. This creates a dynamic tension with standard operating procedures, safety regulations, and oversight of support and research activities. The Panel does not seek to resolve this tension, but does note that maturation of this discussion, greater clarity of shared values related to the research and support missions, and a collective focus on the development of an SMS that serves the goals of both the science and support communities should be an explicitly stated goal.

Comprehensive data on safety performance is a critical component of an SMS. Compilation and collection of records, performance measures, and statistics related to safety programs are the responsibility of the support contractor. Although historical injury data are available, accurate population data for calculating rates are generally available only for contractor personnel. Therefore, the overall safety performance of activities conducted in Antarctica and the Southern Ocean cannot be credibly calculated. In addition, data provided to the Panel regarding lost workdays and restricted duty were of limited usefulness due to the number of caveats associated with them and differences in medical judgment of the various physicians in treating and reporting injuries.

Recordable injury rates for USAP contractor personnel versus those in other commercial and government sectors reflect only on-duty injuries of a severity greater than first aid. (Treatment in excess of first aid is considered "medical treatment" and makes the injury "reportable.") The USAP contractor uses the same definitions as OSHA to permit comparability (100 employees working 50 weeks per year at 40 hours per week; 200,000 hours). All of the USAP rates are declining, reflecting increasing emphasis on safety and better-engineered workplaces and processes. However, there are some other factors that are probably at work as well, having to do, for example, with how injuries are treated, which now keeps some in the first aid category.

The widely distributed and diversely organized elements of the USAP would benefit from a more nearly unified SMS that specifies policies, expectations, and responsibilities. Such a system should incorporate the concepts of personal responsibility and reasonable accountability

Table 4.4. Total Recordable Injury Rate Comparisons

Year	Raytheon Polar Services Company	All Private Industry	Private Trade, Transportation and Utilities	Local Government	Federal Government
2004	7.62	4.8	5.5	Not readily available	4.95
2005	8.29	4.6	5.2	Not readily available	4.90
2006	6.42	4.4	5.0	Not readily available	4.45
2007	4.22	4.2	4.9	Not readily available	4.26
2008	4.26	3.9	4.4	7.0	4.24
2009	3.58	3.6	4.1	6.3	3.94
2010	4.07	3.5	4.1	6.1	3.87

for exercising appropriate care and avoiding unnecessary risks. It should mandate appropriately detailed and documented risk assessments of science and support projects and clearly state the authority and responsibility of the support contractor for implementing the safety system and enforcing safe practices. Although workforce turnover and multiple organizational relationships can be a challenge, the USAP should strive to strengthen the workforce culture for avoiding inappropriate risks.

ACTION 4.8-7. ***Promulgate a uniform set of safety policies and procedures for USAP operations and research that promote a culture of workplace safety throughout the program. Greatly increase usage of signage and other forms of communication in promoting safety.***

ACTION 4.8-8. ***Provide training to all participants in the use of fundamental operational risk management tools that can be continuously employed to identify and avoid high-risk safety situations.***

ACTION 4.8-9. ***State in a written procedure that the authority and responsibility of the ASC is to enforce safe practices among its employees, scientists, and subcontractors.***

ACTION 4.8-10. ***Provide statistics concerning safety mishaps and other key measures of station performance to the participant population in a readily available form.***

Members of the Panel visited McMurdo Station, received briefings, and conducted tours during which safety issues were discussed. McMurdo Station, as the largest and most complex facility in Antarctica, hosts significant logistical, diving, and industrial activities. Many maintenance and supply chain issues, discussed in other sections, also have safety implications.

Outdated buildings, facilities, and infrastructure create maintenance and safety concerns. The condition of warehousing was of particular concern, as was the reliance on pump-pressurized water for some major firefighting systems at the station. These systems are susceptible to mechanical failure and, as currently configured, lack redundancy for continued operation in the event of a loss of power.

ACTION 4.8-11. ***Investigate the feasibility of storing McMurdo fire protection water in a gravity tank to improve reliability of the supply and the quantity of water available.***

South Pole Station's unforgiving environment and lack of access for a good portion of the year make it the most significant safety challenge. As noted elsewhere in this report, during the Austral winter this environment imposes challenges similar to some of those associated with operations in space. That said, many past conditions and facility shortfalls have been corrected with the construction of the new station.

At Palmer Station, waterside facilities, small boats, and boat handling equipment are critical to research operations and support. As has been discussed, the pier is in need of improvement, and access to the Zodiac inflatable boats is over a rocky and frequently slippery shore that is traversed by persons carrying heavy and bulky loads and wearing cumbersome clothing. Housing and maintenance shops at Palmer

Station do not meet reasonable fire safety standards. The Panel noted that there are fire protection issues at Palmer Station similar in nature to those observed at McMurdo Station, suggesting value for a USAP-wide evaluation.

ACTION 4.8-12. ***Address safety concerns at Palmer Station regarding fire protection associated with personnel berthing in direct proximity to kitchen, power plant, and industrial workspaces.***

ACTION 4.8-13. ***Undertake a comprehensive evaluation of safety hazards and repeat periodically.***

4.8.4.2. Health and Medical

Advanced medical facilities do not exist on the continent and the distance to New Zealand or South America can delay emergency transport even under the most favorable weather conditions. As discussed, modern communication technologies have made it possible for physicians at these stations to consult with off-continent medical experts via a telemedicine system. The ability to use telemedicine remains a priority and is dependent on access to the communications infrastructure and in most cases satellite communications.

Figure 4.66. Boarding Zodiac boats at Palmer Station over snow and ice covered rocks. Source: Craig Dorman.

Each permanent station has a medical facility but these facilities are neither staffed nor equipped to treat major illnesses or severe injuries. Facilities at the South Pole are more modern, having just been constructed as part of the new station. Capabilities at the other stations, however, are not, but can (and should) be improved. The medical facilities and equipment at all permanent stations will need to be evaluated on a regular basis to assure the appropriate level of medical care. McMurdo Station, in particular, appears to have dated and inadequate facilities—even as compared with Palmer Station. On the ships, the Marine Projects Coordinator and usually one other person are trained as Emergency Medical Technicians, and their facilities appear to be adequate given the circumstances.

ACTION 4.8-14. ***Upgrade medical facilities and equipment at USAP Antarctic continental and marine locations on a routine basis, with current priority to McMurdo Station, and introduce an electronic medical records management system.***

To assure risks to health are minimized while working in Antarctica, all personnel currently must undergo a physical examination and medical tests and be found physically qualified (PQ'd) before deploying. Medical risks in Antarctica vary with the job assignment as well as location and duration of deployment, but the current medical screening guidelines, while taking

Figure 4.67. Medical facilities at (a) McMurdo, (b) South Pole, and (c) Palmer Stations. The facilities at South Pole and Palmer Stations are up-to-date, but that at McMurdo has not yet received modernization. Sources: Don Hartill, Brien Barnett, and Kristan Hutchison.

age into account, are otherwise basically the same for everyone. That is, the same tests and examinations apply whether one is spending the winter at the South Pole, deploying on a ship for a few weeks, living in the deep field, or visiting McMurdo for a few days. Most medical crises and evacuations are due to injuries, acute illnesses, or other conditions that are not preventable or foreseeable through the PQ screening. Reevaluating the required medical tests and determining if all tests are necessary for all personnel, or whether a newer medical test replaces several previously required tests, may reduce costs while still providing confidence that an individual is physically qualified to deploy.

Simple innovations could improve safety and health and reduce costs because time lost while personnel are sick or injured is a nontrivial expense. At McMurdo and Palmer, placing a hand-washing sink near the galley has encouraged hand washing before meals as a ritualized means of reducing illness, and there might be opportunities for additional preventive measures.

Those working outdoors, at the ice edge, in the Dry Valleys, and in the interior in remote camps are trained in survival and other safety skills. Field safety training, including refresher courses for those who have previously deployed, is required for everyone working or traveling beyond the boundaries of established stations and is generally viewed as effective.

ACTION 4.8-15. ***Revise the criteria for physical qualification examinations to better and more individually match qualification to task, location, and risk.***

4.8.5. PERSONAL EQUIPMENT

The USAP provides an array of protective clothing and field gear to assure that all individuals are protected against the sometimes brutal weather. A full issue of ECW clothing is provided off-continent prior to traveling to Antarctica. The clothing issued to all researchers and employees is a baseline preventive measure for safety. The type of work, the location of the work, and the ever-changing weather all influence how long an individual may be exposed and the types of conditions to which individuals will be exposed. The minimal personal gear package assures that all personnel are outfitted for the prevailing weather conditions and usages.

Continued research and development related to new fabrics and materials can bring benefits in health and safety. DoD makes considerable investments in this area that may benefit the USAP.

With approval, personally owned clothing can be substituted for items of required clothing. However, the use of personal gear in place of standard clothing can be problematic because of the inability to subject the wide variety of available clothing to quantitative tests. In addition, the approval process is inherently subjective and findings may not be consistent from year to year or site to site. Research on ECW clothing and protective gear conducted by the military, mountain rescue teams, and other organizations periodically offers new alternatives, and it might be useful for the USAP to develop a standard list of approved alternatives from which those desiring to do so could choose.

Figure 4.68. Illustrations of Extreme Cold Weather clothing: (a) examples of USAP-provided clothing, and (b) outer wear required for USAP flights over Antarctica. Source: (a) Craig Dorman; (b) USAP.

The USAP also provides tents, cookware, skis, snowmobiles, and other general field gear that can be reused year after year.

ACTION 4.8-16. ***Continue to provide basic clothing for safety and health reasons (rather than leaving to individual option).***

ACTION 4.8-17. ***Provide modern replacements for obsolete or inappropriate field gear as the latter ends its useful life.***

ACTION 4.8-18. ***Provide greater clarity and consistency in guidance concerning gear approved for use in the field and when flying.***

4.9. ENVIRONMENTAL STEWARDSHIP

The USAP is recognized for its leadership in environmental stewardship and has a record of utilizing science to address emerging issues that affect the natural environment. Cases in point are the U.S. approach to benchmarking carbon emissions and the introduction of alternate energy sources at McMurdo Station. The approach was recommended to all Treaty Parties following an NSF presentation at a Treaty-organized workshop.

4.9.1. INTRODUCTION

For over 100 years, people traveling to Antarctica and the Southern Ocean have impacted the environment, yet many regard this area still to be relatively unchanged—with the Ross Sea region considered the last "pristine" ocean in the world. Nonetheless, there is widespread recognition that oil and clothing industries benefitted from humans slaughtering whales and seals in the 1800s. In the 1960s, intensive commercial fishing around Antarctica resulted in the collapse of the fisheries, an outcome that was followed in the 1980s by industrial-scale krill fishing. At many scientific stations, researchers, explorers, and tourists have released sewage onto ice-free land, left food and refuse from expeditions in remote areas of the continent and, more recently, have brought non-native species to the continent. Human activities outside Antarctica have also affected the Antarctic environment—for example, climate change, creation of the ozone hole, and global transport of pollutants. Increasing numbers of cruise vessels now arrive in Antarctica every year and with them come the potential for adverse environmental impacts, such as oil spills and the transport of alien organisms and infectious disease agents.

The Antarctic Treaty that came into force in 1962 was designed to ensure that Antarctica is set aside for peaceful purposes, with freedom of scientific research. Subsequently, a number of policy instruments, collectively referred to as the Antarctic Treaty System, added environmental protection to the original agreement.

4.9.2. THE USAP AS AN ENVIRONMENTAL LEADER

The USAP evinces true dedication to environmental stewardship. All logistics and research activities conducted by the USAP are subject to an Environmental Impact Assessment process in order to mitigate or minimize adverse consequences while allowing critical activities to proceed in a responsible fashion. The USAP Environmental Monitoring Program that is currently in place at McMurdo Station is widely considered the most comprehensive among similar programs undertaken by other nations in Antarctica. Annually, all USAP participants are required to participate in training to learn proper waste management practices, environmental codes of conduct for work in the field, and acceptable behavior near wildlife. At a minimum, the USAP follows U.S. federal standards for assuring clean water, removal of pollutants, and clean-up of spills of fuel, hazardous chemicals, or other pollutants.

In Antarctica, any area sampled or occupied by scientists—as well as sites of remotely operated instruments—must be documented, providing geographic coordinates recorded in a database to inform future scientific work in the area. All human waste in ice-free regions such as the Dry Valleys is now removed to the nearest U.S. station and disposed of according to the applicable regulatory regime.

In recent years, the USAP has successfully instituted a number of changes to decrease human impacts. These include removal and cleanup of legacy research sites, upgrades to the fuel system at McMurdo, development of SPCC (Spill Prevention, Control and Countermeasures) plans for all stations as well as for Marble Point and the BITF, alternatives to fossil fuels, and preparation of a carbon footprint study.

4.9.3. ENVIRONMENTAL PLANNING

NSF's environmental and operations staff annually prepare, prioritize, and fund projects selected from an Environmental Top Ten list that is regularly maintained. Projects must meet two criteria to be added to the list: (1) a possibility of significant environmental risk and (2) retiring or mitigating the risk requires cooperation between multiple programs and work centers. Projects are prioritized based on significance and immediacy of the risk.

The availability or lack of funding does not always control whether a project is implemented—oftentimes, the availability of logistics is a factor. For example, drums of fuel are occasionally strategically placed in the field as emergency supplies for aircraft. These caches can become unrecoverable or unusable if they are not properly tracked and maintained. Once a cache is deemed unusable it must be removed (often by aircraft) to assure that there cannot be a release of hazardous substances to the environment. These sites are remediated as resources allow; however, it may be possible to make changes in flight planning that would reduce the need for fuel caches, cache maintenance, or recovery flights.

There is a large accumulation of nonhazardous waste at the South Pole that must be flown out or removed by traverse. The "waste berms" where this material is stored require annual maintenance so that the waste does not become permanently buried by drifting snow. The portable modular causeway system deployed for ship off-load at McMurdo in 2010/11 displaced shipboard containers that otherwise would have been available to remove waste at the end of the season. As a result, waste will further accumulate at McMurdo Station. A pilot program to employ a shredder to reduce the volume of waste prior to retrograde from South Pole to McMurdo Station was recently funded and shows considerable promise. As previously noted, modern compactors and incinerators would also likely be advantageous.

ACTION 4.9-1. ***Expedite removal or conversion into energy of the significant volume of waste remaining at South Pole Station.***

4.9.4. OTHER ENVIRONMENTAL ISSUES

4.9.4.1. Wastewater Treatment

The wastewater treatment plant at McMurdo Station is generally state-of-the-art; however, those at Palmer and South Pole Stations are in need of upgrading. Upgrades would enhance water conservation and environmental stewardship.

ACTION 4.9-2. ***Install a modern wastewater treatment facility at Palmer Station and review the priority now assigned to providing such facilities for South Pole Station.***

4.9.4.2. Water Quality and Quantity

Although the need for water conservation is already emphasized, making USAP participants more aware of the true cost of the water used in living quarters, galleys, and research projects could increase conservation consciousness—which in turn could produce energy savings.

ACTION 4.9-3. ***Increase emphasis on water conservation, especially at McMurdo Station, and improve understanding of water costs among all deployed participants.***

4.9.4.3. Climate Change

Climate change is affecting infrastructure and operations on the continent and adding new costs. Planning that includes the most recent scientific data and forecasts could assist the USAP in understanding the ramifications of environmental change on the USAP, its budget and its Treaty obligations. Noteworthy changes include rising lake levels in the Dry Valleys that have required moving camps, laboratories, and helicopter pads; melting permafrost at McMurdo that has caused the fuel line stanchions to list; and warm temperatures and runoff into Winter Quarters Bay that have imposed limitations to the ice pier and the Pegasus Runway. These and other emerging concerns have long-term implications for the conduct of science as well as maintaining leadership in environmental stewardship.

ACTION 4.9-4. ***Utilize frequently updated scientific data concerning climate change to better understand and plan for its impacts on operation of the USAP, its budget and its obligations under the Antarctic Treaty.***

In summary, the Panel notes that:

- The USAP has placed a priority on environmental protection.
- A process exists to select, evaluate, and achieve priority goals that affect Antarctica's environment but there are areas where that effort can be improved.
- The changing natural environment in Antarctica itself is likely to impose new challenges that will need to be addressed.

The USAP has an aggressive and highly commendable program to assure its continued environmental stewardship, including a process to assess and address the impact of its activities.

4.10. INTERNATIONAL CONSIDERATIONS

4.10.1. GOVERNANCE

The Antarctic Treaty has a primary stated purpose that is to ensure "in the interests of all mankind that Antarctica shall continue forever to be used exclusively for peaceful purposes and shall not become the scene or object of international discord." The basic principles of the Treaty include agreement that:

- Antarctica shall be set aside for peaceful purposes
- Freedom of scientific investigations throughout Antarctica, as applied during the International Geophysical Year, shall continue
- International cooperation in scientific research shall be promoted
- Scientific observations in Antarctica shall be freely available
- Participating nations do not have to relinquish a territorial claim, but no new claims will be made and no existing claim pursued
- Nuclear explosions and disposal of radioactive waste are prohibited
- Observers from member nations can freely carry out inspections of other members' installations

Since the first Antarctic Treaty meeting, the Parties have addressed a variety of issues with decisions taken by consensus. Discussions of environmental issues have resulted in agreements to increase the protection of Antarctica and the Southern Ocean. These include the Agreed Measures for the Conservation of Antarctic Flora and Fauna (1964), the Convention for the Conservation of Antarctic Seals (1972), the Convention for the Conservation of Antarctic Marine Living Resources (1980), and the Protocol on Environmental Protection to the Antarctic Treaty (1991). The Treaty and these additional instruments are collectively referred as the Antarctic Treaty System (ATS).

Following the tenets of environmental protection in the ATS, the USAP has set high environmental standards for the conduct of scientific research and the logistical and operational activities required that support that research.

4.10.2. LOGISTICS COLLABORATION

The Council of Managers of National Antarctic Programs (COMNAP) was established in 1988 and is composed of the leaders of the national

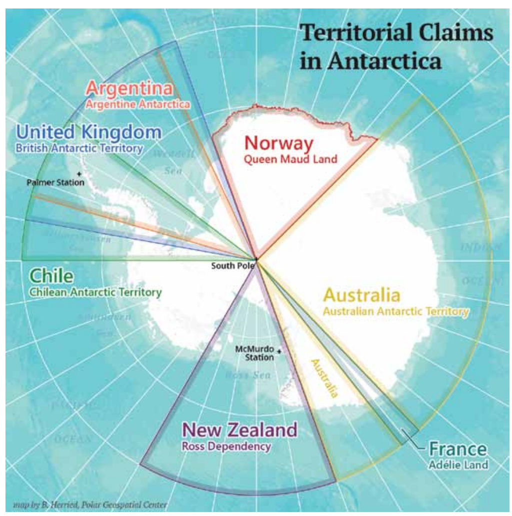


Figure 4.69. Map of Antarctica showing territorial claims. Source: Brad Herried.

Figure 4.70. Balloon launch for the U.S.-France Concordiasi project. Source: USAP photo archives.

Antarctic operating agencies. The head of NSF's Office of Polar Programs serves as the manager of the U.S. national program. The aim of COMNAP is to develop and promote best practices in managing scientific research in Antarctica and to encourage international cooperation in logistics support. Additionally, COMNAP provides advice to the Treaty Parties on a range of practical matters.

Several national Antarctic programs operate in close proximity to McMurdo in the Ross Sea region or otherwise exchange logistics support, including New Zealand, Italy, France, and Australia. South Korea intends to develop a permanent station in the area of Terra Nova Bay (225 miles, 362 kilometers, from McMurdo) and has expressed an interest in cooperative logistics arrangements. A recent Memorandum of Understanding entered into between the United States and Russia also calls for cooperative logistics.

Cooperative logistics arrangements are generally negotiated annually on a quid pro quo basis, with each party supplying mutually beneficial resources. The most evolved of these arrangements is with New Zealand, dating back to the early days of the U.S. program. The United States and New Zealand exchange support annually through a joint logistics pool from which each can withdraw assets in proportion to its contributions. For example, both countries contributed fixed-wing and helicopter flights in accord with an annual program plan, New Zealand recently provided capital funding for three wind turbines at McMurdo Station, and the United States contributes other in-kind resources from McMurdo Station.

The planning and execution of emergency medical support and evacuation is another area where national Antarctic programs provide cooperative services. The USAP has considerable expertise in planning and executing these missions, and it is also a core mission for the U.S. Air Force and ANG that is often called upon by other international programs. The USAP has performed rescue evacuations from virtually every corner of the continent for multiple national programs and nongovernmental organizations. Rescue operations are not an

Figure 4.71. The U.S. HF meteor radar array at the U.K.'s Rothera research station, used to study thermospheric winds. Source: David Fritts.

Figure 4.72. Transantarctic Mountains Camp. Source: Peter Rejcek.

exclusive USAP capability; the New Zealand Air Force and Australian Antarctic Division aircraft have also supported USAP emergencies.

As activity increases across Antarctica, the need for aeromedical support will also increase. National programs are willing to reimburse the USAP for expenses, but the unpredictable nature of the support can be quite disruptive to the USAP's work and it is not at all clear to the Panel that fully burdened costs are used when calculating the value of or the bill for providing these important services.

Collaborations in support of research are coordinated by NSF staff working with their counterparts in other countries. For example, joint studies of the upper atmosphere are conducted using balloons launched at U.S. and French research stations. France provides the launch equipment and controls while the United States transports the equipment to Antarctica. Each country places its own instruments on the balloons. Another example is the radar array operated by the U.K. at its Rothera research station in support of U.S. research.

4.10.3. SCIENTIFIC COLLABORATION

Exchanges of scientists and other cooperative research practices have taken place among nations for many decades; however, integrated scientific and logistics collaborations have enabled the achievement of major scientific goals that were previously not possible. The International Geophysical Year (IGY) was a major milestone in collaborative activities by providing an opportunity for wide-scale international cooperation in the physical sciences. Published international Antarctic papers with coauthors from two or more nations increased from 15 papers in 1980 to 41 papers in 2007, the start of IPY. International collaborations during IPY were also extensive—with NSF-funded researchers collaborated with colleagues in 28 other countries. The bibliographic record also shows that other scientists cite international papers more often than they cite single-nation papers, offering further evidence that

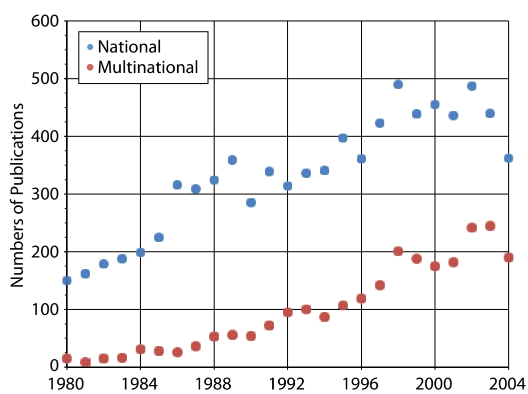


Figure 4.73. U.S. Antarctic research publications from 1980 to 2004, showing those with U.S.-only and multinational authorship. Data source: Dastidar and Ramachandran (2008).

international cooperation increases the progress of science and enables research that otherwise would be unaffordable or even infeasible.

Partnerships developed for and since IPY enabled dramatic advances in major scientific challenges. China, the United Kingdom, France, the United States, and several other countries have worked together to study and model the future evolution of the entire Antarctic ice sheet in order to reduce uncertainties in the Intergovernmental Panel on Climate Change estimates of long-term global sea level rise. Of particular importance are the efforts maintained over a number of years to characterize the rates of loss of ice from the main drainage basins. Given that the continent is as large as the United States and Mexico combined, linking individual nations' projects together can produce efficiencies as well as broader reach of research observations. Antarctica's Gamburtsev Province project was an IPY effort, in this case involving the United States, United Kingdom, Germany, China, and Australia. The collaboration discovered river valleys in the Gamburtsev Mountains under the Antarctic ice sheet. This is the region where the ice sheet first began to grow some 34 million years ago and it is thereby believed to harbor very old ice. The mountains themselves were a tectonic enigma because there was no evidence of a low-density root—a characteristic that should be present for mountains if they were truly 34 million years old. In addition to the above discoveries, the project, with its strong international collaboration in science, technology and logistics, provided the first detailed insight into what that part of the continent, as large as the Alps, might have been like before it was covered with ice.

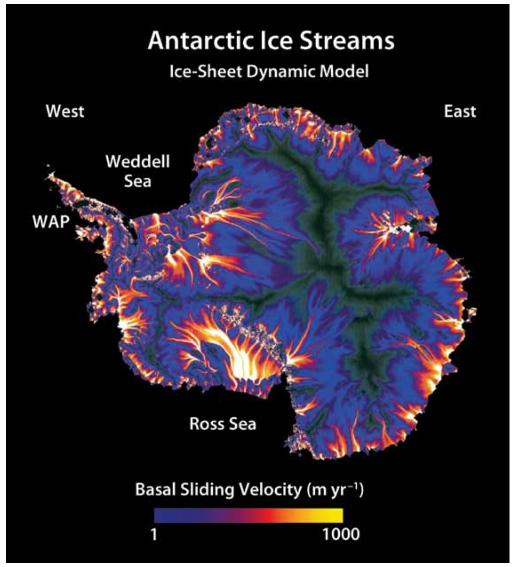


Figure 4.74. Antarctic ice sheet drainage. Source: Snowball Earth.

Another IPY effort, the Larsen Ice-Shelf System, Antarctica (LARISSA) project, involved collaboration by Argentina, Belgium, Korea, Ukraine, and the United States to study another apparent regional anomaly having significant potential global change implications. The abrupt disintegration of Antarctica's Larsen Ice Shelf system triggered substantial interest in investigating the effects this change had on the overall natural ice-atmosphere-ocean system as well as the effects on the marine ecosystem in the region. The Larsen Ice Shelf system was investigated using marine and terrestrial geosciences, cryosphere and ocean studies, and research into marine ecosystems.

As an example of the role of education in IPY, a course was presented in the United States in 2010 under the auspices of the Australia-based International Antarctic Institute using marine

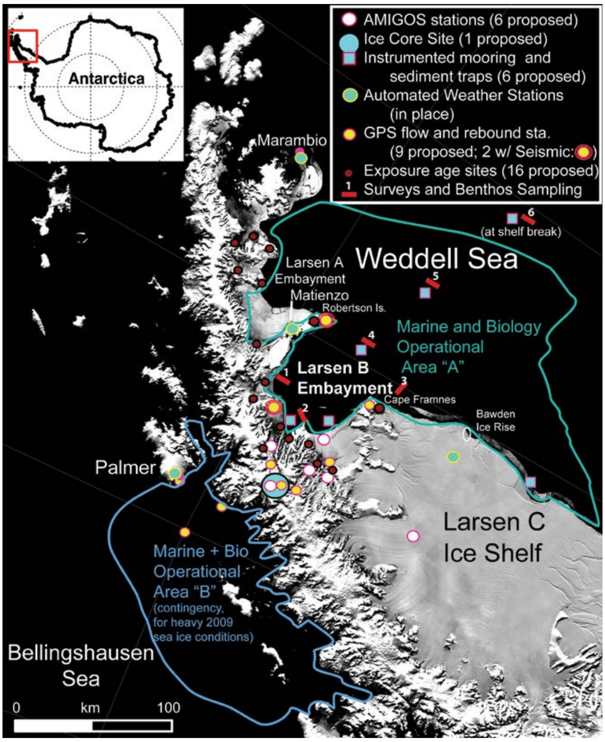


Figure 4.75. Map of the Larson Ice Shelf System, Antarctica (LARISSA) study area. Source: LARISSA project team.

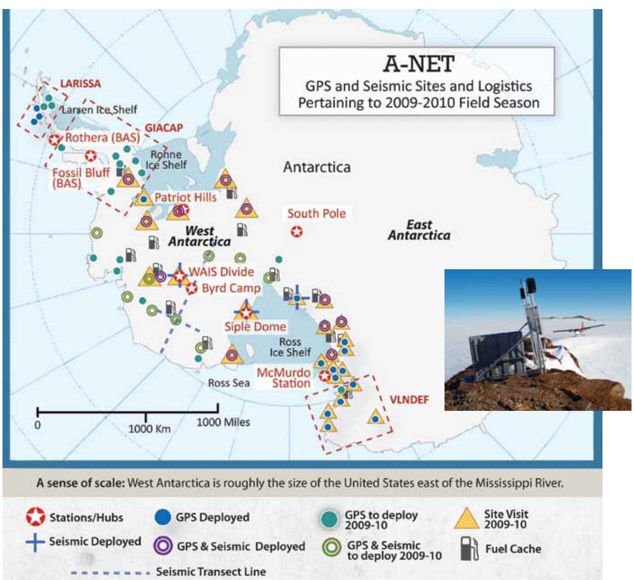


Figure 4.76. (map) A-NET GPS/seismic network sites and related logistics for the 2009/10 Antarctic field season. (photo) POLENET installation on Cordiner Peak, Antarctica. Source: Seth White.

data, sediment cores, and imagery acquired during the LARISSA project to structure its curriculum.

Today, twenty-eight countries collaborate in POLENET to map uplift of the Antarctic crust resulting from the decrease in mass of the covering ice sheet. Data from new GPS and seismic stations spanning much of the Antarctic and Greenland ice sheets are being used to model how much ice was lost over the 10,000 years since the Last Glacial Maximum. These data, derived from measurements recorded by satellites, help to determine where, and at what rate, the ice sheets are changing in response to recent climate change. Such measurements are critical in refining estimates of future global sea level rise. The collaborations have led to new technology for making continuous measurements at autonomous observatories operating in polar conditions and have provided a legacy framework for ongoing international geophysical observations.

Thirteen countries are participating in the International Trans-Antarctic Scientific Expedition (ITASE) that is collecting ice core samples that provide signatures of how constituents of the atmosphere have changed since the beginning of the Industrial Revolution. Having started in 1990, ITASE is

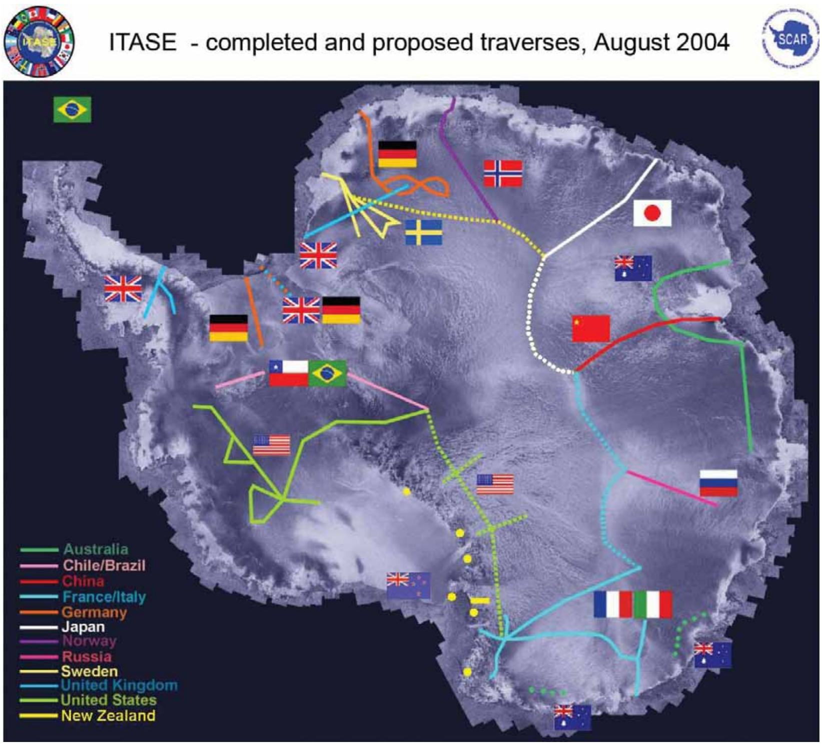


Figure 4.77. Map of completed International Trans-Antarctic Scientific Expedition (ITASE) traverses, August 2004. Source: ITASE/SCAR.

an example of a project that flourished during the IPY period. Like the ice sheet drainage collaborations, ITASE has distributed its goals geographically among the participating nations. A workshop identified the tasks for each national participant and the SCAR Global Change Program provides coordination.

Germany, Italy, New Zealand, and the United States contributed to the Antarctic Geological Drilling Program (ANDRILL) and obtained deep sediment cores from the seabed that record Earth's climate 15–30 million years ago. These paleoclimate perspectives increase confidence in the ability to predict future change. Using the McMurdo Ice Shelf as a drilling platform, the project found new evidence that even a slight rise in atmospheric carbon dioxide affects the stability of the West Antarctic Ice Sheet.

Figure 4.78. ANDRILL field site, Source: ANDRILL Science Management Office.

France and the United States combined their capabilities in the Concordiasi project to develop a new way of measuring the constituents of the atmosphere, layer by layer, with instruments that are dropped from long-duration stratospheric superpressure balloons deployed from McMurdo. Their data are coupled with surface observations at a number of Antarctic locations to reduce uncertainties in aspects of climate change that could affect the mass balance of the Antarctic ice sheet.

In biology, a major impetus for marine science was the Census of Antarctic Marine Life (CAML). The Southern Ocean comprises approximately ten percent of the world's ocean, yet it is perhaps the least studied. It is a major carbon sink and may also have been the center for the evolution of much of the world's deep-water organisms. The five-year CAML program involved 27 cruises on research vessels of the United States, United Kingdom, Australia, New Zealand, France, Russia, Belgium, Germany, Spain, Italy, Brazil, Chile, Uruguay, Peru and Japan, all searching both the seafloor and the water column for new species, hundreds of which have been identified to date.

These international collaborations have not only enabled scientists to attack problems requiring capabilities beyond those of any single nation, they have also breathed new life into Antarctic science, focusing it in many cases on altogether new areas of research. They have also had major implications for future logistics, suggesting that this support will be not only geographically more dispersed and continuous in time, it will also require international cooperation—with greater standardization, interoperability and efficiency, if it is to be affordable.

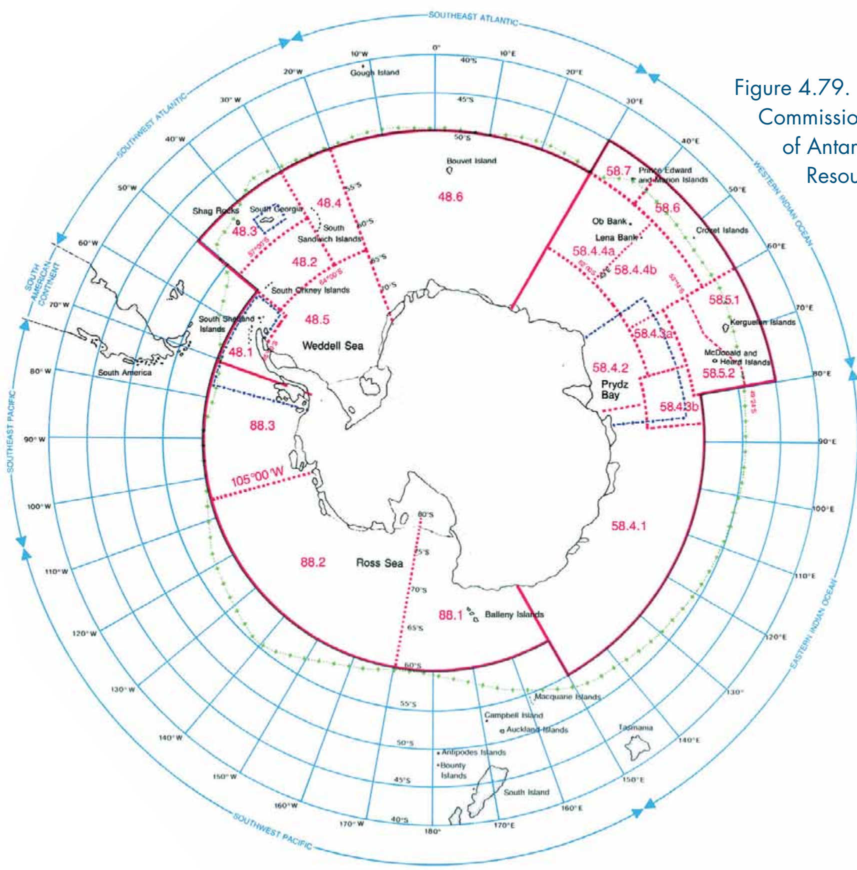


Figure 4.79. Boundaries of Commission for the Conservation of Antarctic Marine Living Resources reporting areas.

4.10.4. COORDINATION OF INTERNATIONAL COLLABORATION

Multinational projects in Antarctica are particularly effective when nations share access to their national infrastructure and logistics pipelines. There are many such examples:

- The French-Italian station at Dome C hosts, among many other projects, a significant portion of the Concordiasi project
- The Airbus A-319 operated by the Australian Antarctic Program is an important component of the logistics pool, as are the wheeled and ski-equipped C-130s that New Zealand and the U.S. operate
- The Swedish icebreaker *Oden* has hosted joint U.S.-Swedish research in the Southern Ocean and has opened the channel through the sea ice that enables annual resupply of the U.S. research stations at McMurdo and the South Pole

The USAP's new Amundsen-Scott South Pole Station hosts researchers from around the world in the tradition of partnership that characterizes

Figure 4.80. Australia's Airbus A-319 at McMurdo. Source: USAP photo archives.

Figure 4.81. Swedish icebreaker *Oden* working in Antarctic sea ice. Source: USAP photo archives.

Antarctic activity. Clearly, Antarctica itself, with its unique treaty and its long heritage of scientific research, remains a model of international cooperation, one with lessons for international science and perhaps other activities everywhere. At the same time, much more will be accomplished through future international cooperation, particularly with regard to logistical support.

Scientists from one or more nations working together can perform some forms of research at the frontier of science. But when complicated logistics partnerships are required, as is the case for much of the research in the huge and distant Antarctic, a legal framework such as that provided by the Antarctic Treaty and the intellectual framework provided by IPY are essential. Together, these frameworks enable partnerships to develop and flourish over the several years required for planning, the conduct of fieldwork, and follow through in laboratories on other continents.

One of the duties of COMNAP is to provide a venue for discussion among the national Antarctic program managers concerning logistical support of their nation's science programs. This often results in barter agreements. The United States has the largest and most important presence, providing assets that most other countries could not replicate. Additionally, the United States provides redundancy of services that relieves other countries of that responsibility.

ACTION 4.10-1. ***Periodically review the activities of other national Antarctic programs to identify opportunities for collaborative research, logistics, energy provision, technology, infrastructure, education and other areas that would eliminate duplication of effort, standardize equipment, and reduce costs to the international community.***

ACTION 4.10-2. ***Periodically review the current and projected shared-service "balance sheet" to assure equity of international cooperative activities.***

ACTION 4.10-3. ***Initiate an effort to better "standardize" equipment and through COMNAP to reduce costs and eliminate unnecessary redundancy.***

ACTION 4.10-4. ***Engage with Italy, New Zealand, and South Korea to identify opportunities for collaborative science and logistics arrangements that would appropriately benefit all three programs due to the proximity of their stations in the Ross Sea region.***

Figure 4.82. National flags of the original Treaty signatories at Amundsen-Scott South Pole Station.
Source: Craig Dorman.

4.11. GOVERNANCE OF U.S. PROGRAM

The ATS provides the overall framework governing nearly all human activities south of 60°S or just about 10 percent of Earth's surface. The Department of State leads the U.S. delegation to the annual Antarctic Treaty Consultative Meeting where issues can be addressed with other parties to the Treaty. For over 50 years since the United States became an original signatory of the Antarctic Treaty, U.S. policy related to Antarctica has endorsed the ATS as serving the national interests. Moreover, an active and influential U.S. science presence in Antarctica is recognized to be paramount to a U.S. leading role in the ATS. NSF has been charged since 1971 with the responsibility of budgeting for and managing the entire United States national program in Antarctica, including logistic support activities, so that the program may be managed as a single package.

The most recent extant expressions of U.S. Antarctic policy are recorded in two documents now decades old[31]:

- Presidential Memorandum 6646 (PM 6646) of February 5, 1982, United States Antarctic Policy and Operations
- Presidential Decision Directive/NSC-26 (PDD/NSC-26) of June 9, 1994, United States Policy on the Arctic and Antarctic, superseded for the Arctic by NSPD-66/HSPD-25 of January 9, 2009, but still in effect for the Antarctic

For several decades the USAP has sought to operate in strict accordance with these directives, and both the 2011 NRC report and the deliberations of this Panel have been based upon them. The Panel found no reason to suggest changes to their fundamental objectives or provisions that have led to today's strong U.S. scientific and operational presence in the Antarctic[32]. However, the Panel believes that there are several reasons that, as was recently accomplished for the Arctic, PDD/NSC-26 and PM 6646 should be reviewed and updated for the Antarctic. One specific deficiency is that the organization charged with coordination and implementation of Antarctic policy called out by PDD/NSC-26—the Antarctic subgroup of the Interagency Working Group on Global Environmental Affairs—no longer exists and has no extant successor. The existence and character of interagency bodies resides within the purview of each administration and modifications through several administrations account for the current lack of an Antarctic policy group.

[31] The full text of these documents is reproduced in Appendix III.

[32] Specifically, strong support for the ATS; maintenance of a strong and influential science presence including year-around occupation of the South Pole and two coastal stations; management of the program in a manner that maximizes cost-effectiveness and return on investment; single-point budgeting and management of the entire program including logistic support activities by NSF; and provision, on a reimbursable basis, of logistic support requested by NSF, by the Departments of Defense and [Homeland Security].

Among changes in the Antarctic region in the decades since these documents were put into place that prompt the Panel to suggest a review of U.S. Antarctic policy at this time are the following:

- The USAP is increasingly reliant upon support from partner nations, most notably New Zealand and Chile; collaborations and logistics support agreements are evolving or under development with many nations including the United Kingdom, Italy, South Korea, Australia, France, and Russia.
- As cited in the 2011 NRC report, changing climate conditions in the Antarctic—one of the major topics driving research interest in the region—have global and societal impact, not the least being the potential for sea level rise related to changes in the ice sheets.
- Both the NRC and this report call for a significantly greater degree of international collaboration in both science and logistics, potentially to include joint ownership and/or operation of resupply and support ships, as well as internationalization of increasingly sophisticated deep field research camps and a continent-wide observing system.
- Other nations' stations in the vicinity of McMurdo are increasingly interested in, and to a degree already dependent upon, USAP support for air operations.
- Because of the strong U.S. presence on the continent and the diversity and capability of U.S. logistics assets, the USAP is frequently called upon to support search and rescue (SAR) operations; given the increasing number of Antarctic stations and the growing complexity, geographical spread and international nature of field operations, the demand for U.S. SAR support will undoubtedly increase in both assets required and cost.
- Certain Treaty parties that are claimant states are combining oceanographic cruises with mapping of continental shelf extensions, with the potential to support claims under the United Nations Convention on the Law of the Sea.
- Commercial harvesting of marine resources in the area—particularly the krill fishery in the peninsula region and the toothfish fishery in the Ross Sea—as well as illegal, unregulated, and unreported fishing—is increasing in the Southern Ocean.
- The International Maritime Organization is developing a mandatory Polar Code to address safety for ships operating in both polar regions; the Code will address design, construction, equipment, operations, training, search and rescue, and environmental protection matters.
- Antarctic tourism is increasing dramatically in both scope and character and with it interest in access to U.S. research stations and commercial use of U.S. logistics resources in Antarctica is growing—as are SAR events for nongovernmental entities.
- The U.S. polar ocean fleet has decreased significantly in size and capability, mandating at least temporary reliance on foreign icebreakers to support the annual break-in for resupply of McMurdo and South Pole Stations.
- Economic interests may drive bio-prospecting and mineral, oil, and gas exploration in the Antarctic and Southern Ocean regions, potentially by non-Treaty states.

- Non-Treaty states have expressed interest in joining the Treaty and establishing stations in Antarctica.
- USAP research continues to be broad in scope as it was at its inception, but over the last 15 years has entailed considerably stronger participation by physical and biological scientists supported by NSF, other federal agencies, and international partners.
- Technology developments pioneered by federal agencies (DoD, NASA, DOE, and NOAA for example) hold great promise for facilitating Antarctic research and for advancing scientific frontiers in areas ranging from astrophysics to microbiology.

While altogether new policies do not appear to be warranted and the Panel believes that NSF should remain as the U.S. agent for planning and operating matters concerning the Antarctic, some national-level government body should be charged with high-level review, coordination and oversight of policy issues that transcend NSF, such as the need for a national icebreaking capability and other high-level matters of import that arise for the USAP, possibly in both polar regions. It is noted that revisions in U.S. policies concerning environmental protection have traditionally been addressed through coordination chaired by the Department of State.

Taking the other changes described above into account, it would be useful to strengthen implementing mechanisms for interactions with other federal agencies. In this regard, it is worth emphasizing that the USAP is a national program budgeted and managed as an entity by NSF. One implementing mechanism in place is memoranda of agreement or understanding for logistics and scientific support between NSF and DoD, NASA, DOE and NOAA, to name a few organizations. The May 1, 2007, DoD-NSF Memorandum Of Agreement for logistics support and its predecessors have been extremely effective.

Agreements should be reviewed and revised as appropriate in order that long-term science and support activities and interests of other agencies are well governed. Although NSF is responsible for all U.S. activity in the Antarctic, it is not always fully apprised of such activity or enabled to thoroughly and effectively review and manage it with regard to compliance. Further, the scientific programs of other agencies (especially NASA) both have, and will continue to require, financial support well beyond the ability of NSF to provide within the USAP budget.

NSF should establish and exercise agreements that take advantage of technological developments and logistical capabilities possessed by other agencies. These could lead to improvements in areas such as supply chain management, transportation, energy, utilities usage, waste management, communications, and advanced sensor systems. Means to achieve improvements in these areas could assist NSF in carrying out its overall responsibilities.

The NSF Director has appropriately sought to induce recommendations for Antarctic research from across the entire Foundation and from their research communities. Research programs in polar regions must be competitive with any other program in any other scientific discipline and geographical area. The Director's

"One NSF" initiative, construed broadly, is of great significance for the quality and stature of NSF's scientific contributions to the USAP.

The Panel considers it critically important that the budgetary, logistical, environmental, and other ATS compliance issues remain under the management of a qualified, dedicated, and fully staffed office reporting to the NSF Director. This will ensure that, as mandated by PM 6646, the total national Antarctic program is "managed as a single package" so as to continue to successfully serve national scientific and geopolitical interests.

ACTION 4.11-1. ***Review PM 6646 and PDD/NSC-26 to update these governing policy documents, as necessary, to ensure full implementation of their requirements under today's environment.***

NSF and its Office of Polar Programs should be commended for the effectiveness of its management of the USAP, including its handling of responsibilities for consolidated budgeting and logistics support for the program, and for compliance with environmental requirements of the Antarctic Treaty and applicable U.S. statutes.

5. COST CONSIDERATIONS

On behalf of the Panel, the Institute for Defense Analyses Science & Technology Policy Institute performed a number of cost evaluations relating to the U.S. Antarctic Program (USAP). In doing so it created a cost model that should prove valuable to the USAP as it refines the trade studies reported herein. The Panel conducted certain trade studies—generally those where ancillary impacts on cost could be isolated from secondary effects.

5.1. SENSITIVITY ANALYSIS

Costs used in the formal tradeoff analyses were fully burdened. For example, the cost determined for a container of food at the South Pole includes not only the initial cost of purchasing the food but also the cost of special packaging, a pro rata share of the charge for sailing a cargo vessel to McMurdo as well as a portion of the icebreaker that must precede it, a share of the cost of flying the container to South Pole Station in an LC-130 aircraft, plus a charge for storage at the station. The impact of such an allocation on the ultimate cost of an item or service is significant. The Panel believes that if there were greater awareness of these numbers by researchers and support personnel there would be more conservation of resources.

The formal analyses that were performed use net present value as the decision criterion (with zero ten-year terminal value). Nonetheless, the calculations can only be considered as indicators because the complexity of Antarctic operations (for example, the extreme nonlinearity of costs and savings) in many cases mandates undertaking detailed analyses before making final decisions. The following are examples of this complexity:

- A gallon of fuel that is conserved at the South Pole may only reduce the overall cost to the USAP by about $3.50—in contrast with the average allocated cost of placing it there of $24.00—unless the gallon saved happens to be the gallon that permits use of a smaller and less expensive tanker or eliminates the need for an LC-130 flight or the need for an additional storage tank—in which case it produces major savings.
- Reducing the use of water (which, at South Pole Station, must be melted from ice, with a corresponding energy usage) may produce no savings because the ice is normally melted using waste energy resulting from electricity generation. However, if that same waste energy could be diverted to, say, heating a building, the resulting cost reduction from conserving water could be substantial.

- A similar argument pertains to energy savings derived from insulating buildings in Antarctica. It seems reasonable that if it is justified to insulate homes in the U.S. Midwest it should make even more sense at McMurdo—with its average winter temperature of −58°F (−50°C). However, if the above consideration regarding the cost savings from fuel economy applies, it becomes difficult to justify the considerable expense of improving the insulation of buildings at such a remote location unless enough fuel can be saved collectively to permit the use of a smaller tanker, etc.
- If it becomes possible through, for example, fuel economy to avoid a number of LC-130 flights, there will be a significant saving to the USAP—but that savings may not accrue to the United States Treasury because it may be that the United States wishes to maintain a fleet of operational LC-130s for military contingencies, irrespective of the aircraft's performing, or not performing, missions in Antarctica.

The hazard in marginal analyses of the type described above is that one can demonstrate that there is modest benefit in attempting to conserve fuel, water, heat, etc.—a conclusion that *in general* would be unjustified. Cumulatively, small savings can, in a nonlinear process, eventually have a very large impact in reducing the overall cost of operations. The tradeoff analyses conducted herein can thus be viewed as analogous to mathematical partial derivatives and, in most cases, will understate potential savings.

It should be noted that in monitoring costs the USAP uses a less complex cost allocation model based upon direct outlays. For example, there is no cost of seagoing vessels included in bookkeeping the cost of operating the South Pole Station—which seems logical in that obviously no such vessels can reach the South Pole. However, this approach does not recognize the nontrivial cost of oceangoing vessels in performing the sea leg of supplying South Pole Station. Such accounting serves a useful purpose, particularly in budgeting; however, the user of the results must be mindful of the inherent assumptions when making choices among alternative allocations of funds.

By the above accounting technique, the annual cost of operating the USAP's vessels is $28M; the cost of Palmer Station is $9M; South Pole Station is $32M; and McMurdo is $231M—revealing the dominant impact of McMurdo as a principal logistics base.

Table 5.1. Annual USAP Costs by Location

	ANNUAL COST[a] ($ MILLIONS)
McMurdo	231
South Pole	32
Palmer	9
Vessel[b]	28
Total	$300

[a] Includes an estimate of the annual depreciation cost of NSF equipment and buildings
[b] The vessel cost includes Palmer re-supply

From either of these analyses certain fundamental observations become evident. For example, it is beneficial to reduce researcher-days on the ice because many other costs tend to scale with that factor. Correspondingly, reducing the amount of fuel consumed on the ice can be highly leveraged because air transport and shipping are also major cost drivers.

For each research grantee-day spent on the ice approximately seven days on the ice are devoted by those performing operations and maintenance functions. Only 20 cents of each dollar assigned to Antarctic activities is devoted to science—a figure that nonetheless represents an improvement from the 16 cents experienced as recently as a decade ago.

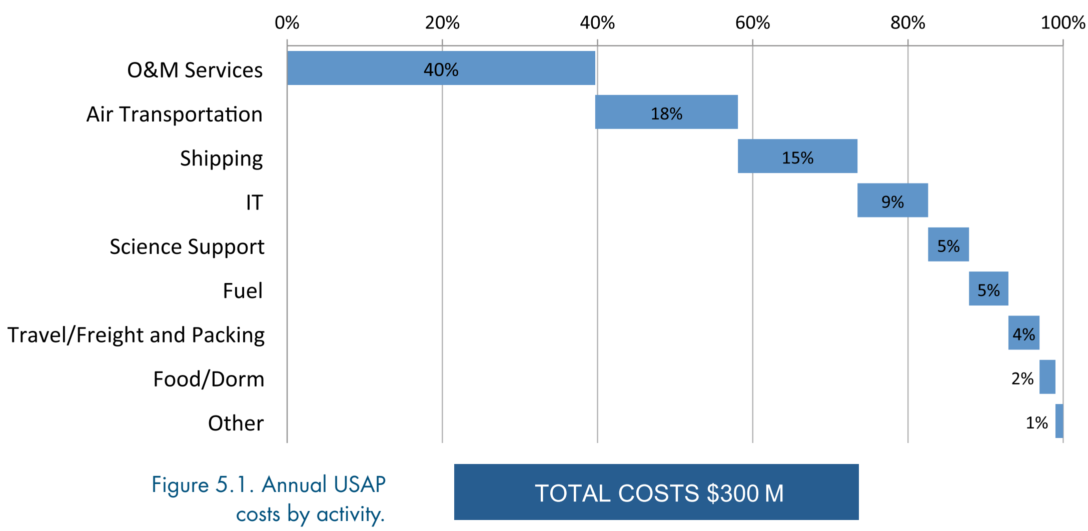


Figure 5.1. Annual USAP costs by activity.

5.2. COST TRADEOFFS AND INVESTMENT STRATEGY

A number of specific revisions to operational practices have been assessed and discussed herein. Among the more significant of these, in terms of their cost saving potential, are:

- Reduce person-days on the ice
- Reduce fuel consumption
- Automate "follower" vehicles in a traverse using station-keeping technology (to reduce crew size), thereby doubling the number of traverse trips and reducing the equivalent number of LC-130 flights
- Construct a runway at the South Pole to permit C-17 operations at that location
- Place additional wind turbines at McMurdo
- Place a wood burner at McMurdo
- Burn waste oil at McMurdo to save fuel and handling costs during retrograde
- Construct a solar-heated garage at the South Pole Station

During its evaluation, the Panel discerned a widespread and commendable "can-do, make-do" culture within the USAP. Flaws in the system, however, diminish the ability of the program's participants to make the most of their research. These flaws persist despite substantial financial and human investment. Overcoming these barriers requires a fundamental shift in the manner in which capital projects and major maintenance are planned, budgeted, and funded. Simply working harder doing the same things that have been done in the past will not produce efficiencies of the magnitude needed in the future. Not only must change be introduced into *how* things are done, but *what* is being done must also be reexamined. In this regard, the ongoing introduction of a new prime support contractor provides an extraordinary, albeit brief, window to bring about major change.

Although many opportunities for cost savings have been cited, this report has not attempted in all cases to determine the required front-end investment. For example, it is the Panel's collective judgment, based primarily upon years of experience, that a reduction in contractor personnel of some 20 percent should be feasible. A more detailed analysis will be needed before implementing this.

The Panel emphasizes that the USAP is facing major expenditures for the replacement of existing inefficient, failing, and unsafe facilities and other assets. Delays in initiating the needed work will only increase the cost and further squeeze the research funding that is already only a fraction of total dollars allocated to the program. While significant savings are in fact achievable through operational efficiencies, some of the front-end investments that are needed if the United States is to continue USAP activities at the present level cannot all be justified solely on an economic basis. Some upgrades are essential for personnel and equipment safety. The Panel has sought to identify changes that hold initial investment to the minimum reasonable level.

In spite of the above challenges, USAP science and science support could be vastly enhanced within about five years. The improvements could be funded by increasing for each of the next four years the USAP's annual appropriation for support by six percent (real dollars) relative to the FY 2012 appropriation (an additional $16 million per year), diverting six percent of the planned science expenditures over the next four years to upgrades of the science support system ($4 million), and permitting the savings accrued from five high payout projects and the 20 percent reduction in contractor labor to be reinvested in upgrading support capabilities (averaging $20 million net per year for four years).

The investments thus made would be repaid in approximately seven years if five high payout projects produce the expected return and a 20 percent reduction in contractor staff is in fact possible and implemented. Thereafter, the annual savings generated will allow the USAP to increase science awards while ensuring safe and effective science support and appropriately maintained facilities. Given the important improvements in safety and science opportunities contained within the above option, a seven-year financial breakeven is considered by the Panel to be a reasonable investment, particularly when compared to the cost of not making one.

In making this proposal the Panel has sought to be mindful of the severe budgeting challenge facing the nation while at the same time respond to the serious need to rebuild much of the nation's Antarctic infrastructure.

Once the recommendations made herein have been implemented, it will be possible to substantially increase science activity—assuming a stable overall budget.

It should be noted that this construct does not address the extremely important icebreaker issue that transcends the Antarctic program's resources and responsibilities, at least as they are understood by the Panel.

Table 5.2. Five High Payout Projects

	INVESTMENT, $M	NET PRESENT VALUE, $M
Automate and Double Number of Traverses	1.80	15.00
Increase Number of Wind Turbines at McMurdo	0.50	1.40
Construct Solar Garage at South Pole	0.03	0.75
Install Wood Burner at McMurdo	0.40	0.70
Burn Waste Oil at McMurdo	0.09	0.70

APPENDIX I.
Statement of Work

CHARTER OF THE REVIEW OF THE U.S. ANTARCTIC PROGRAM BLUE RIBBON PANEL

1. Official Designation

Review of the U.S. Antarctic Program Blue Ribbon Panel ("the Panel"), #76826

2. Authority

Having determined that it is in the public interest in connection with the performance of National Science Foundation (NSF) duties under law and in consultation with the Office of Science and Technology Policy in the Executive Office of the President (OSTP), the NSF Director hereby establishes the Review of the U.S. Antarctic Program Blue Ribbon Panel pursuant to the Federal Advisory Committee Act (FACA), as amended, 5 U.S.C. App.2.

3. Scope and Objectives

The Panel will conduct an independent review of the current U.S. Antarctic Program to ensure the nation is pursuing the best twenty-year trajectory for conducting science and diplomacy in Antarctica—one that is environmentally sound, safe, innovative, affordable, sustainable, and consistent with the Antarctic Treaty. The Panel should aim to identify and characterize a range of options for supporting and implementing the required national scientific endeavors, international collaborations, and strong U.S. presence in Antarctica. The identification and characterization of these options should address the following objectives:

(a) expediting a renewed and more efficient U.S. capability to support the changing landscape of scientific requirements in Antarctica and the Southern Ocean;

(b) supporting U.S. federal agencies' needs for access to Antarctica and the Southern Ocean;

(c) stimulating scientific and technological innovation in polar endeavors; and

(d) fitting within the current budget profile of the U.S. Government's Antarctic activities.

In addition to the objectives described above, the review should examine the appropriate amount of R&D and complementary scientific activities (e.g., satellite and observational missions) needed to make Antarctic activities most productive and affordable over the long term, as well as appropriate opportunities for international collaboration.

4. Description of Duties

The Panel will provide advice only.

5. Official to Whom the Panel Reports

The Panel reports to the Director, NSF and the Director, OSTP. The Panel will submit its report within approximately 270 days of its first meeting.

6. Support

The NSF Office of Polar Programs will provide financial and administrative support (including contractor staff as necessary) and operating funds for the Panel.

7. Estimated Annual Operating Costs and Staff Years

The estimated operating cost associated with supporting the Panel's functions is estimated to be approximately $673,500, including all direct and indirect expenses. It is estimated that approximately 2 full-time equivalents will be required to support the Panel.

8. Designated Federal Officer

The DFO will be either a full-time or a permanent part-time employee who will approve or call all of the Panel's meetings, prepare and approve all meeting agendas, attend all Panel and subcommittee meetings, adjourn any meeting when he/she determines adjournment to be in the public interest, and chair meetings when directed to do so by the Directors of NSF and OSTP. The DFO will be the Director, Office of Polar Programs, NSF. The Alternate DFO will be the Division Director, Antarctic Infrastructure & Logistics, Office of Polar Programs. NSF. Other DFO's may be designated by the DFO.

9. Estimated Number and Frequency of Meetings

The Panel will conduct approximately four meetings as appropriate at various locations throughout the United States.

10. Duration

The Panel will exist for a term not to exceed 12 months, unless earlier renewed.

11. Termination

The Panel will terminate no later than 12 months from the date of its establishment.

12. Membership and Designation

The Panel will consist of members to be appointed by the Director, NSF and the Director, OSTP. The Directors will ensure a balanced representation in terms of the points of view represented and the functions to be performed. Each member serves at the pleasure of the Directors. The Panel will consist of approximately 10–12 members. It is anticipated that the members will serve as Special Government Employees for the duration of the Panel, renewable at the discretion of the Directors. The NSF Director will designate the chair of the Panel.

13. Subcommittees

Subcommittees, task forces, and/or work groups may be established by NSF to conduct studies and/or fact-finding requiring an effort of limited duration. Such subcommittees, task forces, and work groups may not work independently and must report their recommendations and advice to the full Panel for full deliberation and discussion. If the Panel is terminated, all subcommittees, task forces, and work groups will also terminate.

14. Recordkeeping

The records of the Panel will be handled in accordance with General Records Schedule 26, Item 2, and the applicable agency records disposition schedule.

15. Certification

This Panel is determined to be necessary and in the public interest.

(signed)
Karl A. Erb
Director, Office of Polar Programs
National Science Foundation

CHARGE TO THE BLUE RIBBON PANEL

Excerpt from letter to Director, National Science Foundation from Director, Office of Science and Technology Policy

The second, independent blue ribbon panel, should use the results from the NRC Panel to review and make recommendations on the operational plans needed to deliver future Antarctic science. The Panel should evaluate the status and capabilities of NSF's current Antarctic infrastructure, examine appropriate opportunities for international Antarctic collaborations, examine the role of and future requirements for permanent stations, remote camps, mobile stations, ships, and aircraft support, and review the management and logistics support options required for this projected suite of scientific operations. The blue ribbon panel should also examine the appropriate amount of R&D and complementary scientific activities (e.g., satellite missions) needed to make Antarctic activities most productive and affordable over the long term.

Revised for the Blue Ribbon Panel

The Blue Ribbon Panel should assess the current U.S. Antarctic Program operations, logistics, and management and make recommendations on a long-term strategy to deliver an efficient and effective national research Program for Antarctica and the Southern Ocean, informed by the recommendations of the National Research Council. To this end, the Panel should consider:

- the status and capabilities of the current U.S. Antarctic infrastructure;
- appropriate opportunities for international collaborations;
- the role of and future requirements for permanent stations, remote camps, mobile stations, ships, and aircraft support;
- the management and logistics support options required to support the projected scientific Program; and,
- complementary R&D activities (e.g., satellite measurements, technology development, etc.) that would help make Antarctic activities even more productive and affordable over the long term.

The Panel is strongly encouraged to consider and recommend innovative operational and technological approaches to maximize the scientific impact of the U.S. Program in a necessarily constrained budget environment.

CONTEXT FOR THE U.S. ANTARCTIC PROGRAM REVIEW

The Office of Science and Technology Policy and the National Science Foundation have initiated a major review of the U.S. Antarctic Program to ensure that it continues to support the most relevant and important science in the most effective, efficient, sustainable, technologically advanced, innovative, safe, and environmentally-friendly manner, and to set the stage for the next two decades of U.S. research, discovery, and environmental stewardship in Antarctica. The results of the study will inform policy and future budget requests.

The formal charge to the Blue Ribbon Panel contains the primary elements of interest to the Administration, recognizing that the Panel may well also consider and make recommendations on other appropriate topics. In addition to the formal charge, the Administration would like to share a number of important questions and considerations that should be helpful to the Panel during its deliberations:

- agility: options for increasing the ability of logistics and infrastructure to respond to evolving and changing challenges in the Southern Ocean and on the continent as new scientific drivers evolve;
- complexity: what are the implications for logistics and infrastructure associated with the increasing sophistication of forefront research;
- efficiency: options for maximizing the efficiency and cost-effectiveness of research stations, ships, and short-term and multi-year field camps;
- research and development: concepts and investments that could improve USAP efficiency and effectiveness and reduce infrastructure and logistics life-cycle costs;
- research station resupply: options for reducing annual resupply requirements and for meeting resupply requirements more reliably and efficiently;
- sustainability: options and tradeoffs for moving toward more sustainable USAP science and operations; and using renewables, alternative energies, and other means to reduce the logistics burden and the carbon footprint of fossil fuels;
- technology: options for increasing utilization of remote sensing, autonomy, and information technology to reduce environmental footprint and increase scientific reach, including a sustained technology development effort;
- communications: options for meeting forecasted information, computational, and communication infrastructure needs and challenges;
- data legacy: options for assuring that important data and specimens from scientific investigations are accessible, curated, and preserved for long-term use;

- international cooperation: the pros and cons of cost- and resource-sharing with international partners in meeting U.S. requirements; and
- agency collaboration: ways in which mission agency capabilities can be brought to bear to enhance Program capabilities and performance.

The Administration would also appreciate a review that examines potential management, programmatic, logistics, and infrastructure options relative to the following evaluation parameters:

- environment, safety, and health standards;
- interagency logistical support;
- 20-year life-cycle costs (including operations costs);
- programmatic and technical risks;
- potential to spur innovation, encourage competition, and lower the cost of Antarctic operations;
- potentially expanded opportunities for science;
- potential for enhanced international cooperation;
- potential for inspiring the nation, and motivating young people to pursue careers in science, technology, engineering and mathematics subjects; and,
- contractual implications.

The Panel is encouraged to fully examine more than one approach for meeting the Program's future needs. Where more than one option exists, it would be helpful if the Panel were to examine the costs and benefits of the several alternative approaches. It would be helpful if the options considered were framed in terms of whether different logistics or infrastructure approaches would achieve more or less research since in practice the Program seeks to balance research and operations funding within a given top line funding envelope.

The Panel is encouraged to consider existing and evolving collaborations, partnerships, and partnership needs within the NSF, across the Federal agencies, and with the international community of researchers and operators. The Panel may also wish to recommend means by which the private sector might further contribute to the advancement of the Program goals through collaborative arrangements.

The Panel is encouraged to consult with the Department of State concerning foreign policy objectives and the way they intersect with the Program's support for research, education, and environmental protection, given the role of the Department in coordinating U.S. policy relating to the Antarctic Treaty and related instruments.

APPENDIX II. Member Biographies

NORMAN R. AUGUSTINE, CHAIR

Norm Augustine was raised in Colorado and attended Princeton University where he graduated with a BSE in Aeronautical Engineering, magna cum laude, and an MSE. He was elected to Phi Beta Kappa, Tau Beta Pi, and Sigma Xi. In 1958 he joined the Douglas Aircraft Company in California where he worked as a Research Engineer, Program Manager, and Chief Engineer. Beginning in 1965, he served in the Office of the Secretary of Defense as Assistant Director of Defense Research and Engineering. In 1973 he was confirmed as Assistant Secretary of the Army and in 1975 became Under Secretary, and later Acting Secretary. Joining Martin Marietta Corporation in 1977 as Vice President of Technical Operations, he was elected CEO in 1987, and chairman in 1988. He served as president of Lockheed Martin Corporation upon the formation of that firm in 1995, and became CEO later that same year. He retired as chairman and CEO of Lockheed Martin in 1997 and he became a Lecturer with the Rank of Professor on the faculty of Princeton University. He has served as President of the Boy Scouts of America, Chairman and Principal Officer of the American Red Cross, Chairman of the Council of the National Academy of Engineering, Chairman of the Defense Science Board and a member of the president's Council of Science and Technology for 16 years. He is a former member of the Board of Directors of ConocoPhillips, Black & Decker, and Proctor & Gamble, and was a member of the Board of Trustees of Colonial Williamsburg. He is a Regent of the University System of Maryland, Trustee Emeritus of Johns Hopkins, and a former member of the Board of Trustees of Princeton and MIT.

Mr. Augustine was presented the National Medal of Technology by the President of the United States and the National Science Board's Vannevar Bush Award. He has received the Joint Chiefs of Staff Distinguished Public Service Award. He has five times received the Department of Defense's highest civilian decoration, the Distinguished Service Medal. He is a member of the National Academy of Sciences, the American Philosophical Society, and the National Academy of Arts and Sciences. He has traveled in 111 countries and stood on both the North and South Poles of the Earth.

THAD ALLEN

Admiral Thad W. Allen (U.S. Coast Guard, retired) was the Commandant of the Coast Guard from 2006 to 2010. He has been extensively involved in polar policy issues during his career. He was a member of the President's Ocean Policy Task Force and has spoken and written frequently in favor of United States ratification of the Law of the Sea Treaty. He led the United States delegation to the International

Maritime Organization for four years. He has traveled to Antarctica and the South Pole and made several visits to New Zealand. The Antarctic visit coincided with the last simultaneous deployment of both the *Polar Sea* and *Polar Star* to break out McMurdo Base. As Commandant he commenced summer deployments of Coast Guard personnel and equipment to the North Slope of Alaska to develop operating concepts and lessons learned in executing missions to expanded open water due to the shrinking Arctic ice cap. He has had extensive interaction with the Native populations of Alaska. He has worked closely with Canadian counterparts to increase cooperation and joint operations in the Arctic. More recently he has worked with both the Center for Strategic and International Studies and the Pew Charitable Trust on issues related to oil and gas exploration in the Arctic.

In 2010 Allen was designated the National Incident Commander for the unified response to the Deepwater Horizon oil spill in the Gulf of Mexico. In 2005 he was designated the Principal Federal Official for the response to Hurricane's Katrina and Rita. Allen has lectured widely on emergency response and crisis leadership. He is a Distinguished Professor of Practice at the Trachtenberg School of Public Policy and Public Administration of The George Washington University where he teaches Leadership in Large Complex Organizations in Crisis.

Allen is a 1971 graduate of the Coast Guard Academy. He holds two masters degrees from George Washington University (MPA '86) and the MIT Sloan School of Management (MS '89). He has been awarded honorary doctorate degrees from George Mason University and the National Defense University.

CRAIG E. DORMAN

Craig Dorman attended Dartmouth College on a Navy scholarship and remained in naval service until he retired as Rear Admiral in 1989. His naval career was equally divided between operational tours and command in Naval Special Warfare (UDT/SEAL Teams) and management of oceanographic and antisubmarine warfare research and development programs from Washington, D.C.

After leaving the Navy, he served as Director of the Woods Hole Oceanographic Institution until 1993. He returned to Washington, D.C., to become Deputy Director, Defense Research and Engineering for Laboratory Management, and then moved to London as Chief Scientist and Technical Director of the Office of Naval Research's International Field Office from 1995 to 1997. While in London, he was on an Intergovernmental Personnel Act assignment from the Applied Physics

Laboratory of Pennsylvania State University and held an appointment as Visiting Professor at Imperial College.

He returned to Washington to serve as special assistant and then Chief Scientist at the Office of Naval Research from 1998 through 2001. During this period, he was actively involved in interagency issues dealing with the intersection of national security, intelligence, and the environment. In 2002, he began service as Vice President for Research for the University of Alaska Statewide System, and in 2003 added responsibility for Academic Affairs. Mr. Dorman retired from the University of Alaska in September 2007. He has served on Boards of both industry and academic institutions and directed studies and reviews for the National Research Council, the National Oceanic and Atmospheric Administration, the National Science Foundation, and the Smithsonian Institution.

HUGH W. DUCKLOW

Hugh Ducklow is the Director of The Ecosystems Center at the Marine Biological Laboratory (MBL) in Woods Hole, MA.

Dr. Ducklow is a biological oceanographer and has been studying plankton foodwebs in estuaries, the coastal ocean, and the open sea since 1980. He and his students work on microbial ecology and ocean biogeochemistry. Dr. Ducklow has participated in oceanographic cruises in Chesapeake Bay, the North Atlantic Ocean, the Bermuda and Hawaii Time Series observatories, the Black Sea, the Arabian Sea, the Ross Sea, the Southern Ocean, the Equatorial Pacific, and the Great Barrier Reef. Much of the work was done in the decade-long Joint Global Ocean Flux Study of the ocean carbon cycle, which he led in the 1990s. He has led or participated in 15 expeditions to Antarctica since 1994.

Currently, Dr. Ducklow leads the Palmer Antarctica Long Term Ecological Research Project on the West Antarctic Peninsula and is investigating the responses of the marine ecosystem to rapid climate warming in one of the world's most rapidly changing areas. After majoring in History of Science at Harvard College, Ducklow received his Ph.D. in Environmental Engineering from Harvard University in 1977. Before coming to the MBL in 2007, Ducklow was Glucksman Professor of Marine Science at The College of William and Mary.

BART GORDON

Mr. Gordon served 26 years in the U.S. Congress representing the 6th Congressional District of Tennessee. During that time he served on a variety of committees, including the House Science and Technology Committee, where he was ranking Member from 2005–2006 and Chairman from 2007–2011. The Science and Technology Committee has jurisdiction over the National Science Foundation and the U.S. Antarctic Program; pursuant to these duties, he visited the Antarctic in 1995. Mr. Gordon was also a senior member of the House Committee on Energy and Commerce, and served on the House Committee on Financial Services and the House Committee on Rules, Transatlantic Parliamentary Dialogue, and the NATO Parliamentary Assembly. Mr. Gordon is currently a partner at K&L Gates in Washington, D.C.

R. KEITH HARRISON

Keith Harrison recently retired after 41 years at Procter & Gamble. For the last ten years at P&G he was the Global Product Supply Officer, responsible for the company's global supply chain including purchasing, engineering, manufacturing, quality and customer service, and logistics. Previously, he held positions of increasing responsibility in product supply, marketing, and general management.

Mr. Harrison is on the Boards of the Midmark Corporation, Hayco (Hong Kong), THP (Ho Chi Minh, Vietnam), and Hauser Capital Partners. He is a past Chair of the Cincinnati Museum Center and currently Chair of the Cincinnati Museum Center Foundation. Mr. Harrison is also advising a number of companies on supply chain, corporate strategy, and leadership challenges.

Keith Harrison was born in Union City, Indiana. He graduated from Duke University in 1970 with a Bachelor of Science Degree in Mechanical Engineering.

DON HARTILL

Dr. Hartill is a professor of physics at Cornell University. He received his B.Sc. in physics from MIT and his Ph.D. in physics from Caltech. He is an experimentalist in high-energy physics currently specializing in accelerator physics with a focus on RF accelerating systems, including low-frequency superconducting cavities suitable for accelerating muon beams. In the past, he developed large cylindrical drift chambers and their associated fast high sensitivity electronics as the central tracking detectors for the e+e- collider experiment CLEO at Cornell.

He has served as Chair of several NSF review panels for Major Research Equipment and Facilities Construction projects, including the Laser Interferometer Gravitational Wave Observatory (LIGO) and IceCube, and participated in the initial reviews of the U.S. portion of the Atacama Large Millimeter Array (ALMA) and Ocean Observing Initiative (OOI). He currently is a member of the High Energy Physics Advisory Panel (HEPAP) and is the Chair-elect of the Division of the Physics of Beams of the American Physical Society and is a Fellow of the society. From 2004 to 2010 he was a member of the Scientific Policy Committee of CERN. During the 2008–2009 winter, he chaired one of the two external review committees formed to recommend modifications to the Large Hadron Collider (LHC) to avoid future cryogenic accidents due to system failures.

Since 1996 he has served as Mayor of the Village of Lansing, New York, which has 3,300 residents and is adjacent to Ithaca in the Finger Lakes Region. It has an annual budget of $3.9 M, has one of the lowest village tax rates in New York State, and has no debt.

GÉRARD JUGIE

Dr. Gérard Jugie is an Emeritus Research Director of the French government-funded research organization CNRS, formerly working in the field of coordination chemistry and nuclear resonance spectroscopies. He has published more than 50 papers in refereed journals and presented at more than 100 conferences both in fundamental chemistry, science policy, and more recently polar subjects. Jugie received his graduate degrees from the University of Toulouse (France) and has been research fellow of the Royal Society for two years at Queen Elizabeth College (London-Kensington).

Jugie began at the CNRS headquarter as director of the industrial office and then became responsible for the western part of France and later for Languedoc Roussillon district. From 1997 to 2010, Jugie was Director of the French Polar Institute (IPEV). During this period, he was elected chairman of COMNAP (Council of Managers of National Antarctic Programs), chairman of EPB (European Polar Board), and chairman of EPC (European Polar Consortium).

LOUIS J. LANZEROTTI

Louis J. Lanzerotti joined the technical staff of AT&T Bell Laboratories in 1967, after serving two years as a postdoctoral fellow at Harvard University and at Bell Laboratories. He retired in 2002 and remained a consultant to Alcatel-Lucent through 2008. In 2002, he was appointed a Distinguished Research Professor of Physics in the Center for Solar-Terrestrial Research at the New Jersey Institute of Technology in Newark, New Jersey.

Lanzerotti has conducted geophysical research in the Antarctic and the Arctic since the 1970s, directed largely toward understanding Earth's upper atmosphere and space environments. He has served as principal investigator or co-investigator on several U.S. NASA interplanetary and planetary missions, including Applications Technology Satellites (ATS), IMP, Voyager, Ulysses, Galileo, and Cassini. Currently, he is a principal investigator on the NASA Radiation Belts Storm Probes mission scheduled for an August 2012 launch.

He has co-authored one book, co-edited four books (one on Antarctic upper atmosphere research), and is an author of more than 500 refereed engineering and science papers. He is founding editor for *Space Weather, The International Journal of Research and Applications*, published by the American Geophysical Union. He has eight patents issued.

Lanzerotti is an elected member of the National Academy of Engineering and of the International Academy of Astronautics (IAA), and a Fellow of the Institute of Electrical and Electronics Engineers (IEEE), the American Institute of Aeronautics and Astronautics (AIAA), the American Geophysical Union (AGU), the American Physical Society (APS), and the American Association for the Advancement of Science (AAAS). He is the recipient of two NASA Distinguished Public Service Medals, the NASA Distinguished Scientific Achievement Medal, the COSPAR William Nordberg Medal, the AGU William Bowie Medal, the IAA Basic Science Award, and the Antarctic Service Medal of the United States. Minor Planet 5504 Lanzerotti recognizes his space and planetary research, and Mount Lanzerotti (74.50°S, 70.33°W) recognizes his research in the Antarctic. He was appointed to the National Science Board in 2004.

DUNCAN J. MCNABB

General McNabb is the former Commander, U.S. Transportation Command, Scott Air Force Base, Illinois. USTRANSCOM is the single manager for global air, land, and sea transportation for the Department of Defense. He had command of all DoD's strategic transportation assets and over 150,000 Soldier, Sailors, Airmen, Marines and civilians. This included responsibility for DoD's transportation support to the National Science Foundation and the Antarctic mission.

General McNabb graduated from the U.S. Air Force Academy in 1974. A command pilot, he has amassed more than 5600 flying hours in transport and rotary wing aircraft and has held command and staff positions at squadron, group, wing, major command, and Department of Defense levels. In his most recent assignments, General McNabb served as the Director for Logistics on the Joint Staff and was responsible for operational logistics and strategic mobility support to the Chairman of the Joint Chiefs of Staff and the Secretary of Defense. He then commanded the USAF Air Mobility Command and led 134,000 airmen in providing rapid global mobility, aerial refueling, special airlift, and aeromedical evacuation for America's armed forces. Before taking command of USTRANSCOM, Gen. McNabb served as the 33rd Vice Chief of Staff of the Air Force.

ROBERT E. SPEARING

Robert Spearing was the Deputy Associate Administrator for Space Communications within the NASA's headquarters Space Operations Mission Directorate. He retired from that position in April 2007. His duties encompassed all aspects of the NASA space communications program including policy development, strategic planning, program oversight, budget development and defense, and senior level interface with other government organizations both nationally and internationally. The program encompasses spaceflight mission operations, systems acquisition, architecture planning, data standards development, technology maturation, and spectrum management.

He has managed, both at Goddard Space Flight Center and NASA Headquarters, space and ground communications networks including the Space Network (TDRSS), the Deep Space Network (DSN), the Ground Network (GN), and the NASA Integrated Services Network (NISN).

Before his most recent assignment, Mr. Spearing held several positions at the division president and senior vice president level with private sector IT companies. His earlier career totaling 27 years was with the NASA at Goddard Space Flight Center where he rose to the position of Director of Mission Operations and Data Systems. He joined the Senior Executive Service in 1985.

Mr. Spearing was recognized for his accomplishments with a number of awards, including NASA's outstanding leadership medal and its distinguished service medal. His academic degree is in electrical engineering from Clarkson University.

Since his retirement from NASA Mr. Spearing has maintained a consulting practice.

DIANA H. WALL

A soil ecologist and environmental scientist, Dr. Wall is actively engaged in global research to sustain soils and has spent more than 20 seasons in the Antarctic McMurdo Dry Valleys examining how global changes impact soil biodiversity, ecosystem processes and ecosystem services.

Dr. Wall is a University Distinguished Professor and Director of the School of Global Environmental Sustainability at Colorado State University. She is a member of the U.S. Standing Committee on Life Sciences for the Scientific Committee on Antarctic Research (SCAR) and Scientific Chair of the Global Soil Biodiversity Initiative. She received the 2012 SCAR President's Medal for Excellence in Antarctic Research, and Wall Valley, Antarctica, was designated to honor her research contributions. In 2011 she was named as The British Ecological Society 2011 Tansley Lecturer.

Dr. Wall is a National Associate of the National Academy of Sciences, has an Honorary Doctorate from Utrecht University, the Netherlands, and is a Fellow of the American Association for the Advancement of Science. She served as member of the NRC Polar Research Board and the U.S. Commission of UNESCO, and was co-lead author of the Millennium Development Goals Committee Chapter of the Millennium Ecosystem Assessment. She is a Board Member of the World Resources Institute and Island Press, and has served as President of the Ecological Society of America, and the American Institute of Biological Sciences, and as Chair, Council of Scientific Society Presidents and other scientific societies. Diana is a Professor of Biology and received her Ph.D. from the University of Kentucky, Lexington.

APPENDIX III.
Governance Documents

III.1. ANTARCTIC TREATY SUMMARY

The 12 nations listed in the preamble (below) signed the Antarctic Treaty on 1 December 1959 at Washington, D.C. The Treaty entered into force on 23 June 1961; the 12 signatories became the original 12 consultative nations.

As of April 2010, 16 additional nations (Brazil, Bulgaria, China, Ecuador, Finland, Germany, India, Italy, Netherlands, Peru, Poland, Republic of Korea, Spain, Sweden, Ukraine, and Uruguay) have achieved consultative status by acceding to the Treaty and by conducting substantial scientific research in Antarctica. Russia carries forward the signatory privileges and responsibilities established by the former Soviet Union.

Another 20 nations have acceded to the Antarctic Treaty: Austria, Belarus, Canada, Colombia, Cuba, Czech Republic, Democratic Peoples Republic of Korea, Denmark, Estonia, Greece, Guatemala, Hungary, Monaco, Papua New Guinea, Portugal, Romania, Slovak Republic, Switzerland, Turkey, and Venezuela. These nations agree to abide by the treaty and may attend consultative meetings as observers.

The 48 Antarctic Treaty nations represent about two-thirds of the world's human population.

Consultative meetings have been held approximately every other year since the treaty entered into force, but since 1993 they have been held more frequently. Each meeting has generated recommendations regarding operation of the treaty that, when ratified by the participating governments, become binding on the parties to the treaty.

Additional meetings within the Antarctic Treaty system have produced agreements on conservation of seals, conservation of living resources, and comprehensive environmental protection. For detailed information about the Treaty System, please visit the Antarctic Treaty Secretariat web site at http://www.ats.aq.

What follows is the complete text of the Antarctic Treaty. The headings for each article were added by the National Science Foundation and are unofficial.

[preamble]

The Governments of Argentina, Australia, Belgium, Chile, the French Republic, Japan, New Zealand, Norway, the Union of South Africa, The Union of Soviet Socialist Republics, the United Kingdom of Great Britain and Northern Ireland, and the United States of America, Recognizing that it is in the interest of all mankind that Antarctica shall continue forever to be used exclusively for peaceful purposes and shall not become the scene or object of international discord; Acknowledging the substantial contributions to scientific knowledge resulting from international cooperation in scientific investigation in Antarctica; Convinced that the establishment of a firm foundation for the continuation and development of such cooperation on the basis of freedom of scientific investigation in Antarctica as applied during the International Geophysical Year accords with the interests of science and the progress of all mankind; Convinced also that a treaty ensuring the use of Antarctica for peaceful purposes only and the continuance of international harmony in Antarctica will further the purposes and principles embodied in the Charter of the United Nations; Have agreed as follows:

Article I [Antarctica for peaceful purposes only]

1. Antarctica shall be used for peaceful purposes only. There shall be prohibited, inter alia, any measures of a military nature, such as the establishment of military bases and fortifications, the carrying out of military maneuvers, as well as the testing of any type of weapons. 2. The present Treaty shall not prevent the use of military personnel or equipment for scientific research or for any other peaceful purposes.

Article II [freedom of scientific investigation to continue]

Freedom of scientific investigation in Antarctica and cooperation toward that end, as applied during the International Geophysical Year, shall continue, subject to the provisions of the present Treaty.

Article III [plans and results to be exchanged]

1. In order to promote international cooperation in scientific investigation in Antarctica, as provided for in Article II of the present Treaty, the Contracting Parties agree that, to the greatest extent feasible and practicable: (a) information regarding plans for scientific programs in Antarctica shall be exchanged to permit maximum economy and efficiency of operations; (b) scientific personnel shall be exchanged in Antarctica between expeditions and stations; (c) scientific observations and results from Antarctica shall be exchanged and made freely available. 2. In implementing this Article, every encouragement shall be given to the establishment of cooperative working relations with those Specialized Agencies of the United Nations and other international organizations having a scientific or technical interest in Antarctica.

Article IV [territorial claims]

1. Nothing contained in the present Treaty shall be interpreted as: (a) a renunciation by any Contracting Party of previously asserted rights of or claims to territorial sovereignty in Antarctica; (b) a renunciation or diminution by any Contracting Party of any basis of claim to territorial sovereignty in Antarctica which it may have whether as a result of its

activities or those of its nationals in Antarctica, or otherwise; (c) prejudicing the position of any Contracting Party as regards its recognition or nonrecognition of any other State's right of or claim or basis of claim to territorial sovereignty in Antarctica. 2. No acts or activities taking place while the present Treaty is in force shall constitute a basis for asserting, supporting or denying a claim to territorial sovereignty in Antarctica. No new claim, or enlargement of an existing claim, to territorial sovereignty shall be asserted while the present Treaty is in force.

Article V [nuclear explosions prohibited]

1. Any nuclear explosions in Antarctica and the disposal there of radioactive waste material shall be prohibited. 2. In the event of the conclusion of international agreements concerning the use of nuclear energy, including nuclear explosions and the disposal of radioactive waste material, to which all of the Contracting Parties whose representatives are entitled to participate in the meetings provided for under Article IX are parties, the rules established under such agreements shall apply in Antarctica.

Article VI [area covered by Treaty]

The provisions of the present Treaty shall apply to the area south of 60° South latitude, including all ice shelves, but nothing in the present Treaty shall prejudice or in any way affect the rights, or the exercise of the rights, of any State under international law with regard to the high seas within that area.

Article VII [free access for observation and inspection]

1. In order to promote the objectives and ensure the observation of the provisions of the present Treaty, each Contracting Party whose representatives are entitled to participate in the meetings referred to in Article IX of the Treaty shall have the right to designate observers to carry out any inspection provided for by the present Article. Observers shall be nationals of the Contracting Parties which designate them. The names of the observers shall be communicated to every other Contracting Party having the right to designate observers, and like notice shall be given of the termination of their appointment. 2. Each observer designated in accordance with the provisions of paragraph 1 of this Article shall have complete freedom of access at any time to any or all areas of Antarctica. 3. All areas of Antarctica, including all stations, installations and equipment within those areas, and all ships and aircraft at points of discharging or embarking cargoes or personnel in Antarctica, shall be open at all times to inspection by any observers designated in accordance with paragraph 1 of this Article. 4. Aerial observation may be carried out at any time over any or all areas of Antarctica by any of the Contracting Parties having the right to designate observers. 5. Each Contracting Party shall, at the time when the present Treaty enters into force for it, inform the other Contracting Parties, and thereafter shall give them notice in advance, of (a) all expeditions to and within Antarctica, on the part of its ships or nationals, and all expeditions to Antarctica organized in or proceeding from its territory; (b) all stations in Antarctica occupied by its nationals; and (c) any military personnel or equipment intended to be introduced

by it into Antarctica subject to the conditions prescribed in paragraph 2 of Article I of the present Treaty.

Article VIII [personnel under jurisdiction of their own states]

1. In order to facilitate the exercise of their functions under the present Treaty, and without prejudice to the respective positions of the Contracting Parties relating to jurisdiction over all other persons in Antarctica, observers designated under paragraph 1 of Article VII and scientific personnel exchanged under subparagraph 1(b) of Article III of the Treaty, and members of the staffs accompanying any such persons, shall be subject only to the jurisdiction of the Contracting Party of which they are nationals in respect to all acts or omissions occurring while they are in Antarctica for the purpose of exercising their functions. 2. Without prejudice to the provisions of paragraph 1 of this Article, and pending the adoption of measures in pursuance of subparagraph 1(e) of Article IX, the Contracting Parties concerned in any case of dispute with regard to the exercise of jurisdiction in Antarctica shall immediately consult together with a view to reaching a mutually acceptable solution.

Article IX [Treaty states to meet periodically]

1. Representatives of the Contracting Parties named in the preamble to the present Treaty shall meet at the City of Canberra within two months after date of entry into force of the Treaty, and thereafter at suitable intervals and places, for the purpose of exchanging information, consulting together on matters of common interest pertaining to Antarctica, and formulating and considering, and recommending to their Governments, measures in furtherance of the principles and objectives of the Treaty including measures regarding: (a) use of Antarctica for peaceful purposes only; (b) facilitation of scientific research in Antarctica; (c) facilitation of international scientific cooperation in Antarctica; (d) facilitation of the exercise of the rights of inspection provided for in Article VII of the Treaty; (e) questions relating to the exercise of jurisdiction in Antarctica; (f) preservation and conservation of living resources in Antarctica. 2. Each Contracting Party which has become a party to the present Treaty by accession under Article XIII shall be entitled to appoint representatives to participate in the meetings referred to in paragraph 1 of the present Article, during such time as the Contracting Party demonstrates its interest in Antarctica by conducting substantial scientific research activity there, such as the establishment of a scientific station or the dispatch of a scientific expedition. 3. Reports from the observers referred to in Article VII of the present Treaty shall be transmitted to the representatives of the Contracting Parties participating in the meetings referred to in paragraph 1 of the present Article. 4. The measures referred to in paragraph 1 of this Article shall become effective when approved by all the Contracting Parties whose representatives were entitled to participate in the meetings held to consider those measures. 5. Any or all of the rights established in the present Treaty may be exercised as from the date of entry into force of the Treaty whether or not any measures facilitating the exercise of such rights have been proposed, considered or approved as provided in this Article.

Article X [discourages activities contrary to Treaty]

Each of the Contracting Parties undertakes to exert appropriate efforts, consistent with the Charter of the United Nations, to the end that no one engages in any activity in Antarctica contrary to the principles or purposes of the present Treaty.

Article XI [settlement of disputes]

1. If any dispute arises between two or more of the Contracting Parties concerning the interpretation or application of the present Treaty, those Contracting Parties shall consult among themselves with a view to having the dispute resolved by negotiation, inquiry, mediation, conciliation, arbitration, judicial settlement or other peaceful means of their own choice. 2. Any dispute of this character not so resolved shall, with the consent, in each case, of all parties to the dispute, be referred to the International Court of Justice for settlement; but failure to reach agreement on reference to the International Court shall not absolve parties to the dispute from the responsibility of continuing to seek to resolve it by any of the various peaceful means referred to in paragraph 1 of this Article.

Article XII [review of Treaty possible after 30 years]

1. (a) The present Treaty may be modified or amended at any time by unanimous agreement of the Contracting Parties whose representatives are entitled to participate in the meetings provided for under Article IX. Any such modification or amendment shall enter into force when the depositary Government has received notice from all such Contracting Parties that they have ratified it. (b) Such modification or amendment shall thereafter enter into force as to any other Contracting Party when notice of ratification by it has been received by the depositary Government. Any such Contracting Party from which no notice of ratification is received within a period of two years from the date of entry into force of the modification or amendment in accordance with the provisions of subparagraph 1(a) of this Article shall be deemed to have withdrawn from the present Treaty on the date of the expiration of such period. 2. (a) If after the expiration of thirty years from the date of entry into force of the present Treaty, any of the Contracting Parties whose representatives are entitled to participate in the meetings provided for under Article IX so requests by a communication addressed to the depositary Government, a Conference of all the Contracting Parties shall be held as soon as practicable to review the operation of the Treaty. (b) Any modification or amendment to the present Treaty which is approved at such a Conference by a majority of the Contracting Parties there represented, including a majority of those whose representatives are entitled to participate in the meetings provided for under Article IX, shall be communicated by the depositary Government to all the Contracting Parties immediately after the termination of the Conference and shall enter into force in accordance with the provisions of paragraph 1 of the present Article. (c) If any such modification or amendment has not entered into force in accordance with the provisions of subparagraph 1(a) of this Article within a period of two years after the date of its communication to all the Contracting Parties, any Contracting Party may at any time after the expiration of that period give notice to the depositary

Government of its withdrawal from the present Treaty; and such withdrawal shall take effect two years after the receipt of the notice by the depositary Government.

Article XIII [ratification and accession]

1. The present Treaty shall be subject to ratification by the signatory States. It shall be open for accession by any State which is a Member of the United Nations, or by any other State which may be invited to accede to the Treaty with the consent of all the Contracting Parties whose representatives are entitled to participate in the meetings provided for under Article IX of the Treaty. 2. Ratification of or accession to the present Treaty shall be effected by each State in accordance with its constitutional processes. 3. Instruments of ratification and instruments of accession shall be deposited with the Government of the United States of America, hereby designated as the depositary Government. 4. The depositary Government shall inform all signatory and acceding States of the date of each deposit of an instrument of ratification or accession, and the date of entry into force of the Treaty and of any modification or amendment thereto. 5. Upon the deposit of instruments of ratification by all the signatory States, the present Treaty shall enter into force for those States and for States which have deposited instruments of accession. Thereafter the Treaty shall enter into force for any acceding State upon the deposit of its instrument of accession. 6. The present Treaty shall be registered by the depositary Government pursuant to Article 102 of the Charter of the United Nations.

Article XIV [United States is repository]

The present Treaty, done in the English, French, Russian, and Spanish languages, each version being equally authentic, shall be deposited in the archives of the Government of the United States of America, which shall transmit duly certified copies thereof to the Governments of the signatory and acceding States. In witness whereof, the undersigned Plenipotentiaries, duly authorized, have signed the present Treaty. Done at Washington the first day of December, one thousand nine hundred and fifty-nine.

For Argentina: Adolfo Seilingo and F. Bello
For Australia: Howard Beale
For Belgium: Obert de Thieusies
For Chile: Marcial Mora M., L. Gajardo V., and Julio Escudero
For the French Republic: Pierre Charpentier
For Japan: Koichiro Asakai and T. Shimoda
For New Zealand: G.D.L. White
For Norway: Paul Koht
For the Union of South Africa: Wentzel C. du Plessis
For the Union of Soviet Socialist Republics: V. Kuznetsov
For the United Kingdom of Great Britain and Northern Ireland: Harold Caccia
For the United States of America: Herman Phleger and Paul C. Daniels

III.2. PRESIDENTIAL MEMORANDUM 6646

Memorandum 6646 February 5, 1982
THE WHITE HOUSE
WASHINGTON

MEMORANDUM FOR
THE SECRETARY OF STATE
THE SECRETARY OF THE TREASURY
THE SECRETARY OF DEFENSE
THE SECRETARY OF THE INTERIOR
THE SECRETARY OF COMMERCE
THE SECRETARY OF TRANSPORTATION
THE SECRETARY OF ENERGY
THE DIRECTOR, OFFICE OF MANAGEMENT AND BUDGET
THE DIRECTOR OF CENTRAL INTELLIGENCE
CHAIRMAN, JOINT CHIEFS OF STAFF
DIRECTOR, ARMS CONTROL AND DISARMAMENT AGENCY
DIRECTOR, OFFICE OF SCIENCE AND TECHNOLOGY POLICY
ADMINISTRATOR, ENVIRONMENTAL PROTECTION AGENCY
DIRECTOR, NATIONAL SCIENCE FOUNDATION

SUBJECT: United States Antarctic Policy and Programs

I have reviewed the Antarctic Policy Group's study of United States interests in Antarctica and related policy and program considerations, as forwarded by the Department of State on November 13, 1981, and have decided that:

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

I have also decided that the National Science Foundation shall continue to:

- budget for and manage the entire United States national program in Antarctica, including logistic support activities so that the program may be managed as a single package;
- fund university research and federal agency programs related to Antarctica;
- draw upon logistic support capabilities of government agencies on a cost reimbursable basis; and
- use commercial support and management facilities where these are determined to be cost effective and will not, in the view of the Group, be detrimental to the national interest.

Other agencies may, however, fund and undertake directed short-term programs of scientific activity related to Antarctica upon the recommendation of the Antarctic Policy Group and subject to the budgetary review process. Such activities shall be coordinated within the framework of the National Science Foundation logistics support.

The expenditures and commitment of resource necessary to maintain an active and influential presence in Antarctica, including the scientific activities and stations in the Antarctic, shall be reviewed and determined as part of the normal budget process. To ensure that the United States Antarctic Program is not funded at the expense of other National Science Foundation programs, the OMB will provide specific budgetary guidance for the antarctic program.

To ensure that the United States has the necessary flexibility and operational reach in the area, the Departments of Defense and Transportation shall continue to provide, on a reimbursable basis, the logistic support requested by the National Science Foundation and to develop, in collaboration with the Foundation, logistic arrangements and cost structure required for effective and responsive program support at minimum cost.

With respect to the upcoming negotiations on a regime covering antarctic mineral resources, the Antarctic Policy Group shall prepare a detailed U.S. position and instructions. These should be forwarded for my consideration by May 15, 1982.

Ronald Reagan

APPENDIX IV.
State Department's Views

United States Department of State

Under Secretary for Economic Growth, Energy, and the Environment

Washington, D.C. 20520-7512

June 8, 2012

N. R. AUGUSTINE
JUN 18 2012

Mr. Norm Augustine
Chairman
U.S. Antarctic Program Blue Ribbon Panel

Dear Mr. Augustine: Norm

On behalf of the United States Department of State, I would like to convey our strong support for the U.S. Antarctic Program Blue Ribbon Panel's work and to thank you and the members of the Panel for this important effort. The United States stands in strong support of both the Antarctic Treaty and its purpose: to maintain Antarctica as a place of peace and to use the science that can only be performed there to benefit the entire planet.

The United States has critical national security, foreign policy and scientific interests in Antarctica and has the largest national presence on the continent (including three all-year stations and the only station at the South Pole). Our strategic interests in Antarctica and our leadership of the Antarctic Treaty system are reflected by this presence and our activities in the area. Hence, we must continue to send a strong signal of U.S. interest and involvement in Antarctica through our active and influential presence.

Our international scientific collaborations in Antarctica strengthen relationships with governments and build people-to-people ties while also ensuring that U.S. scientific standards and practices help establish international benchmarks. This scientific collaboration has indirect foreign policy benefits as well, promoting good will, strengthening political relationships, helping to foster democracy and civil society, and advancing the frontiers of knowledge for the benefit of all.

Sincerely,

Robert D. Hormats

APPENDIX V.
U.S. Science Support Activities in Antarctica and the Southern Ocean

The National Science Foundation (NSF) provides funding for scientific research, a directing mission of the U.S. Antarctic Program (USAP). The number of projects supported annually depends on the available funding, cost and complexity of the projects supported, and competition for resources from non-science activities such as major construction.

NSF also provides direct support for scientific research—the bridging of research requirements to the project-specific assignments of personnel, equipment, transportation, and infrastructure—through the Antarctic Support Contractor. Examples of 2010–2011 activities are noted below. Although not exhaustive, the accomplishments are representative of the types and extent of support required on an annual basis.

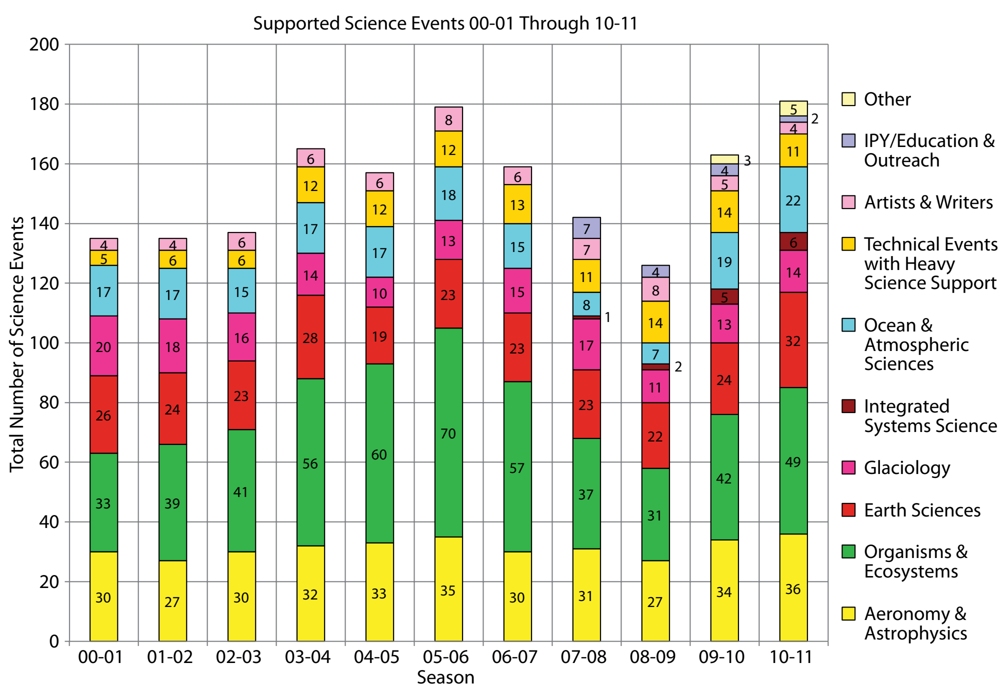


Figure V.1. U.S. Antarctic Program science events requiring logistics support from the USAP contractor, 2000–2001 through 2010–2011, sorted by scientific discipline.

V.1. USAP SCIENCE SUPPORT ACTIVITIES DURING THE 2010–2011 FIELD SEASON

V.1.1. SOUTH POLE

At the South Pole, 26 science projects required planning and support. Grantee deployments ranged from eight during the Austral winter to approximately 80 at the peak of the summer season. Contractor activities included:

- Installing several cryogenically cooled receivers for a multiyear cosmic microwave background effort at the Martin A. Pomerantz Observatory;
- Establishing a test-bed of radio frequency neutrino receivers and erecting three trial wind turbines for the IceCube Lab;
- Providing liquid helium and a cryogenics technician for various experiments;
- Installing the Gattini ultraviolet camera and the High Elevation Antarctic Terahertz telescope for testing and possible deployment at Dome A/Ridge A on the east Antarctic plateau; and,
- Replacing the data acquisition recording system and extending the Global Positioning System (GPS) antenna masts at the South Pole Remote Seismic Science Observatory.

V.1.2. MCMURDO AND NEARBY REGION (INCLUDING DRY VALLEYS)

More than 560 grantees in almost 100 research projects participated in McMurdo-based science. For a majority of the summer season, the Crary Lab was at more than 90 percent capacity. The contractor is responsible for providing science support and on-site training for grantees, as well as for specialized support that included:

- Coordinating a new type of forecast process to conform flying schedules for the Polar Earth Observing Network project;
- Providing data recorded from deep-field ceilometers to a researcher at Ohio State University;
- Supplying liquid helium for McMurdo Station and liquid nitrogen for McMurdo and South Pole stations;
- Constructing a temporary camp and launch pad on the sea ice adjacent to McMurdo Station to support the Concordiasi stratospheric balloon campaign;
- Designing, constructing and installing a Fe-Boltzmann Light Detection and Ranging (lidar) instrument (elecromagnetic interference required the contractor to undertake an extensive assessment to identify and remedy the issue);
- Supporting 20 scientific divers; and,
- Issuing 330,000 pounds (150,000 kilograms) of gear for field camps.

V.1.3 ANTARCTIC PENINSULA

Palmer Station supported 19 projects, with the laboratory at more than full capacity during the peak summer season. Other activities included:

- Providing a flow-through seawater system for ambient incubations;
- Modifying small boat operations and regulations to accommodate growing research needs;
- Remodeling the Terra Lab Building for installation of a Fabry-Perot Interferometer; and,
- Supporting six science divers and working on repairs to the station pier.

V.1.4 CONTINENTAL DEEP FIELD

The contractor supported field science events based out of both McMurdo and South Pole stations; the field camp population peaked at 333 personnel at 36 locations in December 2010. Contractor activities included:

- Supporting ice core drilling to 10,981 feet (3331 meters) and retrograding ice cores to McMurdo Station from the West Antarctic Ice Sheet Divide project;
- Supporting a project at Siple Dome, originally planned as a three-person refueling camp, when bad weather at the intended destination put the project in jeopardy;
- Supporting four balloon launches and planned balloon recoveries for the National Atmospheric and Space Administration's Long Duration Balloon Program; and,
- Relocating an Automated Weather Station, repairing two existing stations and installing new systems at Bear Peninsula, Thurston Island, and Evans Knoll for the Pine Island Glacier project.

V.1.5 SOUTHERN OCEAN

The Research Vessel Icebreaker (RVIB) *Nathaniel B. Palmer* (*Palmer*) and the Antarctic Research and Supply Vessel (ARSV) *Laurence M. Gould* (*Gould*) supported 32 science projects. Contractor activities included:

- Supporting a multinational science cruise involving the *Palmer* and the Swedish icebreaker *Oden* into the Amundsen Sea Polynya;
- Successfully recovering all data and all scientific instruments (except for one set of acoustic releases) from two Catenary Anchor Leg Moorings after automatic release failures on both moorings left them stranded;
- Assisting researchers who attached digital acoustic recording tags to 10 whales, deployed three "critter-cam" tags, and surveyed for krill populations;
- Installing a state-of-the-art, high-resolution three-dimensional GPS system on the *Gould*;
- Providing technical support for the continent-based Whillans Ice Stream Subglacial Access Research Drilling project through evaluations of proposed winch and wire systems and assistance in the development of the operational platforms that, although mounted on a sled, resemble working from the deck of a ship; and,
- Acquiring and putting into service a new Trace Metal Clean water sampling system for use on both the *Gould* and *Palmer*.

APPENDIX VI.

Evaluation of Alternative Sites to McMurdo

For the continental U.S. Antarctic Program (USAP)—McMurdo Station, South Pole Station, field camps, and research traverses—McMurdo Station is the present operational hub. (Palmer Station, on the Antarctic Peninsula, is essentially a separate USAP activity, supported and resupplied independently.)

The choice of the Ross Island location for the principal USAP base was historically guided by its proximity to the site chosen by polar explorers, notably the 1910-1913 Scott Expedition, as their base camp due to its being nearly the farthest south sea-accessible point in Antarctica in the majority of years, with a significant portion of the access route to the South Pole over the large, floating Ross Ice Shelf. The Ross Island location was chosen by Admiral Dufek in 1955 for Operation Deep Freeze 1 to support International Geophysical Year (IGY) activities. It was originally intended to locate that base at the Bay of Whales, where Admiral Byrd had set up four prior camps, but the IGY needed a site capable of supporting wheeled aircraft. As researchers and logistics experts increasingly learned, the Ross Island location is the best overall site for supporting continental research in Antarctica. This view is supported by an examination of the Ross Island location vis-a-vis other locations which might be considered.

In the analysis which follows, we assume that the USAP will continue to support activities at South Pole Station and research at various field camps in the interior of the Antarctic continent. These assumptions are essential to the analysis. We make note of alternatives were these assumptions are not valid.

What are the basic logistics requirements?

- Access to the continental interior has been dominated by air support for recent decades. With development of new technologies and practices, traverse support is now practical to some locations, saving fuel and lowering pollutants and cost. Hence a location for a USAP continental research and support facility must offer both skiway support for LC-130 and similar aircraft used in the interior, and also reasonable terrain, routing, and distances for ground traverses. Because aircraft carried-cargo capacity drops rapidly with increasing flight distance (and in Antarctica aircraft normally carry sufficient fuel to support their return to base), the continental support facility must be as close as practical to South Pole Station and much of the continental interior. This also reduces traverse time and cost, if overall routing is practical and safe.

- Considering that the USAP support facility exists primarily to support Antarctic continental science, that all such science and related activity is essentially expeditionary, and that expeditionary activities require a pyramid-like broad base of support, it is clear that the USAP continental support facility will need to be a substantial "town" providing housing, warehousing, fuel supply, ground transportation, assorted shops and maintenance activities, construction crews, marine support, aircraft support, laboratories and research support facilities—and power, water, and waste support and the like—with a population scaled roughly in proportion to the number of researchers supported in the field (including South Pole Station). Even with paying increasing attention to moving non-critical activities off-continent, a substantial presence is required to support continental science.

- The support facility itself should be located on ground (as opposed to ice or snow) if possible, because ice moves and shifts, and ice and snow are thermally unstable.

- Due to the huge cost advantage of marine cargo transportation over air cargo, the USAP continental support facility should be accessible to cargo ships and tankers of appropriate construction for Antarctic marine conditions.

- If at all possible, sufficient draft and seasonal ice conditions should exist for cargo ships and tankers to reach the base itself, rather than (for example) an ice shelf or seasonal ice sheet near the base. This requirement is not absolute, but considering the large size of the present USAP annual delivery of cargo and fuel, and U.S. and other nations' prior experiences off-loading onto an ice shelf or seasonal ice, this condition should be met for safety, personnel, expediency, and related issues.

- Due to the relatively large number of persons involved in the overall USAP continental support pyramid, and the need for moving some cargo by air, if at all possible the support facility should have reasonable access to a location for landing wheeled aircraft originating outside Antarctica, such as C-17 and commercial passenger aircraft from New Zealand, Australia, South Africa, or South America.

- To reduce transit distances to research sites—and hence reduce personnel, facilities, and a host of costs—the USAP continental support facility should if possible be located nearby a wide range of top-priority research sites.

The research reach of the USAP on-continent program includes nearly all the continent, when supported from the present sites of McMurdo and South Pole stations. The USAP ice-capable research and supply ship *Laurence M. Gould* (*Gould*) operates almost exclusively in the Antarctic Peninsula region. The USAP light/medium research icebreaker *Nathaniel B. Palmer* (*Palmer*) has operated most frequently in the Ross Sea region and east to the peninsula in recent years, but historically has also operated in other Antarctic marine regions. In Figure VI-1 the yellow lines show all Antarctic coastal locations where, if an airfield of some type could be established, a ski-equipped LC-130 aircraft could, in theory, reach the USAP South Pole station and return, with a partial ("greater than nil") cargo load. (The yellow line relates only to aircraft range to the USAP South Pole station. It does not indicate areas where ships can be safely and expeditiously unloaded, where airfields could be established, where a permanent base could be established, where an icebreaker or any other ship could reasonably reach, or where any of myriad other USAP requirements might be met.) The closest-to-South-Pole sites in Antarctic coastal regions are circled in red. "Coastal" in Antarctica means only a location where either the continent (itself mostly ice-covered) meets the ocean, or the leading edge of a massive floating ice shelf extruding from the continent reaches the ocean. In particular there is no necessary coincidence with a non-ice-covered region ("land"), a harbor, a location where an airfield can be constructed, a region an icebreaker or ice-strengthened ship can reach, and so forth. The USAP McMurdo Station is located on one of the three closest-to-South-Pole locations on the Antarctic coastal region. Terra Nova Bay in the western Ross Sea is another location considered for Antarctic bases.

One area of the Ross Ice Shelf well east of Ross Island has been used for U.S. and other Antarctic interior support: the Bay of Whales, near the eastern (left) end of the red-circled region on the Ross Ice Shelf. The Bay of Whales

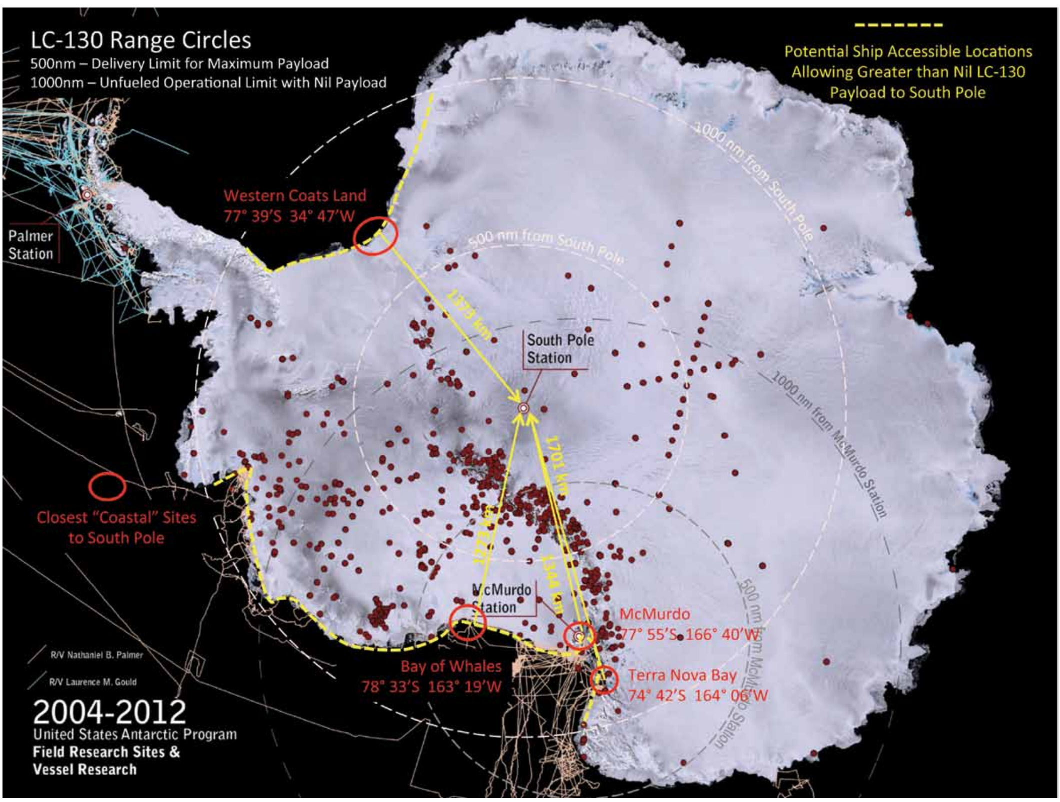


Figure VI.1. Map of Antarctica showing LC-130 range circles, potential ship-accessible locations capable in terms of aircraft range for supporting South Pole Station, and closest coastal sites offering support of South Pole Station (see text). Source: George Blaisdell was a natural ice harbor indenting the front of Ross Ice Shelf just north of Roosevelt Island (a completely ice-covered island). This is the southernmost point of open ocean. The natural harbor made the Bay of Whales a suitable point of entry and logistics support for several Antarctic expeditions, including the first three Byrd expeditions (1928–1941). The configuration of the Bay of Whales is continuously changing because it lies at the junction of two separate glacial ice systems, the movements of which are influenced by the presence of Roosevelt Island. Calving of the ice shelf formerly rendered the use of the bay as a port temporarily unusable. But the natural bay itself was eliminated in 1987 when an iceberg broke off from the Ross Ice Shelf, so there is no longer a natural harbor there.

The remainder of the northern front of the Ross Ice Shelf west (right) of Roosevelt Island has a very tall ice edge (much too tall to reach with ship's cranes, for example), and is a moving, floating, frequently calving ice shelf highly unsuitable for use as a major USAP scientific base and logistical support facility. There are times, however, at a few locations on the Ross Ice Shelf within traverse range from McMurdo Station where some ships' cranes can reach the top of the ice. In theory, then, it may be possible in those places to transfer cargo onto the shelf for traverse to McMurdo Station, and pump fuel into large containers for traversing. Considering safety issues such as the instability of the ice shelf (including the routes to McMurdo Station), the enormous amount of cargo and fuel delivered annually for the USAP, the cost and complexity of the traverse infrastructure, the large personnel complement that would need to be dedicated to this single aspect of station operation, and so forth, this is not regarded as a viable means of resupply for normal use, though it has potential for supporting partial/emergency/caretaker resupply in the event that ship access to McMurdo Station was temporarily not possible. Another similar mode of resupply would be to unload cargo and fuel onto nonglacial sea ice within traverse reach of the station, and transport them to the station. This is widely considered as unsuitable for the present-day USAP for essentially the same reasons as unloading on the glacial Ross Ice Shelf would be. The chief positive compared to unloading on the ice shelf would be shorter traverses, and the chief negative would be even more hazardous conditions. But this might be considered for partial/emergency/caretaker resupply in the event that ship access to McMurdo Station was temporarily not possible.

Also assessed was a Weddell Sea (Filchner Ice Shelf) region in the western Coats Land region. Assessment of this site for location and/or resupply of a major USAP facility follows nearly the same arguments as those made for the Ross Ice Shelf. For example, Berkner Island is a completely ice-covered island, there is very little exposed rock in the wider Western Coats Land coastal region, most of the Filchner Ice Shelf has a tall ice edge and is a moving, floating, frequently calving ice shelf. Small bases have been constructed in this vicinity, but not major stations on the order of one needed to support continental science.

Terra Nova Bay, along the coast of Victoria Land, is often ice free. The Italian (summer-only) Zucchelli Station is located in the bay, as will be the South Korean Jang Bogo Station. There is limited level rock exposure for station infrastructure, no deep water harbor to directly support cargo and tanker ship operations, weak sea ice which does not offer support for a sea-ice runway, no nearby or drivable site for a full-summer-season runway, very challenging (steep, crevassed) vehicle access to the continental interior, and relatively long air distance to the South Pole.

McMurdo Station on Ross Island has unique characteristics to Ross Island itself has large areas of permanently exposed rock, and it abuts a deep natural harbor. Ross Island is adjacent to the glacial McMurdo Ice Shelf, which is used to support a glacial ice runway, a skiway, and a balloon launch facility. Sea ice seasonally forms on McMurdo Sound, and provides a seasonal runway and area for sea-ice research. Surface access from Ross Island to the Antarctic interior is excellent.

Sea ice is an important consideration in siting of an Antarctic base. Partly because sea ice is not a dominating factor in the Antarctic Peninsula region—and partly for ease of access from outside Antarctica—many nations who wish to maintain an Antarctic presence have bases there. To support continental research and related operations, bases further south are required, and there, Antarctic sea ice must be taken into account. Sea ice conditions around Antarctica vary hugely with the seasons, and also vary year to year in any given location.

Figure VI.2 illustrates one reason the southern Ross Sea region was chosen for early polar exploration and present-day continental

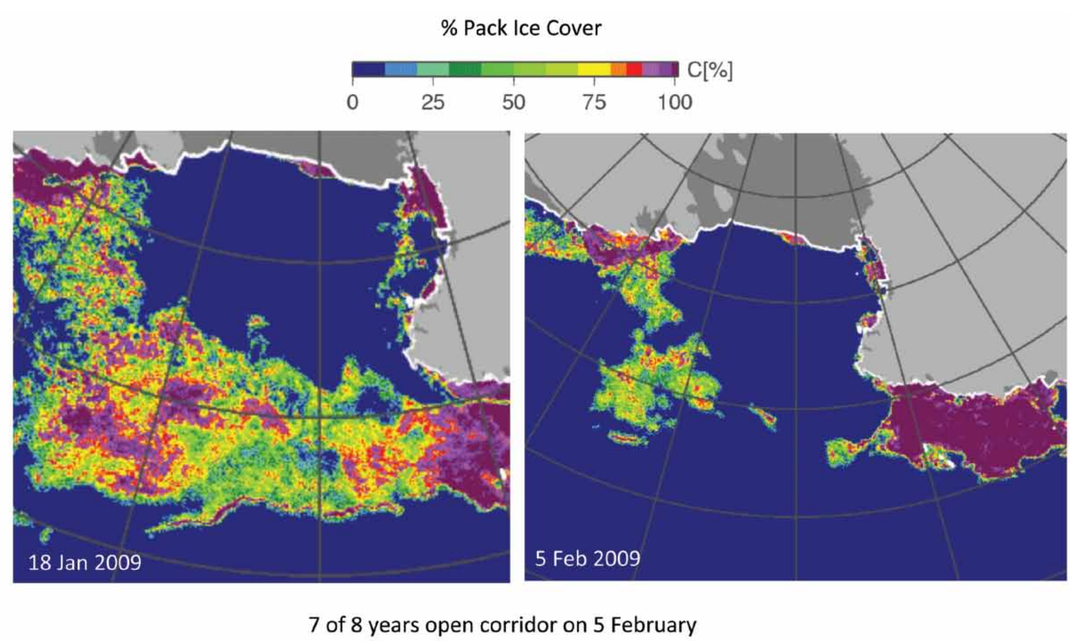


Figure VI.2. Early season and near-ice-minimum sea ice conditions around Antarctica during the 2011/12 Austral summer season.

research support: sea ice conditions are more favorable there. The figure does not, however, illustrate well an important consideration—every southern Ross Sea coastal site which is considered suitable for siting a logistics support facility requires icebreaker support to reach the site itself (as opposed to a seasonal ice edge or ice shelf edge), though Terra Nova Bay and the (former) Bay of Whales potentially require a lower level of icebreaking (somewhat less powerful icebreaker) than does the Ross Island location of McMurdo Station.

The physical characteristics of the four top locations examined by the Panel for locating a research and logistics support facility to support a continental research program, including South Pole Station, are compared in Table VI.1.

The Panel also compared the research opportunities offered nearby these four locations, partly because the closer the proximity to research sites the lower the effort and cost of supporting research at those sites. Table VI-2 lists the research-related attributes of McMurdo Station.

Table VI.1. Comparison of Logistical Factors Influencing Choice of Ross Island as the Present Location of Resupply and Support for USAP Continental Research and Related Activities

	MCMURDO	BAY OF WHALES	TERRA NOVA BAY	WESTERN COATS LAND
Harbor for 9-m Draft Ship	Yes; Winter Quarters Bay	No; Ice Shelf Edge	No	No; Ice Shelf Edge
Direct Ship to Shore Off-Load	Yes	Yes	No	Yes
Vertical Offset for Ship Off-Load	Land at Sea Level	15–50 m	N/A	40 m
Location for Wheeled Runway(s)	Yes; Sea Ice and Glacial Ice Shelf	No; Skiway	Yes; Active Glacier (reached only by helo)	No; Skiway
Length of Season for Wheeled Runway(s)	All year	N/A	Oct–Nov and Feb	N/A
Distance to South Pole (air)	1340 km	1270 km	1700 km	1370 km
Dates of Sea Ice Minimum	15 Jan – 15 Mar	11 Dec – 26 Feb	26 Dec – 10 Mar	10 Jan – 10 Mar
Sea Ice Extent at Minimum (typical)	10 nm	0 nm	0 nm	30 to >100 nm
Icebreaker Required for Access (typical)	Yes	Yes	Yes	Yes
Ice Free Land for Infrastructure	~1.5 mi^2	None	Some	None
Level Surfaces for Infrastructure	~0.75 mi^2	Unlimited; On Snow	Limited	Unlimited; On Snow
Stability of Infrastructure Site	High	Low	High	Moderate
Surface Access to Interior Antarctica	Easy; Via land to Ross Ice Shelf	Easy; Directly across Ross Ice Shelf	Difficult; Across active glaciers and through mountain ranges	Easy; Directly across Filchner Ice Shelf

In its analyses, the Panel considered South Pole Station's needs. McMurdo Station has the closest deep water port to the South Pole, an important consideration for transshipment of sea cargo by air and ground. No other Antarctic coastal location—except for the deep southward embayment of the Weddell Sea with sea ice notably more severe than that of the Ross Sea—is as far south as McMurdo's seaport at the southwest corner of the Ross Sea. Proximity to the South Pole and other regions of the Antarctic interior is critically important for economical high latitude transportation.

The proximity of the Ross Ice Shelf to McMurdo also has allowed the building of Antarctica's most active ice runway, allowing the routine operation of large wheeled aircraft from off-continent including C-17, Airbus 319s, and Boeing 757s. This is the only combination of deep water port and large-aircraft airfield on the continent, and identifies McMurdo as an excellent multimodal operations location.

The distance from McMurdo to South Pole is within the effective LC-130 cargo delivery range. An LC-130 burns 4,400 gallons of fuel to

Table VI.2. Scientific Attributes of McMurdo Station and Nearby Region

	KEY ADVANTAGES	LIMITATIONS
Dry Valleys	Proximity (helicopter accessible); Vast array of valuable research topics and sites available	Distance requires intermediate refueling camp for helicopters
Sea Ice and Glacial Ice Shelf	Proximity (easy access by light vehicle or helicopter) to largest ice shelf; Persistence	None
Ocean Biology and Chemistry (McMurdo Sound)	Proximity (easy access through sea ice for divers, fishing); Persistent ice cover for stable research platform	Persistent ice cover limits water access and biological diversity
Penguins	Several major rookeries nearby; Several species frequent region; Extent and persistence of sea ice allows natural and long-term observation of controlled populations	Emperor and Adélie species
Seals	Several species summer in McMurdo Sound; Persistence of sea ice allows natural and long-term observation of controlled populations	Weddell species
Whales	Several species frequent McMurdo Sound	Orca and Minki species
Volcanology	Active (Mt. Erebus) and extinct volcanoes within easy helicopter range	None
Long-Duration, High-Altitude Ballooning	Good latitude; Good launch site characteristics	None
Glaciology	Proximity (easy helo access to glaciers in the northern Transantarctic Mountains, icebergs, and snowfields and ice shelf features)	Ice streams are distant
Geospace & Upper Atmosphere	Highest geomagnetic latitude; Conjugacy to sites in northern Canada	None
Gateway to Interior Field Sites	Good accessibility to significant portions of East and West Antarctica, all of the Ross Ice Shelf, and nearly all of the Transantarctic Mountains	Much of the region from 115°W longitude (clockwise) to 115°E not easily accessible with current capabilities
Gateway to South Pole	Three hour flying connection; Trail established for overland traverse	None

deliver 3,500 gallons of fuel plus 2,000 pounds (910 kilograms) of cargo to the South Pole. Lengthening that distance only 220 miles would increase the fuel burned to 5,100 gallons and cut the fuel delivered to 2,800 gallons, hiking the ratio of fuel burned to fuel delivered from 1.3 to 1.8 to 1.

The geography is also well suited to surface traverse of cargo from McMurdo to South Pole. The Ross Ice Shelf provides a nearly level route to 84°S, about two-thirds the distance to the pole. After a climb through mountain passes to the polar plateau, the rest of the way also is nearly level.

While the linkage of South Pole to McMurdo is an excellent fit for both surface and air delivery, McMurdo also is well situated to support the extensive reach of surface and air operations across the continent that make the U.S. Antarctic Program so productive scientifically.

If McMurdo Station existed only to support local-area research, its present location would still be desirable due to the wide range of scientific interests in the region. It is possible, however, that if the USAP no longer supported South Pole Station or deep field on-continent research, and if McMurdo Station were closed, a much smaller, local-science-only station might be placed across McMurdo Sound at Marble Point, because that location is closer to more local research areas. Such a base would conceivably be small enough—if science activities were constrained—to risk its much-reduced logistics support to ice edge off-load, traversing fuel and supplies across the ice, or, much more expensively, nearly exclusively via air, via building a hard runway at Marble Point. But this is not the case—McMurdo's critical function to the USAP is as an intermodal freight depot, resupplied by sea, supporting its continental activities. The present location fits this very well.

South Pole Station and on-continent research are dependent upon marine resupply. Ship-based resupply into McMurdo Station requires vessels to travel through the Southern Ocean, the Ross Sea and McMurdo Sound. Southern Ocean storms usually only slightly slow the progress of the USAP resupply vessels in their transit from New Zealand or Australia, their typical final port call points before steaming for McMurdo. The Ross Sea is subject to annual build-up and retreat of seasonal sea ice. Pack ice in the Ross Sea is currently the controlling factor in the overall timing of the resupply activity, which requires approximately 18-22 days of operations in the ice-susceptible waters south of 60°S.

Sea ice in the Ross Sea does not simply grow north from the Antarctic continent and retreat south from the ultimate ice edge over the course of a year. At the beginning of the Austral summer season, a polynya-like behavior in the southern Ross Sea results in the growth of a large circular melt area at the same time as the northern edge of the sea ice begins to retreat southward. In many years, a nearly or completely ice-free corridor naturally opens to allow ships to pass through the Ross Sea with little likelihood of the need for icebreaker support in the region north of McMurdo Sound. Data from U.S. sources show that, on average, an ice-free passage is most likely to be present between 21 January and 4 March, but the duration of open water in the Ross Sea varies interannually from as little as a few days to more than two months.

Timing the USAP marine resupply dates to align with the window when the least amount of Ross Sea ice is present is the most efficient and also represents the least amount of risk. Use of this window of opportunity, skewed toward its beginning to provide a safety margin against unforeseen delays, has for many years permitted the USAP to resupply successfully.

The final marine approach to McMurdo Station requires icebreaking. The chief limitation of the Ross Island location is usually thought to be that an icebreaker is required annually to open a channel in the sea ice for shipborne delivery of cargo and fuel.

The recent use of contracted icebreakers which require no fuel from McMurdo (unlike the Coast Guard icebreakers that had been used previously), combined with energy saving initiatives, have provided greater flexibility in scheduling the fuel tanker and the cargo ship to coincide with more favorable ice conditions. Flexibility for later arrival of the fuel tanker is important because there is a later, naturally-occurring local ice break-out in McMurdo Sound which can be relied on to do some of the work previously done by icebreakers. Thus, since 2007, icebreaking activities have been initiated after 8 January to take advantage of this naturally-occurring sea ice behavior. Icebreaking to prepare for arrival of the first resupply ship now requires about seven days, a savings of 13 to 23 days of icebreaker effort (and cost) over past practice. Additionally, this

Table VI.3. Recent First and Last Dates of an Ice-Free Corridor Through the Ross Sea

ROSS SEA PACK ICE STATISTICS (0 TENTHS ICE)			
YEAR	FIRST OPEN DATE	LAST OPEN DATE	DURATION OF OPEN PERIOD
2003	3 Feb	10 Feb	7
2004	13 Jan	26 Feb	44
2005	5 Jan	9 Mar	63
2006	6 Jan	14 Mar	67
2007	12 Jan	8 Mar	55
2008	16 Feb	18 Feb	2
2009	1 Feb	5 Mar	32
2010	10 Jan	9 Mar	58
2011	5 Jan	17 Mar	71
Average	21 Jan	28 Feb 09	44
Earliest (Shortest)	5 Jan	10 Feb 09	(2)
Latest (Longest)	16 Feb	14 Mar 09	(67)

flexibility has allowed increased use of the icebreaker for science activities when not engaged in icebreaking.

It is clear from the historical data that after January 15th, on the average, a long-duration window opens during which the icebreaking distance to reach McMurdo station is minimum, and that optimum Ross Sea marine transit—in terms of minimal sea ice en route—takes place approximately three weeks after the start of the local ice minimum.

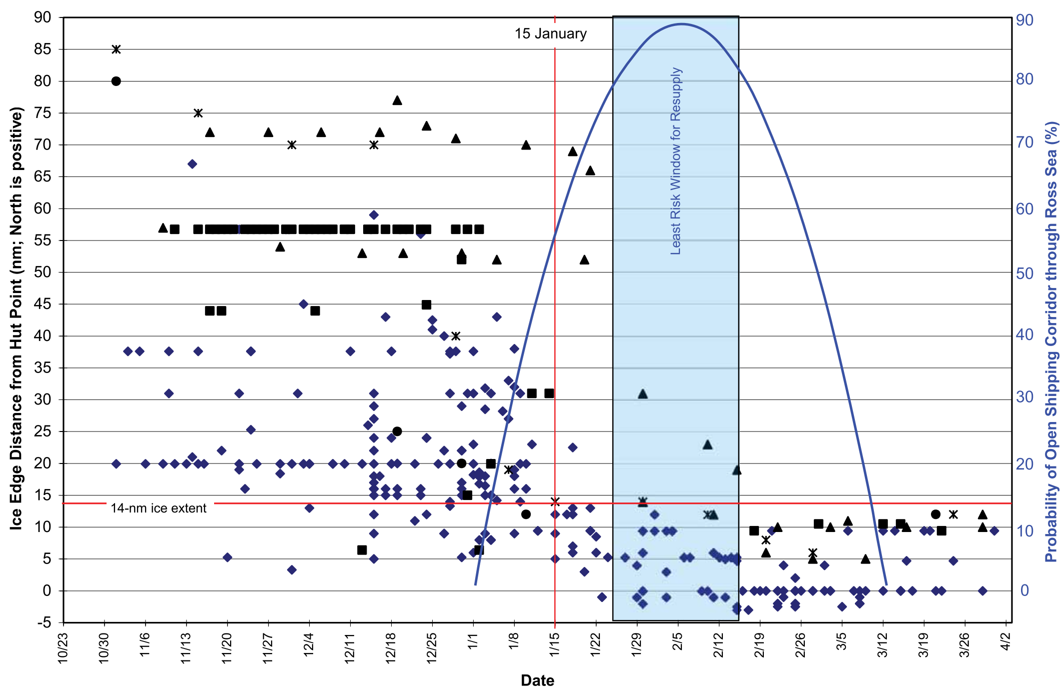


Figure VI.3. Long-term ice-edge-to-McMurdo distance data, month by month, along with calculated probability of open-sea transit through the Ross Sea north of McMurdo Sound.

APPENDIX VII.

Recommendations and Implementing Actions

VII.1. RECOMMENDATIONS

The Panel's ten recommendations are presented below in priority order, with brief parenthetical examples of implementing actions. Supporting information is presented in the relevant sections of this report.

1. ANTARCTIC BASES. Continue the use of McMurdo, South Pole, and Palmer Stations as the primary U.S. science and logistics hubs on the continent. (There is no reasonable alternative, particularly concerning McMurdo.)

2. POLAR OCEAN FLEET. Restore the U.S. polar ocean fleet (icebreakers, polar research vessels, mid-sized and smaller vessels) to support science, logistics, and national security in both polar regions over the long term. (Follow through on pending action in the President's FY 2013 Budget Request for the USCG to initiate the design of a new icebreaker.)

3. LOGISTICS AND TRANSPORTATION. Implement state-of-the-art logistics and transportation support as identified in this report to reduce costs and expand science opportunities continent-wide and in the Southern Ocean. (Replace some LC-130 flights with additional traverse trips by automating the traverse and by constructing a wheel-capable runway at South Pole Station for C-17 use; reduce the LC-130 fleet.)

4. MCMURDO AND PALMER FACILITIES. Upgrade or replace, as warranted by an updated master plan, aging facilities at McMurdo and Palmer Stations, thereby reducing operating costs and increasing the efficiency of support provided to science projects. (Modify or replace the pier and reconstruct the boat ramp at Palmer Station, install fire suppression—with backup power—in unprotected berthing and key operational facilities, upgrade medical clinics, and improve dormitory use to prevent the transmission of illnesses.)

5. USAP CAPITAL BUDGET. Establish a long-term facilities capital plan and budget for the USAP. (Provide phased plan for modernization of USAP facilities.)

6. SCIENCE SUPPORT COSTS. Further strengthen the process by which the fully burdened cost and technological readiness of research instrumentation and observing systems, as well as overall projects, are considered in the review and selection of science projects. (Increase overall awareness of the true cost of resources provided in Antarctica.)

7. COMMUNICATIONS. Modernize communication capabilities in Antarctica and the Southern Ocean to enable increased science output and reduced operational footprint. (Provide increased bandwidth on as well as to and from the continent.)

8. ENERGY EFFICIENCY. Increase energy efficiency and implement renewable energy technologies to reduce operational costs. (Provide additional wind turbine generators at McMurdo, better insulate selected buildings, and invest in technology for converting trash-to-energy and burning waste oil so that it does not have to be returned to the United States.)

9. INTERNATIONAL COOPERATION. Pursue additional opportunities for international cooperation in shared logistics support as well as scientific endeavors. (The existence of numerous national stations in the peninsula region offers a particularly promising opportunity for an international supply system.)

10. ANTARCTIC POLICY. Review and revise as appropriate the existing documents governing Antarctic Policy (Presidential Memorandum 6646 of 1982 and Presidential Decision Directive 26 of 1994) and implementing mechanisms for Antarctica, taking into account current realities and findings identified by the National Research Council report and the present report. (Focus on policy and national issues as opposed to operational matters.)

VII.2. COMPILATION OF IMPLEMENTING AND ANCILLARY ACTIONS

Listed below are all implementing and ancillary actions recommended by the Panel in the order they appear in Chapter 4 of the report.

RESEARCH SUPPORT: RESEARCH FACILITIES AND EQUIPMENT

ACTION 4.1-1. *Extend the observing season, especially on the continent, and improve the communications network to operate throughout the year to enable automated data collection and transmission from remote instruments.*

ACTION 4.1-2. *Sponsor workshops to promote the development of remote-sensing and other equipment that will minimize the number of people on the ice and on research vessels.*

ACTION 4.1-3. *Aggressively pursue the acquisition of a new polar research vessel with enhanced capabilities to ensure U.S. leadership in pursuing scientific endeavors in the Southern Ocean. Improved capabilities to deploy and recover advanced remote-sensing assets should be a key feature of such a vessel.*

ACTION 4.1-4. *USAP and its international partners should develop a strategy for defining components of the continental-scale long-term observing system to ensure that all components of the system are compatible and complementary.*

ACTION 4.1-5. *Pursue development, with international partners as appropriate, of a comprehensive, coordinated, and networked interdisciplinary observing and prediction system that would encompass all the major elements of the Antarctic environment—the atmosphere, terrestrial, marine and subglacial ecosystems, permafrost, ice shelves, ice sheets, subglacial habitats of the interior as well as the ocean and ocean sea ice.*

ACTION 4.1-6. *Increase the available communications bandwidth to Palmer Station, South Pole Station, McMurdo Station, and the field camps in Antarctica.*

ACTION 4.1-7. *Improve the process for developing plans for fielding complex projects, including realistic budgets and schedules that incorporate adequate contingency, a defined risk analysis, and mitigation measures.*

PEOPLE

ACTION 4.2-1. *Establish a "suggestion box" system that encourages the submission of ideas and issues, and ensure that consideration of suggestions is thorough and communicated to the USAP community.*

ACTION 4.2-2. *Working with the USAP prime contractor, improve the stability and professionalism of the workforce and reduce the number of support personnel on the ice, with a goal of a 20 percent smaller workforce at McMurdo Station. (This reduction should be achieved through investments in infrastructure and other improvements to the supply chain, plus process reengineering and the application of modern business systems.)*

ACTION 4.2-3. *Ensure that the support population for field camps is streamlined and appropriately matched to the needs of the science activities.*

ACTION 4.2-4. *Increase overall awareness of the true cost of resources provided in Antarctica.*

ACTION 4.2-5. *Foster a culture of efficiency and continuous improvement in all aspects of research and operations in order to reduce the overall footprint of activities and provide greater agility to respond to emerging areas of research. Areas of focus include reinforcing the notion that research supported by the USAP should be composed of activities that can only be performed, or are best performed, in the Antarctic.*

TECHNOLOGY

ACTION 4.3-1. *Establish a capital plan and capital budget. The investment strategy should emphasize upgrades to essential facilities, logistics and support infrastructure as well as new technology, all aimed at streamlining operations for efficiency and cost-effectiveness. Included is the establishment of long-range master plans for facilities, logistics, support infrastructure, and technology for each of the three major USAP stations.*

ACTION 4.3-2. *Continue to sponsor workshops that promote the development of remote sensing equipment that will minimize the number of people on the ice and on research vessels. Such workshops should encourage polar researchers to participate in NSF's Major Research Instrumentation program.*

ACTION 4.3-3. *Establish a dedicated DARPA-like polar technology development program within NSF and with other agencies. This could include investments in cyberinfrastructure and activities to enable broad observing systems as recommended in the 2011 NRC report.*

ACTION 4.3-4. *Foster mechanisms to ensure the readiness and training of scientists, engineers, modelers, and technologists that participate in Antarctic and Southern Ocean research.*

ACTION 4.3-5. *Ensure that instrumentation to be deployed for operation at remote field sites has passed a thorough pre-deployment testing process, including environmental testing, and has been developed to enable module-level serviceability and remote calibration.*

ACTION 4.3-6. *Adopt more formal approaches such as successful ones practiced by industry and other agencies for test and evaluation of new systems and technologies and formalize the assessment of technological readiness of new equipment and processes.*

TRANSPORTATION

ACTION 4.4-1. *Continue the use of McMurdo, South Pole, and Palmer Stations as the primary U.S. science and logistics hubs on the continent.*

ACTION 4.4-2. *Invest in robotics and automation to improve the efficiency of the delivery of cargo and fuel via overland traverse, particularly between McMurdo and South Pole stations.*

ACTION 4.4-3. *Work with DoD and ANG to maximize use of dedicated C-17s and thereby refocus most LC-130 operations to support field activities.*

ACTION 4.4-4. *Consider more widespread use of airdrops for resupply operations, particularly for South Pole Station and deep field camps.*

ACTION 4.4-5. *Reduce the flying hour program and the LC-130 fleet by 40 percent, and modify one of the remaining aircraft as an airborne science platform to both reduce costs and expand science opportunities continent wide.*

ACTION 4.4-6. *Continue to explore lighter-than-air hybrid airship technology for possible Antarctic use.*

ACTION 4.4-7. *Make the Pegasus Runway more permanent, including support facilities, fire rescue, air traffic control, and fuel support. Examine the possibility of retaining Williams Field for LC-130 operations to eliminate the need to construct the Sea Ice Runway each year and to provide an alternate runway in the McMurdo Area, eliminating the single point failure represented by the Pegasus Runway. In addition, compact roads to the runways and at Williams Field to reduce wear and tear on skis and the aircraft.*

ACTION 4.4-8. *Construct a compacted snow runway at South Pole Station that is capable of supporting C-17 operations to allow heavy airlift from McMurdo Station or direct resupply of South Pole Station from Christchurch when conditions warrant.*

ACTION 4.4-9. *Modernize the LC-130s with eight-bladed propellers, ADVENT engine modification, SABIR, and crevasse detection radar, and begin building a transition plan to the LC-130J.*

ACTION 4.4-10. *Seek alternate cold weather fuels or otherwise develop alternate sources for AN-8 in order to reduce the refining costs associated with procuring this particular blend of fuel and the transportation costs involved in picking it up from these refineries.*

ACTION 4.4-11. *Continue to examine options to support and improve the delivery and retrograde of cargo to and from McMurdo Station. For example, work with DoD and MSC and in consultation with the appropriate New Zealand authorities to explore the possibility of incorporating the use of commercial vessels to move cargo throughout the year from Port Hueneme to USAP staging facilities in Christchurch and also the use of vessels sourced from New Zealand to deliver cargo to McMurdo.*

ACTION 4.4-12. *Follow through on pending action in the President's FY 2013 Budget Request for the USCG to initiate the design of a new icebreaker, giving due consideration to a design that addresses the USAP's needs, including for example the potential ability to conduct science from the icebreaker itself.*

ACTION 4.4-13. *In collaboration with DoD, DHS and the Department of State, and with oversight from OSTP and OMB, ensure reliable, long-term access to icebreaking services for resupply of McMurdo and South Pole stations.*

ACTION 4.4-14. *Collaborate within NSF and with the University-National Oceanographic Laboratory System and other interested federal agencies to develop science mission requirements for Antarctic Peninsula marine operations in the post-2020 time frame to address sea support after the* Gould *is no longer suitable or available.*

ACTION 4.4-15. *Retrofit the Palmer Station off-load platform to include sufficient draft to and at the platform to accommodate a range of resupply and research vessels, improve small boat access, and introduce RIBs into the Palmer Station boating fleet.*

ACTION 4.4-16. *In consultation with the NSF Division of Ocean Sciences, and other marine research agencies as appropriate, assign a regional or coastal class research vessel to Palmer Station during the Austral summer.*

ACTION 4.4-17. *Commence discussions with counterparts in Chile and the U.K. regarding collaborative logistics and ocean-based research operations in the Antarctic Peninsula region, including personnel transfer to U.S. research sites in the peninsula via King George Island or Rothera Station.*

SUPPLY CHAIN

ACTION 4.5-1. *Develop and implement a vehicle modernization plan, possibly in conjunction with a major vehicle manufacturer.*

ACTION 4.5-2. *Expand the vehicle maintenance facility at McMurdo, adding four bays and replacing the existing bay doors with insulated models.*

ACTION 4.5-3. *Provide a single consolidated facilities maintenance building to house carpentry, electrical, plumbing, pipefitting, and metal work at McMurdo Station.*

ACTION 4.5-4. *Work with Christchurch International Airport and Lyttelton Port of Christchurch to assure that USAP needs are considered in the master plans now being produced by New Zealand.*

ACTION 4.5-5. *Consolidate warehousing and storage at McMurdo Station into a single inside facility, totaling an estimated 300,000-400,000 square feet, and minimize outside storage; in the interim, correct deficiencies in flooring so that they no longer represent safety risks to personnel needing to work in the warehouses.*

ACTION 4.5-6. *Reevaluate on-site transportation and personnel "touches" to streamline product flow, especially at McMurdo Station.*

ACTION 4.5-7. *Consolidate hazardous materials at Palmer Station into a building that is properly constructed and located away from the station.*

ACTION 4.5-8. *Replace the government-owned MAPCON materials management system with a modern, commercially available, inventory management system.*

ACTION 4.5-9. *Develop a multifactor life-cycle planning and implementation process to better organize, implement, and prioritize supply chain projects.*

ENERGY AND UTILITIES

ACTION 4.6-1. *Develop a priority list for improving the insulation of buildings and implement an appropriate plan that includes the previously identified seven buildings with the poorest energy efficiency that are expected to remain in use.*

ACTION 4.6-2. *Together with the New Zealand Antarctic Programme, develop a plan to expand the highly successful Ross Island wind turbine project to achieve the maximum practicable wind energy penetration for the unified McMurdo-Scott Base power grid.*

ACTION 4.6-3. *Together with DOE, determine the feasibility and cost of converting the waste wood, paper, and cardboard into building heat and electricity at McMurdo Station and substantially reduce the amounts that must be transported off-continent.*

ACTION 4.6-4. *Develop a plan to maximize solar generation of heat and electricity at all sites, including both fixed-base and field locations.*

ACTION 4.6-5. *Together with New Zealand, reexamine geothermal opportunities for producing heat and electricity at McMurdo Station.*

ACTION 4.6-6. *Introduce the solar garage concept at South Pole Station and other locations where similar operating and environmental conditions prevail.*

COMMUNICATIONS AND INFORMATION TECHNOLOGY

ACTION 4.7-1. *Augment the NSF Program Office for C&IT to accommodate its growing responsibilities.*

ACTION 4.7-2. *Develop and implement a new architecture for C&IT that is consistent with future program needs, including the provision of increased bandwidth.*

ACTION 4.7-3. *Complete the ongoing assessment of alternatives for future South Pole bulk date transfer service and baseline an approach that does not depend on the TDRS system or GOES satellites. Consider both satellite and terrestrial capabilities, including a "New Start" (new satellite program) option that would provide high reliability and long-term capability.*

ACTION 4.7-4. *Identify those science projects that can benefit from real-time experimental data delivery to the United States and other off-ice sites and establish new Service Level Agreements that reduce the demand for scientists to be on-site in Antarctica.*

ACTION 4.7-5. *Assess the risk posture of the Black Island facility and develop and implement a plan to modernize it over the next five years.*

ACTION 4.7-6. *Identify all legacy elements of the C&IT program that represent serious risk to the mission and develop and implement a plan to mitigate those risks.*

HUMAN CARE

ACTION 4.8-1. *As part of the master plan for Palmer Station, consider health and usability issues, including upgrading or replacing housing and baths as needed.*

ACTION 4.8-2. *Consider a dedicated dorm for those with similar work schedules, such as those working at night at McMurdo Station and researchers, aided by commercially available software to more efficiently and effectively manage housing and minimize the number of residents per room.*

ACTION 4.8-3. *While the Panel commends the ongoing efforts to provide freshly prepared foods at the stations and on ships, the USAP is encouraged to emphasize the provision of a variety of fresh vegetables and fruits to those deployed and the hiring of highly competent, motivated galley staff.*

ACTION 4.8-4. *Investigate means to reduce the time, personnel and energy required for food preparation at remote field camps, such as by utilizing modern prepared foods requiring reduced energy in their preparation, similar to those used in military operations.*

ACTION 4.8-5. *Upgrade or build a centralized recreation building at McMurdo, or make recreation a principal function of a centralized multipurpose facility.*

ACTION 4.8-6. *Investigate and establish practices that would improve communications between the various colocated deployed teams at all Antarctic sites—including NSF personnel, contractor support staff, military personnel, and scientists—and thus promote increased overall awareness and appreciation of ongoing activities, interests, and priorities.*

ACTION 4.8-7. *Promulgate a uniform set of safety policies and procedures for USAP operations and research that promote a culture of workplace safety throughout the program. Greatly increase usage of signage and other forms of communication in promoting safety.*

ACTION 4.8-8. *Provide training to all participants in the use of fundamental operational risk management tools that can be continuously employed to identify and avoid high-risk safety situations.*

ACTION 4.8-9. *State in a written procedure that the authority and responsibility of the ASC is to enforce safe practices among its employees, scientists, and subcontractors.*

ACTION 4.8-10. *Provide statistics concerning safety mishaps and other key measures of station performance to the participant population in a readily available form.*

ACTION 4.8-11. *Investigate the feasibility of storing McMurdo fire protection water in a gravity tank to improve reliability of the supply and the quantity of water available.*

ACTION 4.8-12. *Address safety concerns at Palmer Station regarding fire protection associated with personnel berthing in direct proximity to kitchen, power plant, and industrial workspaces.*

ACTION 4.8-13. *Undertake a comprehensive evaluation of safety hazards and repeat periodically.*

ACTION 4.8-14. *Upgrade medical facilities and equipment at USAP Antarctic continental and marine locations on a routine basis, with current priority to McMurdo Station, and introduce an electronic medical records management system.*

ACTION 4.8-15. *Revise the criteria for physical qualification examinations to better and more individually match qualification to task, location, and risk.*

ACTION 4.8-16. *Continue to provide basic clothing for safety and health reasons (rather than leaving to individual option).*

ACTION 4.8-17. *Provide modern replacements for obsolete or inappropriate field gear as the latter ends its useful life.*

ACTION 4.8-18. *Provide greater clarity and consistency in guidance concerning gear approved for use in the field and when flying.*

ENVIRONMENTAL STEWARDSHIP

ACTION 4.9-1. *Expedite removal or conversion into energy of the significant volume of waste remaining at South Pole Station.*

ACTION 4.9-2. *Install a modern wastewater treatment facility at Palmer Station and review the priority now assigned to providing such facilities for South Pole Station.*

ACTION 4.9-3. *Increase emphasis on water conservation, especially at McMurdo Station, and improve understanding of water costs among all deployed participants.*

ACTION 4.9-4. *Utilize frequently updated scientific data concerning climate change to better understand and plan for its impacts on operation of the USAP, its budget and its obligations under the Antarctic Treaty.*

INTERNATIONAL CONSIDERATIONS

ACTION 4.10-1. *Periodically review the activities of other national Antarctic programs to identify opportunities for collaborative research, logistics, energy provision, technology, infrastructure, education and other areas that would eliminate duplication of effort, standardize equipment, and reduce costs to the international community.*

ACTION 4.10-2. *Periodically review the current and projected shared-service "balance sheet" to assure equity of international cooperative activities.*

ACTION 4.10-3. *Initiate an effort to better "standardize" equipment and through COMNAP to reduce costs and eliminate unnecessary redundancy.*

ACTION 4.10-4. *Engage with Italy, New Zealand, and South Korea to identify opportunities for collaborative science and logistics arrangements that would appropriately benefit all three programs due to the proximity of their stations in the Ross Sea region.*

GOVERNANCE OF U.S. PROGRAM

ACTION 4.11-1. *Review PM 6646 and PDD/NSC-26 to update these governing policy documents, as necessary, to ensure full implementation of their requirements under today's environment.*

APPENDIX VIII. Bibliography

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APPENDIX IX.
Abbreviations and Acronyms

AABW	Antarctic Bottom Water
ABS	American Bureau of Shipping
ADVENT	Adaptive Versatile Engine Technology
AGO	Automatic Geophysical Observatories
ANDRILL	Antarctic Geological Drilling
ANG	Air National Guard
ARSV	Antarctic Research and Supply Vessel
ASC	Antarctic Support Contractor (Lockheed Martin)
ATS	Antarctic Treaty System
AUV	Autonomous Underwater Vehicle
AWS	Automatic Weather Station
BITF	Black Island Telecommunications Facility
C&IT	Communications and Information Technology
CAML	Census of Antarctic Marine Life
CFC	Chlorofluorocarbon
COMNAP	Council of Managers of National Antarctic Programs
DARPA	Defense Advanced Research Projects Agency
DHS	Department of Homeland Security
DoD	Department of Defense
DOE	Department of Energy
DSCS	Defense Satellite Communications System
ECO	Edison-Chouest Offshore
ECW	Extreme Cold Weather
GOES	Geostationary Operational Environmental Satellite
Gould	*Laurence M. Gould*
GPS	Global Positioning System
HF	High Frequency
IGY	International Geophysical Year

IPY	International Polar Year
ITASE	International Trans-Antarctic Scientific Expedition
JPSS	Joint Polar Satellite System
LARISSA	Larsen Ice Shelf System, Antarctica
MSC	Military Sealift Command
NASA	National Aeronautics and Space Administration
NOAA	National Oceanic and Atmospheric Administration
NRC	National Research Council
NREL	National Renewable Energy Lab
NSF	National Science Foundation
OMB	Office of Management and Budget
OSHA	Occupational Safety and Heatlh Administration
OSTP	Office of Science and Technology Policy
Palmer	*Nathaniel B. Palmer*
PDD	Presidential Decision Directive
PDM	Programmed Depot Maintenance
PM	Presidential Memorandum
POLENET	Polar Earth Observing Network
PQ	Physically Qualified
PRV	Polar Research Vessel
RFI	Request for Information
RIB	Rigid-Hull Inflatable Boat
RVIB	Icebreaking Research Vessel
SABIR	Special Airborne Mission Installation and Response System
SAR	Search and Rescue
SCAR	Scientific Committee on Antarctic Research
SMS	Safety Management System
SOOS	Southern Ocean Observing System

STEM	Science Technology Engineering and Math
TDRS	Tracking and Data Relay Satellite
UNOLS	University-National Oceanographic Laboratory System
USAP	U.S. Antarctic Program
USCG	U.S. Coast Guard
USCGC	U.S. Coast Guard Cutter
USGS	U.S. Geological Survey
WAIS	West Antarctic Ice Sheet
WDW	Warm Deep Water
WINFLY	Winter Fly-In

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WHITE HOUSE OFFICE OF SCIENCE AND TECHNOLOGY POLICY

www.whitehouse.gov/administration/eop/ostp

Congress established the Office of Science and Technology Policy (OSTP) in 1976 with a broad mandate to advise the President and others within the Executive Office of the President on the effects of science and technology on domestic and international affairs. OSTP is also authorized to lead interagency efforts to develop and implement sound science and technology policies and budgets, and to work with the private sector, state and local governments, the science and higher education communities, and other nations toward this end.

NATIONAL SCIENCE FOUNDATION

www.nsf.gov

The National Science Foundation (NSF) is an independent federal agency created by Congress in 1950 "to promote the progress of science; to advance the national health, prosperity, and welfare; to secure the national defense…" NSF funds approximately 20 percent of all federally supported basic research conducted by U.S. colleges and universities.

THE U.S. ANTARCTIC PROGRAM

www.nsf.gov/od/opp/ant/memo_6646.jsp

The U.S. Antarctic Program (USAP) is the nation's program for maintaining an active and influential presence in Antarctica through the conduct of scientific research consistent with the principles enunciated in the Antarctic Treaty. In accordance with Presidential Memorandum 6646 (February 5, 1982), NSF is responsible for managing and budgeting for the USAP as a single package.