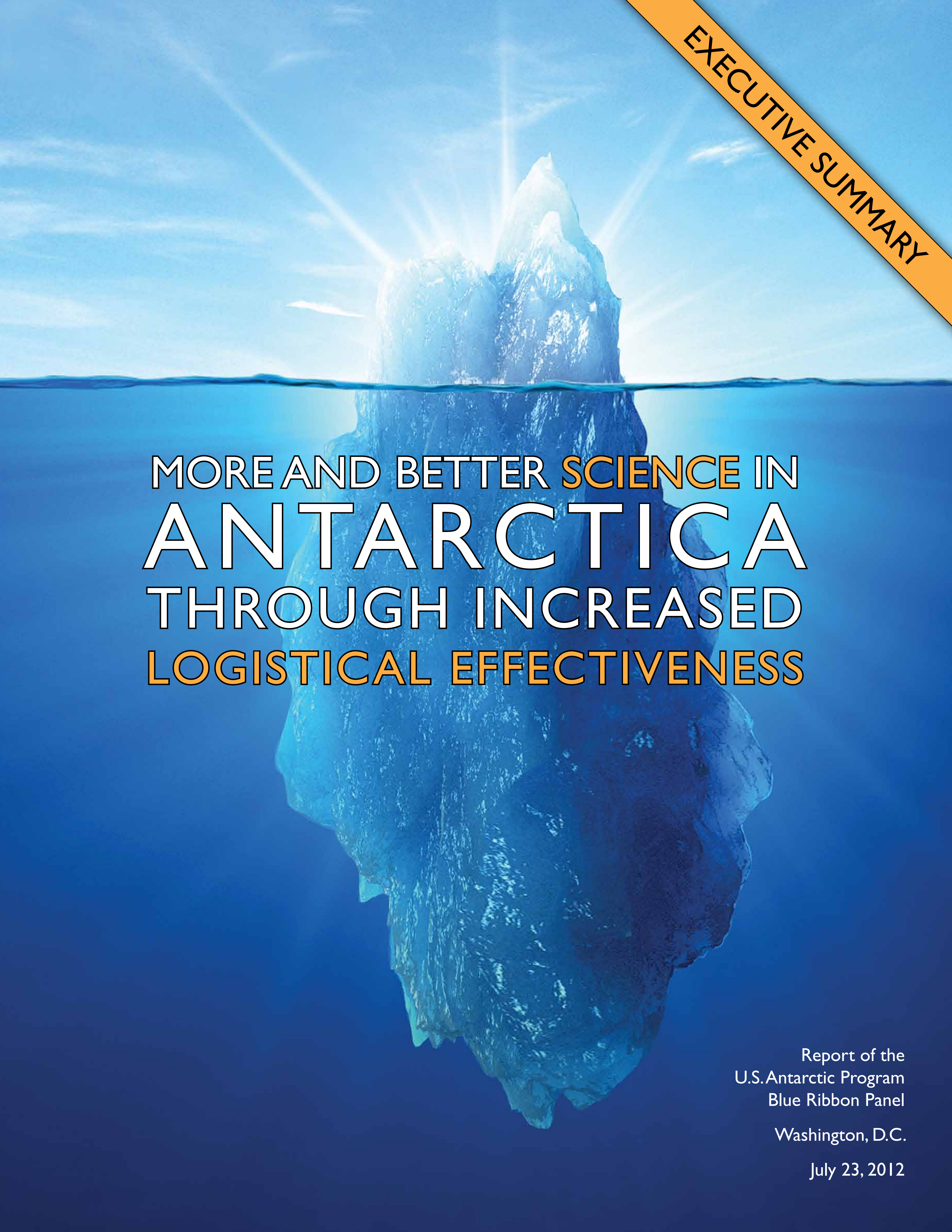
EXECUTIVE SUMMARY



MORE AND BETTER SCIENCE IN ANTARCTICA THROUGH INCREASED LOGISTICAL EFFECTIVENESS

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

Washington, D.C.

July 23, 2012

This booklet summarizes the report of the U.S. Antarctic Program Blue Ribbon Panel, *More and Better Science in Antarctica Through Increased Logistical Effectiveness*. The report was completed at the request of the White House Office of Science and Technology Policy and the National Science Foundation. Copies of the full report 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. Front and back inside covers showing McMurdo's Dry Valleys in Antarctica provided by Craig Dorman.

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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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The South Pole Telescope backlit by
an aurora. Source: Don Hartill.

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.

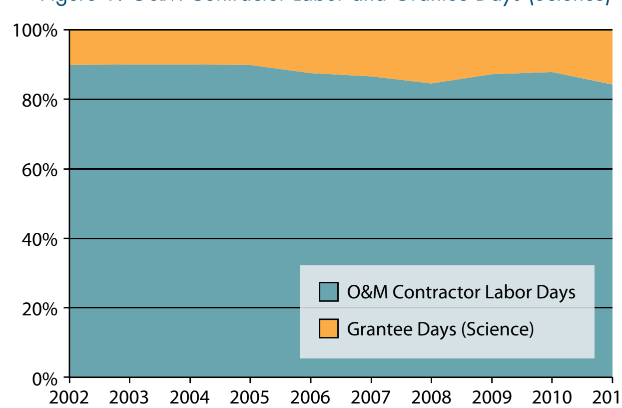
In 2011, the National Research Council published the report *Future Science Opportunities in Antarctica and the Southern Ocean*. The report focused on discovery-driven research and global change research. "Discovery" addresses fundamental questions such as the nature of dark energy and dark matter that 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 (2700-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.

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.

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



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 U.S. 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.

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.

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 (ARSV) *Laurence M. Gould* and Research Vessel Icebreaker (RVIB) *Nathaniel B. Palmer*, and witnessed on the U.S. West Coast the offloading 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.

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.

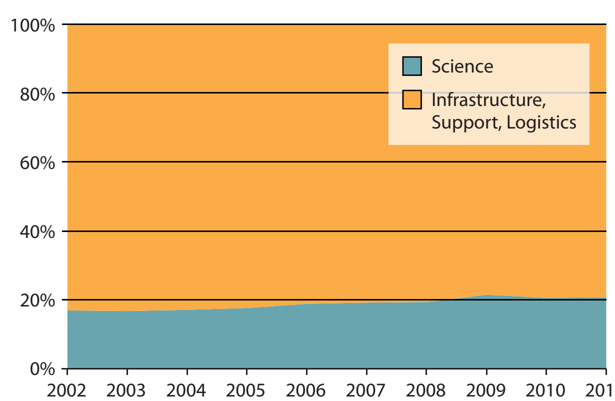
The Panel concludes that by making changes to the logistics support system, such as those proposed, substantial cost savings can be realized using net present value as the basic financial metric. In some instances, more detailed analyses will be warranted prior to making substantial funding commitments—a 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 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 the National Science Foundation (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 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.

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



U.S. FACILITIES IN ANTARCTICA

The three principal U.S. research stations are McMurdo (Figure 3a), 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 (Figure 3b); and Palmer Station on the Antarctic Peninsula (Figure 3c).

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 and aging dock is used for research support and resupply vessels, primarily ARSV *Laurence M. Gould* (*Gould*). 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.

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 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.

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

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

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 (3864 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.

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.

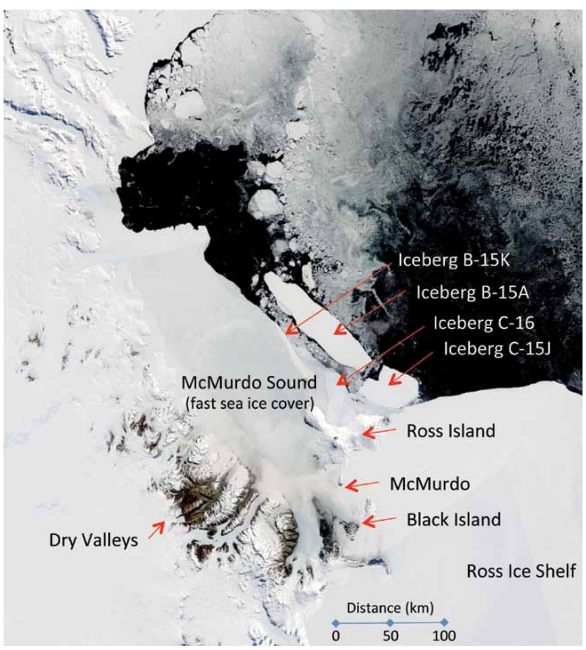


Figure 7. Satellite photo of the McMurdo area, 9 November 2004. The large iceberg B-15 and other icebergs reduced flushing of the sea ice near McMurdo Station, increased the extent of ice from the station from the typical 10 to approximately 50 miles (18 to 93 kilometers), and also increased the amount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

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 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 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.

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) The Chinese Kunlun Station, completed in 2009. Source: Hu Yi, CHINARE.

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 offloading. 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.

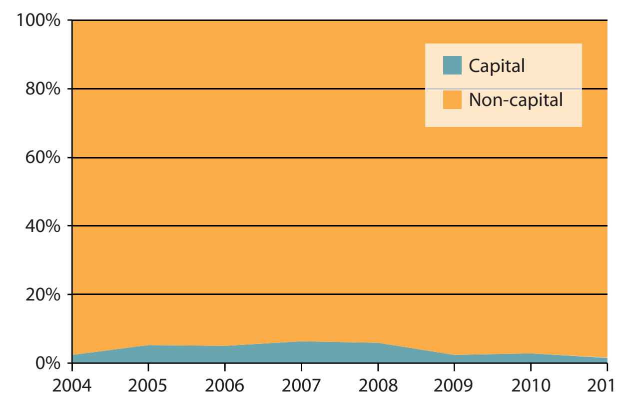
MAJOR ISSUES

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

*Offload onto ice shelf, followed by traverse.

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.

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.

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.

Transportation on the Continent 4

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 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-ANG 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.

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

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.

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

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 sites that are anticipated to increase in number, importance, and remoteness throughout the Antarctic Continent.

Energy 6

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 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.

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

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 satellite, 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.

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

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. 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 (e.g., 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. 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.

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.

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 offloaded 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.

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.

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 (DARPA), 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 (RIBs) 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 for this and other cases.

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 the total dollars. While significant savings are in fact achievable through operational efficiencies, 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 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 the five highest payout projects (Table 2) and the 20 percent reduction in contractor labor to be reinvested in upgrading support capabilities ($20 million per year).

The investments thus made would be repaid in approximately seven years if the five highest 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.

Once the recommendations made herein have been implemented, it will be possible to substantially increase science activity—assuring 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 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

This study was conducted at the request of the White House Office of Science and Technology Policy and the National Science Foundation.

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.