the Optimized Station option. This case will therefore be used in the following Section as the baseline for determining budgetary requirements.

6.7 Level Funding

All costs pertaining to budgeting for a new station will be presented in "then-year" dollars since these are the measure to be used in Government budgetary decisions.* The Panel used the FY97 budget as the baseline for evaluating a so-called "level funded" U. S. Antarctic Program. The purpose of this assessment was to seek ways to fit the needed improvements to the U. S. facilities in Antarctica under a "flat budget" constraint. This assumption results in the funding availability shown in Exhibit 66.

	Actual FY97		FY98-FY02 (5X)	
Science Grants	$30.5M		$152.5M	
Science Support	41.0M		205.0M	
Total Science		$71.5M		$358M
Operations		$59.4M		$297M
Logistics (DoD)		$62.6M		$313M
Total USAP		**$193.5M**		**$968M**

Exhibit 66

Available funding (level profile). Assumed USAP "level" budget, FY98-FY02, in then-year dollars. Total five-year estimates are simply five times the FY97 figure, thus it is implicit that inflation has somehow been offset.

The level funding scenario in Exhibit 66 assumes that inflationary effects will be offset by improved efficiencies, a reduced level of effort, a compensating increase in budget, or a combination of the three. The Panel considers such actions to be part of the baseline program under a level funding scenario and has made no explicit provision for their consequences in the discussion which follows. However, it is noted that in the absence of either budgetary increments to offset inflation or a corresponding improvement in efficiency, the level of effort in FY02 would have to be reduced by some $20M relative to FY97, with a cumulative reduction of $61M for the period FY98-FY02. This would have a serious negative impact on the level of activity and productivity of the USAP. *Further, the Panel notes that many non-governmental sources of future inflation rates provide estimates which significantly exceed the government's values used herein.*

6.7.1 Additional Program Costs (FY98-FY02)

The principal additional cost during the five-year period FY98-FY02 is the construction of a new South Pole Station. The estimated fiscal year cost profile for the Optimized Station (the Panel's recommendation - see Section 7) is shown in Exhibit 67 both in FY97 dollars and in then-year (TY) dollars, assuming that costs will on average be incurred one year after obligation. Included in the numbers are the median estimated costs for quick-fixes for system failures in the existing station prior to its replacement.

	FY97 Dollars	Then-Year Dollars
FY98	26.2M	27.3M
FY99	30.9M	33.0M
FY00	26.3M	28.7M
FY01	25.4M	28.3M
FY02	11.3M	12.9M
Total	**120.1M**	**130.3M**

Exhibit 67

Funding schedule for the South Pole Optimized Station. Each entry includes $5M for quick-fixes to keep the existing station viable until the Optimized Station is ready. Then-year dollars (TY$) assume annual inflation of 2.2 percent, the rate used when these costs were estimated, and assume outlays occur one or more years later than budgeted.

As discussed in section 6.13, the Panel has identified a limited number of near-term infrastructure needs at McMurdo and Palmer Stations. Estimated cost augmentations for the eight systems potentially needing attention at these locations total $32.3M (Exhibit 68).

Although the Panel concludes that the construction of the new South Pole Station should be afforded highest priority, the Panel nonetheless believes that a minimum of $15M must be invested at Palmer and McMurdo Stations during the forthcoming five-year period. Failure to do so will simply place these installations on the same path that has led to the operational and budgetary problems now being encountered at South Pole Station.

6.7.2 Potential Cost Offsets (FY98-FY02) The transition of activities of the Naval Support Force Antarctica to the NSF and NSF contractors, and those of the Naval Antarctic Support Unit in Christchurch to

* Estimated costs in "then-year" dollars assume inflation of 2.2 percent each year from FY97 forward, which was the rate being used by the Government for estimating future inflation at the time cost estimates were made. If the Government's estimated inflation rate is revised, the numbers shown herein should be adjusted accordingly.

	Cost, $M
FACILITIES	
Fuel Tank Replacement	6.0
Galley Upgrade	1.5
Mech. Equip. Center Replacement	1.4
Fire Suppression (Dorms)	1.9
Sewage System	2.5
Total	13.3
EQUIPMENT/COMM	
Air Traffic Control (Ops)	4.0
Power Plant	3.0
Vehicle Fleet Replacement	6.0
Communications Modernization	6.0
Total	19.0
TOTAL, Candidate Items	**32.3**
Minimum Recommended, FY98-FY02	15.0

Exhibit 68

Estimated cost of McMurdo and Palmer infrastructure improvements, then-year dollars.

an NSF contractor, are expected to yield cumulative savings of approximately $19M in FY98-FY02. In addition, the transition of LC-130 operations from the Navy to the Air National Guard (ANG) has been estimated to yield savings of approximately $25M. Thus, these savings, given aggressive management, can be expected to total $44M during the next five-year period. Nonetheless, because of the uncertainty of the estimates and the expectation that certain unbudgeted safety upgrades of the LC-130 aircraft will be required, the Panel has discounted the savings from the transition to a total of $30M.

Cost savings in addition to those just cited can be achieved through temporary reductions in the level of science activity during the five-year period when South Pole Station is being redeveloped. For example, temporarily reducing five percent of the science grant funding and six percent of the science support funding over five years can provide $20M to partially offset the cost of constructing the replacement South Pole Station. Some reduction in the level of scientific activity during this period would very likely be necessary in any event as logistics resources are partially reassigned to support the construction effort. It is noted that because of the large fixed cost component of science support activities in Antarctica, a six percent reduction in *total* science support funds would require a much higher percentage reduction in terms of science support field capability. It is recommended that this reduction in activity in Antarctica be partially offset by increased analysis and preparation at the investigators' home institutions so as to reduce the impact on the research and graduate training program.

The Panel notes that since South Pole science will be the principal beneficiary of the new station, a temporary reduction in science and science support at that location during the construction period is appropriate. Exhibit 69 shows science and support costs by location.

	Science Grants	Science Support
Palmer Station	$ 25.0M	$ 6M
South Pole Station	35.0M	21M
McMurdo Station	17.5M	10M
Field camps	52.5M	83M
Research vessels	22.5M	85M
Total USAP	**152.5M**	**205M**

Exhibit 69

Estimated USAP science grants and science support costs, FY98-FY02, in then-year dollars. A total reduction of $20M in science and science support during funding of construction of the new station at the South Pole is considered reasonable and appropriate by the Panel.

6.7.3 Summary (FY98-FY02) The additional costs required to construct an Optmized Station (relative to the FY97 level of spending), and potential offsetting cost reductions, are summarized in Exhibit 70, with all figures shown in then-year dollars.

As shown in Exhibit 70, a net five-year augmentation of $95M is required beyond that available in a level funded USAP budget. Exhibit 71 presents the profile of the additional funding needs in then-year dollars using the prescribed inflation rate and making no provision of a reserve for contingencies. (A reasonable contingency, based on commercial practices, would be $6M.)

Cost Requirements		
South Pole Station (Optimized)	$130M	
McMurdo/Palmer Infrastructure	$15M	
Total Additional Costs		**$145M**
Cost Reductions		
Transition from Navy Operations	$30M	
Science Grants and Support	$20M	
Total Cost Reductions		**$50M**
Net Cost Augmentation Required		**$95M**

Exhibit 70

USAP level cost five-year (FY98-FY02, then-year dollars) budget assessment using Optimized Station option for South Pole. (Quick-fix costs to repair failures in existing station prior to replacement are included.)

This $95M shortfall represents an $81M reduction relative to previously proposed options, made possible by a temporary reduction in science and science support ($20M), reduced operating costs ($30M) and adoption of a more austere station design ($31M).

Year	Incremental Funding needed	Offsetting Reductions	Shortfall
FY98	28.30	1.60	26.70
FY99	34.90	2.44	32.46
FY00	33.35	13.73	19.63
FY01	31.95	13.73	18.22
FY02	16.70	18.50	-1.80
Total	145.20	50.00	95.20

Exhibit 71

U. S. Antarctic Program funding shortfall, FY98-FY02, in millions of then-year dollars. This is one possible profile intended to approximate the USAP requirement. It assumes otherwise level USAP funding (Exhibit 66). Incremental funding needs include the South Pole Optimized Station (Exhibit 67) and improvement of McMurdo and Palmer stations (Exhibit 68). Offsets include reallocations or decreased costs from reducing science and science support, consolidating LC-130 operations in the New York Air National Guard, transferring functions from the Navy to an NSF contractor, and improving managerial approaches.

6.8 Safety and Health

Based on its review of relevant health and safety documentation, the testimony and written reports provided by both internal NSF and external experts, and its site visit to the South Pole Station, the Panel finds that the living and working conditions of U. S. personnel at South Pole Station are increasingly unsafe and that the point of unacceptability has been, or soon will be, exceeded.

The Panel also finds that the NSF has made significant improvements in the overall health and safety of operations in the U. S. Antarctic Program since the Safety in Antarctica report of 1988. These improvements include major changes made at the South Pole Station such as the construction of several modern buildings for both housing and scientific research, and the provision of additional emergency exits from certain buildings. Indeed, during the time the Panel conducted its investigations, several of the most critical health and safety hazards were being eliminated through the commitment of funds to construct a new garage and to replace the existing fuel bladders with stainless steel tanks. Additional interim measures, both physical and procedural, are being implemented in the garage area to improve the health and safety of the staff prior to the availability of the new construction, albeit at a loss of efficiency to the operation.

Nevertheless, the continuing gradual degradation of most of the working and living spaces, particularly those under the dome, and the aging infrastructure as a whole have inexorably increased the threat to life, property and program to the point where further delay in the decision to either replace the station or immediately initiate major safety retrofits to the existing station would be inadvisable. While many code violations in the existing structures can be documented (not altogether unusual for 23-year-old structures), the cost of refurbishing the existing station to bring it into compliance with current Uniform Building Code and National Fire Protection Association safety criteria would be excessive, if indeed it could be done at all.

Mr. Jon Kumin, a registered architect with 20 years of experience designing facilities for use in extreme cold climates (principally the Alaska North Slope), personally inspected the South Pole Station in 1995. In a report to the Panel, he expressed his belief that certain of the structures under the dome, including the berthing facilities, would not be allowed to be occupied were they located in Alaska. Mr. Kumin concluded his report to the Panel as follows: "A final point — it will take about six years to design, construct and occupy a new facility. Continued delay in addressing the issues discussed above requires a continuation of the good fortune enjoyed to date." The Panel does not believe that the safety of U. S. personnel living and working at the South Pole Station should be left to "continued good fortune," but rather to an immediate decision to replace the current station with a new station consistent with current design standards and safety codes enjoyed by U. S. citizens elsewhere — even in highly challenging environments.

While the Panel addressed much of its attention to the particular health and safety issues at the South Pole Station, it also encountered several matters at McMurdo Station which also need attention. Of particular note, the Panel found that the cold food storage operations at McMurdo are unsafe and that improvements in this operation should be given high priority. Frozen food is currently managed in a large freezer warehouse, from which retrieval is precariously performed by hand from stacked heavy boxes, many feet above the floor. The hazard should be eliminated through implementation of modern rack retrieval equipment.

6.9 Management Effectiveness

The Panel finds that the NSF has met the challenging management tasks of the USAP with professionalism and diligence. The Office of Polar Programs of NSF deals with an exceptionally broad range of scientific subjects (truly from the "a" of astronomy to the "z" of zoology) and has done an excellent job of fostering quality science across this spectrum of topics. Further, the USAP involves not only administration, design, and implementation of scientific programs but also the management of extensive logistics and extremely complex infrastructure functions. Indeed, the scope of the Antarctic Program management task is comparable in many ways to that of operating three small towns — but in an extraordinarily unforgiving environment that places a premium on sound planning — using a mix of governmental and contractor personnel working in a manner unlike that of any mayor/manager/council. Examples of recent management successes include the safe clean-up of accumulated hazardous wastes, community compliance with both the spirit and letter of waste procedures, construction of modern living quarters at McMurdo Station, and the establishment of new research directions. The opportunity to further reinvent the U. S. approach to activities in Antarctica will be presented in the near-term, particularly those associated with changes in military to civilian support, clarifications of authority and responsibility, identification of needs via a dynamic planning process, and implementation of cross-discipline versus functional budgetary control.

6.10 Ongoing Facility Improvements

The Panel examined the approach to cost reduction carried out by the NSF to date. The Panel concludes that the NSF has done an excellent job of achieving efficiencies within the USAP. In particular, NSF has systematically examined and capitalized on opportunities for savings through investment, redesign, and transfer of functions from military to civilian support. For example, investment in updated weather equipment has reduced the number of turn-around flights, substantially cutting the cost of air operations. Design and implementation of the mobile runway support facility has improved the Williams Field operations and generated significant savings in fuel and capital investment (Exhibit 72). The transfer of galley operations to civilian contractors has resulted in cost savings, and transfer of air ticketing for civilian employees to a civilian contractor has reduced the cost of air travel. Cargo handling has been greatly modernized, with a new tracking system in place that enhances the ability to accurately monitor cargo movements. Improvements have been achieved in inventory control, and cost savings have been realized through long-range planning to maximize the use of relatively low-cost cargo ship transport rather than airlift. Helicopter operations have been privatized with considerable attendant savings while maintaining a high degree of safety and customer responsiveness. Exhibit 73 provides another example of a recent USAP cost avoidance measure.

Exhibit 72

Mobile runway support facility. As the U. S. Antarctic Program transitions from military to contract support for all functions except LC-130 operations, efficiencies, improved performance and cost changes are being achieved sometimes by reduced personnel levels, but often through managerial or technological changes in the way the work is performed.

Williams Field is McMurdo's skiway complex on the Ross Ice Shelf that is used by ski-equipped Hercules (LC-130) airplanes during the months that wheeled takeoffs and landing at McMurdo's two hard ice runways (one on sea ice and one on glacier ice) are not possible. Formerly, the 150 or so people who operate Williams Field lived in berthing at the site. Now they commute daily the six miles from McMurdo. The change has reduced the labor to operate the facility from 800 to 150 person-weeks per year, has reduced fuel consumption from 180,000 to 136,000 gallons per year, and has reduced the installation cost for facilities (required every 7 to 10 years for the older facility because the Ross Ice Shelf is in motion) from $8.2M to $5.1M.

Additional cost savings are expected to be achieved as the transition of air transport operations to the ANG is finalized. Still further, efficiencies can be achieved through modernized approaches to coordination of the personnel, cargo and inventory tracking systems. Overall, the Panel concludes that the most obvious sources of cost reductions are already being pursued by the NSF, although, as will be discussed in Section 6.15, additional opportunities remain.

6.11 Cost Visibility

As noted in Section 5, the continuing presence of the U. S. in Antarctica is motivated by several factors. While science is a prime and enduring objective, it is not the sole force behind the U. S. Antarctic Program. Hence, it is difficult to evaluate the true total cost of individual scientific projects, since the facilities and infrastructure in which science is carried out exist not only for scientific reasons but also because of geopolitical and stewardship considerations.

Exhibit 73

Reverse osmosis water production at McMurdo Station. Sea water is desalinated to make McMurdo's supply of domestic fresh water. In 1994 a reverse-osmosis system was installed to replace aging flash evaporators. The shift increased the amount of water available, permitting daily showers for the first time for all residents, and it cut the per-gallon cost in half, from 14 cents to 7 cents. The annual cost to operate and maintain the new system dropped to $52,000 (from $187,000 for the old one). Installation cost for the new unit was $1,018,000, substantially less than the flash evaporator installation cost of $1,650,000.

Within the current USAP, scientific proposals are peer reviewed on a merit basis as are all other proposals to the National Science Foundation. The budgets used in evaluating proposed projects in general include only the university-based and "off-Ice" costs, such as graduate student support, investigator salaries, research equipment unique to the project, and institutional overhead. While funding for the operational infrastructure needed "on-Ice" for the program as a whole may be considered separately, the direct science support cost attributable to individual projects including such items as helicopter support, personnel per diem while in the Antarctic, etc., are not currently included in the direct proposal evaluation process. Consideration of such science support costs — along with scientific merit — in the proposal assessment by peer reviewers could help to achieve cost reductions and motivate researchers to better contain their own science support costs. This would aid the NSF in constructing a balanced program that optimizes science within the overall available budget, including that for infrastructure and support. It is the conclusion of the Panel that insufficient visibility of overall project costs hinders the most efficient use of available resources by both the NSF and its researchers.

6.12 Personnel Issues

The Panel held (voluntary) town meetings at McMurdo and at South Pole Stations, which were attended in total by over 300 individuals. It also met with individual scientists and support staff at both locations as well as at field sites in the Dry Valleys. The scientists, support staff and construction personnel were in general found to be highly motivated individuals willing to work long hours under extremely difficult conditions. It was noted that some individuals are attracted to work in Antarctica in part because of the adventure, danger and hardship that are an inevitable part of working at the bottom of the Earth. In fact, some individuals at South Pole Station were concerned that any redevelopment project might diminish the excitement of being at the Pole — where a generally healthy "can-do" ethos has been generated over the years. Most individuals were very interested in improved communications, especially since the one air drop to South Pole and McMurdo conducted during the winter has been discontinued as an economy measure. The town meeting at McMurdo revealed an interest in having professional counseling available to help work out personal problems which arise from time-to-time.

Also, concerns were expressed which suggested that a review of the management approach by the current food service operator might be in order. Much as Napoleon observed that "an Army travels on its stomach," food takes on extraordinary significance in remote locations with few human outlets beyond working, sleeping, eating and surviving. The Panel has subsequently learned that the food service problem has been corrected and that the NSF is planning for counseling as part of the transition from Navy to contractor medical services. The longer term goal is to reduce or eliminate factors that contribute to stress.

6.13 Support Capacity

The Panel concluded that support elements in Antarctica are fully taxed with the shape and pace of today's operations, causing deferral of projects that would significantly contribute to a modernized, efficient Antarctic presence and scientific capability.

Capital improvements and renewal projects are generally funded from within the operating budget and are vulnerable to the vagaries of what funds might be available in any given year. The resulting understatement of capital requirements jeopardizes an orderly modernization program. Deterioration of the plant then generates greater maintenance costs, which in turn further reduce the ability to properly remedy a growing capital backlog.

The Panel noted a number of conditions extant in the logistics structure located at the principal Antarctic support base, McMurdo Station, which are inconsistent with efficient, effective operations. These concerns include:

- **Heavy Equipment/Vehicle Fleet** The task of maintaining a totally nonstandard fleet (some components from the IGY-era) (Exhibit 74) makes operations very difficult, including the need to keep runways operational — the key to Antarctic operability.

Exhibit 74

Vintage equipment in the heavy vehicle fleet. One of several remaining low ground pressure D8 bulldozers. Caterpillar built about 10 of these units in the 1950s for the International Geophysical Year. Their primary role was to tow heavy sled trains across the ice shelf and parts of the plateau during early exploration and station development (Little America, Byrd). By the 1960s, the U. S. Antarctic Program was concentrated at Palmer, McMurdo and South Pole and no longer conducted long traverses. Modified only by removing the huge fuel tanks, the D8s became station workhorses for tasks for which they are still used (e.g., towing fuel tanks, moving portable buildings, snow grooming; pushing snow to keep Williams Field level, winching equipment from the sea bottom that has fallen through the ice). Despite their dwindling reliability, poor operator comfort and long-ceased parts support, dedicated mechanics have kept these uniquely capable machines operating over the years. Photo courtesy of G.L. Blaisdell, CRREL.

- **Electrical Generation Plant** Although all five generators are of the same age and are nearing the end of their predicted life, there is not a funded plan for phased replacement of these items.
- **HF Transmitters** Transmitters providing for vital aircraft and other communications are obsolete, no longer supported by the original vendor or the Navy. Equipment configurations do not lend themselves to automation, and maintenance is intensified.
- **Warehouses** The lack of a modern inventory system in a number of locations causes shortages, overages, excessive demands of operator-time, and losses due to shelf life expiration.
- **Local Area Network (LAN)** An insufficient number of modern workstations, exacerbated by the incompatibility of operating systems, produces significant inefficiencies. For example, a modern, integrated information infrastructure could potentially obviate the need for costly warehouse centralization.
- **Fuel Tanks** The present condition and capacity of fuel storage threatens continuing environmental compliance and precludes the achievement of economies.
- **GPS Navigation System** Modernization of the aviation navigation system with a system based on GPS (Global Positioning System) would provide both enhanced capability and a reduction in ground personnel required for operations.
- **Galley** Basic structural problems threaten the long-term viability of the facility and jeopardize human services.
- **Dormitories** Significant energy losses and configuration layout constrain creature comfort and efficiency in those buildings not yet modernized.
- **Recreation** Productivity and a spirit of community is adversely affected due to the lack of adequate wellness facilities.

6.14 Management Structure

The current management structure has evolved over a period of years since the Navy first began providing support for U. S. Antarctic activities. During the 1957-1958 International Geophysical Year, the NSF expanded its traditional role of funding U. S. science activity to include Antarctic science. With the 1959 Antarctic Treaty guaranteeing freedom of access for scientific and other peaceful purposes, the U. S. began a long transition to decrease military involvement in Antarctica. Later reductions in defense spending, coupled with the desire to obtain increased operating efficiency, resulted in further reductions in military involvement. As the Navy's role decreased, the NSF moved further into the role of providing support functions. With the cooperation of all involved, the support structure has been made to work remarkably well during the still-ongoing transition period.

The existing organization evolved over three decades of gradual transfer of functions and control from the Navy to the NSF and to support contractors and other government agencies. In 1968, the first civilian prime contractor, Holmes and Narver, was selected to complete the construction of the South Pole Station and to assume operational control of the Pole, Palmer Station, parts of McMurdo and all research vessels. ITT Antarctic Services held the support contract during the 1980s, and in 1990, Antarctic Support Associates (ASA, a joint venture of EG&G, and Holmes and Narver) was selected as the prime support contractor and fills that role today.

As the Navy transition began, the NSF moved additional functions under the prime support contractor. But today, ASA contracts directly with Ken Borek Air for Twin Otter aircraft support, Edison Chouest for the *R/V Palmer* and *R/V Gould* research vessels, and Rieber Corporation for the *Polar Duke* vessel. NSF contracts directly with PHI for the operation of Antarctic helicopter aircraft. The Department of Interior, Office of Aircraft Services, assists NSF in the administration and oversight of the helicopter contract — as it does for a variety of other U. S. Government agencies. It is unclear why ASA, which provides all tasking for helicopter operations, does not contract directly with PHI — as it does for other contractor aircraft.

The Naval Command, Control, and Ocean Surveillance Center in Service Engineering, East Coast Division (NISE-East) located at Charleston, SC, is the Navy's executive agent for Air Traffic Control (ATC) and meteorology and will provide civilian contractor personnel and manage the ATC and weather forecasting functions in Antarctica. The Panel believes that it is in the USAP's best interest that these functions be performed by U. S. Government agencies (military services or the Federal Aviation Administration) due to the legal peculiarities of air operations in Antarctica. Appropriately, the NSF will execute agreements with NISE-East. NSF, believing a contractor should not control a Federal agency, in this particular situation plans for ASA to have direct dealings with NISE-East only at the technical interface level and not at the supervisory level, since the latter could potentially lead to coordination and accountability issues.

6.15 Cost Reduction Opportunities

The Panel identified five general areas for achieving cost reductions: (1) the transition from military to civilian support, (2) reinvention of and reduction in science support, (3) reinvention of and reduction in the cost of science grants, (4) reinvention and reduction in other support/infrastructure systems, and (5) continuing reliance on cost advantages of USCG icebreaker services and DOD bulk fuel and transportation rates.

The Navy will complete the phase-out of its historic support role in 1999. Some cost savings and efficiencies will result from this process, and the USAP command and control structure will be rendered more efficient through consolidation into a more streamlined operation/support train. The completion of the transition from Navy to ANG LC-130 support is estimated to result in savings of up to $25M between 1998 and 2002. The transfer of meteorological, medical/dental, communications, air traffic control, and other services is expected to yield an additional $19M between 1998 and 2002.

The completion of the transition from Navy to civilian and ANG support is estimated to yield a net reduction of some 268 Full-Time-Equivalent (FTE) employees. In order to fully realize the potential long-term gain in efficiency from the transition and contain growth, the Panel believes that population caps at all U. S. Antarctic stations commensurate with at least this reduction will have to be implemented.

Several opportunities for cost savings in general infrastructure and support were identified (although important safety and modernization needs imply *added* costs in other areas, discussed elsewhere). One important function to be evaluated in this regard is fire protection — an extraordinarily important function, particularly in the dryness of Antarctica — but one which at McMurdo now utilizes 44 fully-dedicated personnel. Special needs for fire protection in conjunction with flight operations and fuel handling must, of course, be considered in addressing any potential change, but it is possible that the formal fire department at McMurdo could be downsized and augmented with designated volunteers, much as is done at South Pole and Palmer Stations and New Zealand's nearby Scott Base.

Helicopter fuel and support is another area of potential savings. By moving more of the helicopter support to the Marble Point location, which is closer to the majority of destinations, further economies in fuel consumption would result.

As McMurdo's buildings and other support functions age and are replaced, careful attention should be given to added thermal insulation for energy efficiency.

Science support also deserves further analysis and continued streamlining as it responds to the evolving science requirements. For example, science activities at Palmer Station have changed markedly in recent years: ozone research once demanded year-round operation, but those research efforts have shifted to the South Pole. Other research once carried out at Palmer has moved aboard research vessels. While the Panel finds continuation of Palmer Station to be essential for scientific, stewardship, and geopolitical interests, the possibility that the station not be operated in winters during one or more years of South Pole reconstruction should be examined.

Cost savings in the grants and in the direct science support areas are derived from several sources and largely require changes in both the evaluation and implementation of science projects in a manner which enhances cost visibility. The Panel finds that increased incentives for the investigators themselves (as well as support personnel) to reduce costs would benefit program efficiency. Such an approach is needed to optimize science while achieving the critical infrastructure objectives enumerated throughout this report. Program management can aid this process through avenues such as continuing to discourage multiple trips within a field season and increasing incentives for researchers to fully test and prepare equipment before deployment. Investigators can in some cases be encouraged to conduct further scientific analysis at home rather than collecting additional field data. Some reductions could also be achieved by encouraging researchers to minimize the size of field teams. The proposal evaluation process offers a powerful lever to achieve these objectives.

The Panel finds that some savings can also be realized through more explicit "on-Ice" cost accounting for services and consumables such as sample analysis and materials and supplies. The use of an accounting system that more fully tracks such expenditures and makes investigators responsible for choosing their support requirements within a given budget could be a mechanism to foster cost savings. Such a system, in this age of computerized accounting, should be capable of implementation without creating an unacceptable administrative burden.

Finally, agreements with DOD and USCG on costs of strategically important transportation, material, and icebreaking services need to continue if the Antarctic program is to realize cost advantages as the NSF maintains this nationally significant presence.

6.16 Transition of Aviation Responsibilities

As has been noted, the principal enabler of U. S. activities in the interior of the Antarctic continent is the existence of a small fleet of ski-equipped cargo aircraft (LC-130s) which possess considerable lifting capability and range. In response to the direction of the 1976 National Security Decision Memorandum 318, which instructed the NSF to seek more cost effective support, and by agreement of a March 1993 interagency working group, the Navy announced a five-year withdrawal plan from Antarctica in 1993. The New York ANG currently provides all U. S. LC-130 support in the Arctic and has in the past augmented the Navy in the Antarctic. The ANG is a sound choice to provide LC-130 support because of its broad polar experience and the potential efficiencies of year-round operations as activity shifts between the Arctic summer and the Antarctic summer.

Consolidation of the NSF and ANG LC-130 aircraft assets provides 10 LC-130s in the national fleet to service both the Arctic and Antarctic areas. NSF has research interests in the Arctic, particularly Greenland, that can utilize LC-130 support, and the ANG also has responsibility for certain military missions in the Arctic.

During the next three seasons (1996/7, 1997/8, and 1998/9), the LC-130 roles and activities of the Navy and the ANG will reverse. The Navy will no longer have a role in LC-130 operations (or base operations) after the 1998/9 season. During the current 1996/7 season, the ANG will augment the Navy; during the 1997/8 season the Navy and ANG strengths should be approximately equal; and during the 1998/9 season responsibilities will transfer to the ANG with a small residual Navy augmentation.

The transition from the Navy to ANG and the assumption of other functions by organizations such as ASA results in a decrease from 780 Full Time Equivalents to a projected 256. After offsetting the additional slots that will be required to fulfill certain other functions traditionally provided by the Navy, which will not be assumed by the Air National Guard, a total savings of some 268 Full Time Equivalent personnel will result.

As important as the savings derived from civilianization are for U. S. activities in Antarctica, the Panel believes that it is important to retain the currently planned degree of Department of Defense (DOD) partnership in Antarctica. The DOD has unmatched capabilities to meet unforeseen — and potentially catastrophic — events, such as the need for search and rescue. The U. S. presence and roles are undoubtedly enhanced by a continued, modest involvement of DOD personnel, especially in contingency planning regarding Antarctica. As well, NSF enjoys the benefits of the price advantages of DOD rates and quantity purchases of commodities. These must be continued to assure maximum economy of Antarctic operations despite DOD's reduced involvement in other Antarctic affairs. The U. S. Coast Guard's operating budget within the Transportation appropriation will need to continue to absorb the level of overall fixed icebreaker costs. Changes in either of these practices would produce significant negative impacts on the NSF operating budget. The presumption is that, for example, the U. S. would wish to maintain the existing modest icebreaker capability whether or not it had an Antarctic program.

6.17 Telecommunications

Modern telecommunications with Antarctica enable technologically advanced research by connecting researchers and their data with colleagues in real time; enhance operational support with real time flow of management information; and improve morale by providing contact with family and other associates.

Dependable telephone and Internet service is now provided at all three year-round stations and the two research vessels. A technology partnership with NASA Goddard Space Flight Center has produced the first very high speed (300 million bits per second) data link from Antarctica (McMurdo) via the NASA Tracking and Data Relay Satellite System.

Antarctica challenges the delivery of communications. McMurdo (78°S) lies at the high-altitude fringe of commercial satellite service. Palmer Station (64°S) has a good view of the geosynchronous communications satellite belt (12° elevation view), but the economics of commercial communications for this small station have precluded NSF from providing service beyond occasional use of a commercial maritime satellite telephone (INMARSAT), opting instead for shared access with Government satellites which have exceeded their useful lifetime in normal service.

South Pole (90°S) is inaccessible from geostationary satellites. Contact with South Pole Station can at present be accomplished by two means of communications. High frequency radio (HF) provides primarily voice. HF signals reflect on the ionosphere to reach over the horizon to McMurdo or the United States. The high latitude of South Pole Station results in HF radio being susceptible to disturbances in the ionosphere caused by solar activity (solar flares) and the Earth's magnetic field. Blackouts in HF radio occur for days at a time during the peak of the 11-year sunspot cycle. HF radio is not suited to digital communications at the quality, reliability, and data-rate needed for science at South Pole Station, and the systems in place are old and labor intensive. However, HF radio continues as the best means for on-demand contact between McMurdo and South Pole operations and for communicating with aircraft supporting the station.

Internet and connection to the U.S. telephone system are provided by aging geosynchronous satellites that have drifted out of their original equatorial (geostationary) orbits into a tilted (inclined) orbit that allows South Pole Station periodically to "see" them. These satellites typically have outlived their original missions but have been kept active and can provide a daily link for the 5-7 hours per day, wherein they are in line-of-sight (Exhibit 75).

South Pole Station uses the satellites ATS-3 (simple voice), LES-9 (modest data-rate Internet), and GOES-3 (higher data-rate Internet). Each is an old Government satellite (NASA, USAF, and NOAA, respectively), nonetheless capable of providing useful communications for South Pole Station. These satellites are well beyond their original design lives. Ready alternatives to these satellites are limited (GOES-2, GOES-7). Reliance upon serendipity for future similar Government or commercial satellites does not provide the certainty needed to sustain a science program. Current national and international policy regarding the management of space debris, in the absence of deliberate attention drawn to the unique requirements for South Pole, will further diminish the possibility for the serendipity now being enjoyed.

Commercial low Earth orbit satellite communications systems now being implemented or planned may provide solutions for South Pole Station and other Antarctic locations. The 66-satellite Iridium system (Motorola, Inc., principal investor; a $3.2B system) is to provide total global coverage for satellite-delivered cellular telephone, fax, and low-rate dial-up data. Started in 1990, Iridium may be fully operational by 1998 with the first launches now scheduled for mid-1997. The proposed 840-satellite Teledesic system (Gates, McCaw venture; possible $9B system) also provides full global coverage, but with high speed data links suited for Internet and bulk telephone service. Teledesic may become operational in the latter half of the next decade.

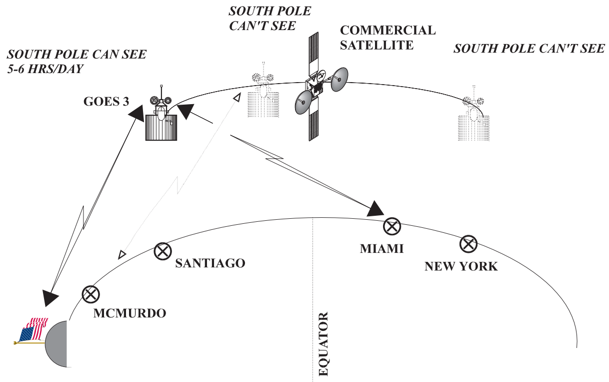

Exhibit 75

Communication with the South Pole. Most communications satellites are launched into orbits that serve the needs of the vast human populations in the mid-latitudes. A satellite 24,000 miles over the Equator is geostationary: it appears to park over a particular location on Earth because its speed to offset gravity equals Earth's speed of rotation. From there it has a line of sight to Earth locations as high as 80° latitude (which includes McMurdo). Small onboard rockets are fired periodically to keep the satellite in place. Without these boosts the satellite tends to drift north and south of the Equator, becoming less able to provide its original prime role.

But these north-south swings place the South Pole in view of the satellite several hours a day. The USAP, rather than trying to budget for a family of dedicated polar communications satellites, uses NASA's ATS-3, Air Force's LES-9, and NOAA's GOES-3, which, out of fuel (solar panels power their communications), move in a fashion where they have line-of-sight to South Pole Station five to six hours a day.

6.18 Robotics

An issue of substantial interest to the Panel is the potential for robotics and telescience to generate program cost reductions while maintaining a high level of quality of scientific work. Within the U. S. space program, robotics result in significant savings as compared to manned spacecraft for many missions. Some robotics applications are evident in the USAP today, particularly the deployment of six Automated Geophysical Observatories on the High Plateau. These relatively simple automated stations collect critical geophysical data from remote locations and report back through the Argos satellites which periodically pass overhead.

The state of the art in robotics, however, is not sufficient to displace economically the bulk of the sophisticated science and support operations now conducted in Antarctica. In contrast to the space program, where robotics can often allow unmanned operations, such technology can only result in partial reductions in personnel in Antarctica and hence far smaller savings — since substantial fixed costs are associated with maintenance of any personnel on site. In addition, a serious impediment to such operations at the South Pole today is the lack of a high-speed digital communications capability which would be necessary to perform substantial telescience. Finally, in many respects the Antarctic environment is more hostile to electronics and mechanical devices than that of space. Nevertheless, the Panel believes that as communications capabilities improve in the future, the USAP can realize benefits from the increased use of robotics, provided the focus of such developments is directed to the displacement of existing operations rather than to enhancements in capability — the latter having often been the case in applying new technology.

6.19 Technology Opportunities

As has been discussed, the focus of U. S. Antarctic activity has traditionally been basic scientific research. This emphasis has been productive, resulting in advances in knowledge in a variety of disciplines including several of global importance. At the other end of the science/technology spectrum, innovative technologies have been incorporated into the operations of the USAP to reduce costs and enhance science support. The disciplines of applied research and technology development that are bounded by the end-members of basic research and technology insertion have to date been a relatively minor part of the USAP. The Panel believes that the USAP offers significant attendant technological opportunities which could be realized at modest incremental cost.

To this end, there have already been a few quite effective partnerships with USAP in the field of technology, such as the demonstration of advanced satellite communications with NASA and development of a heavy over-snow transport capability with Caterpillar, Inc. Broadening the number of technology partnerships and the applied research program base could provide additional funding while spreading the cost of operations across a larger funding/user base. The involvement of new organizations, to include other federal agencies as well as industry, brings the opportunity for leveraging resources and building or expanding cooperative programs that can have both applied research and basic science components.

As with the basic science conducted in Antarctica, the applied research and technology development conducted there should comprise only those activities that demand the unique environmental conditions or physical features present in Antarctica.

6.20 Education Opportunities

For centuries people have been fascinated by Antarctica. Much of the ongoing activity there involves exploration of the unknown, where the geology (lithosphere), climate (atmosphere), ice sheet (cryosphere), ocean (hydrosphere), and inhabitants (biosphere) are delicately linked. For this reason, Antarctica is an ideal natural laboratory upon which to base multidisciplinary science education curricula designed to capture the curiosity of students who might otherwise find science uninteresting.

Other aspects of Antarctica suit it well for education outside the immediate realm of science. For example, science in Antarctica requires the support of people with a wide span of backgrounds and skills ranging from heavy equipment operators to medical doctors; and from electricians to accountants — all of whom share pride and dedication in carrying out challenging tasks as part of a team. As such, they provide excellent role models for youth.

The advent of electronic media and, in particular, the “web,” has paved the way for involving the public in science “on the Ice.” NSF has taken the initiative to foster educational programs that reach out to all segments of the public — pre-school through senior citizen. These programs include live television (e.g., “Live from Antarctica” on PBS) and K-12 curricula involving experiments using current data from Antarctica, such as satellite images of the continent. Another NSF program sends teachers to Antarctica and allows them to share their experiences with students all around the country via the web. There is a new web site (http://www.glacier.rice.edu) which with the help of financial support from NSF contains a wealth of information about Antarctica, including updated weather reports from a number of research stations. “Glacier” provides a home page where scientists can describe their latest discoveries, thereby sharing the excitement of their work. NSF encourages the scientific community to contribute to existing educational programs and to develop new ways of involving the public in the science of Antarctica. This is an effort worthy of encouragement and expansion.

6.21 Tourism

An emerging aspect of human involvement in Antarctica is tourism. The past five years have seen rapid growth in the number of private visitors to Antarctica. Most arrive by ship in the Peninsular region, but the number of these visiting at McMurdo is increasing, and even South Pole Station receives a few tourists each year. Many of these visitors seek to tour U. S. research stations and, as such, can become important ambassadors for the scientific work being conducted. At the same time, there are limited resources available to support such visits and the threat to Antarctica’s slow-to-recover environment can be significant if not responsibly managed.

While the number of scientists in Antarctica has increased by about a factor of two in the past decade, and the number of national programs has increased somewhat less than that over the same period, the number of tourists visiting the continent has increased far more rapidly, from only about 1,000 in the early 1980s to over 6,000 in the early 1990s. Exhibit 76 depicts the total estimated number of tourists visiting Antarctica via ship and air from 1980/1 through 1995/6.

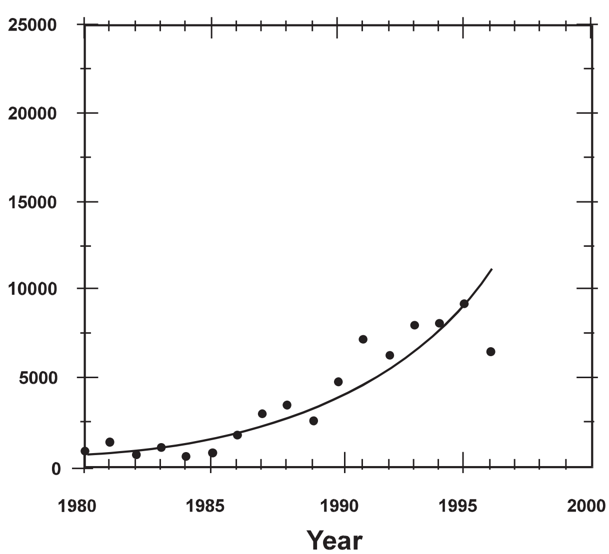

Exhibit 76

Number of tourists visiting Antarctica since 1980. Recent variability is related in part to a few large cruise ships that operate approximately every other year. [From Science and Stewardship in the Antarctic, National Academy Press, pre-1992, and from Nadene Kennedy of the NSF (personal communication), post-1992.]

A quadratic projection of this curve indicates that there will be a substantial number of tourists annually visiting Antarctica by the early part of the 21st century. The increased pressure from tourism must be considered in designing conservation measures and has been one of the major factors prompting the Protocol on Environmental Protection.

It has been the policy of the USAP to allow visitors to its Antarctic facilities while controlling their number. In addition to visitors arriving by ship, tourist sightseeing overflights by air have taken place from time to time — including the Air New Zealand DC-10, which, while flying around Mount Terror in 1979, crashed into Mount Erebus, located only some 20 miles from McMurdo Station, killing all 257 persons aboard. Such flights ceased until 1996, when Australia (Qantas) resumed regular “flightseeing” tours of Antarctica. In 1989, the Argentine government supply and tour ship *Bahia Paraiso* ran aground and sank. While no one was injured, the ship lost 170,000 gallons of fuel to the sea, severely damaging the area’s wildlife.

The International Association of Antarctica Tour Operators was established in 1991 to advocate and promote responsible private-sector travel to Antarctica. In a world of increasing affluence and mobility, tourism will become a growing factor on the Antarctic continent.

6.22 National Commitment to an Antarctic Policy

Since the Antarctic Treaty ratification of 1959, a series of memoranda, circulars and directives has established responsibilities, objectives and practices that, taken together, document U. S. Antarctic Policy. Section 4 contains a summary of these documents and more recent policy-oriented correspondence is presented in Appendix III. The Panel finds the Department of State letter of January 27, 1997 (Appendix III), most helpful in presenting a position that sustains the importance of presence addressed to the National Security Council by the previous State Department memo of 1996. It is noted by the Panel that overseeing U. S. presence in Antarctica far surpasses the normal responsibilities of the National Science Foundation. At the same time, the Panel strongly supports the designation of the NSF as the principal managing and coordinating agent for all U. S. activities in Antarctica.