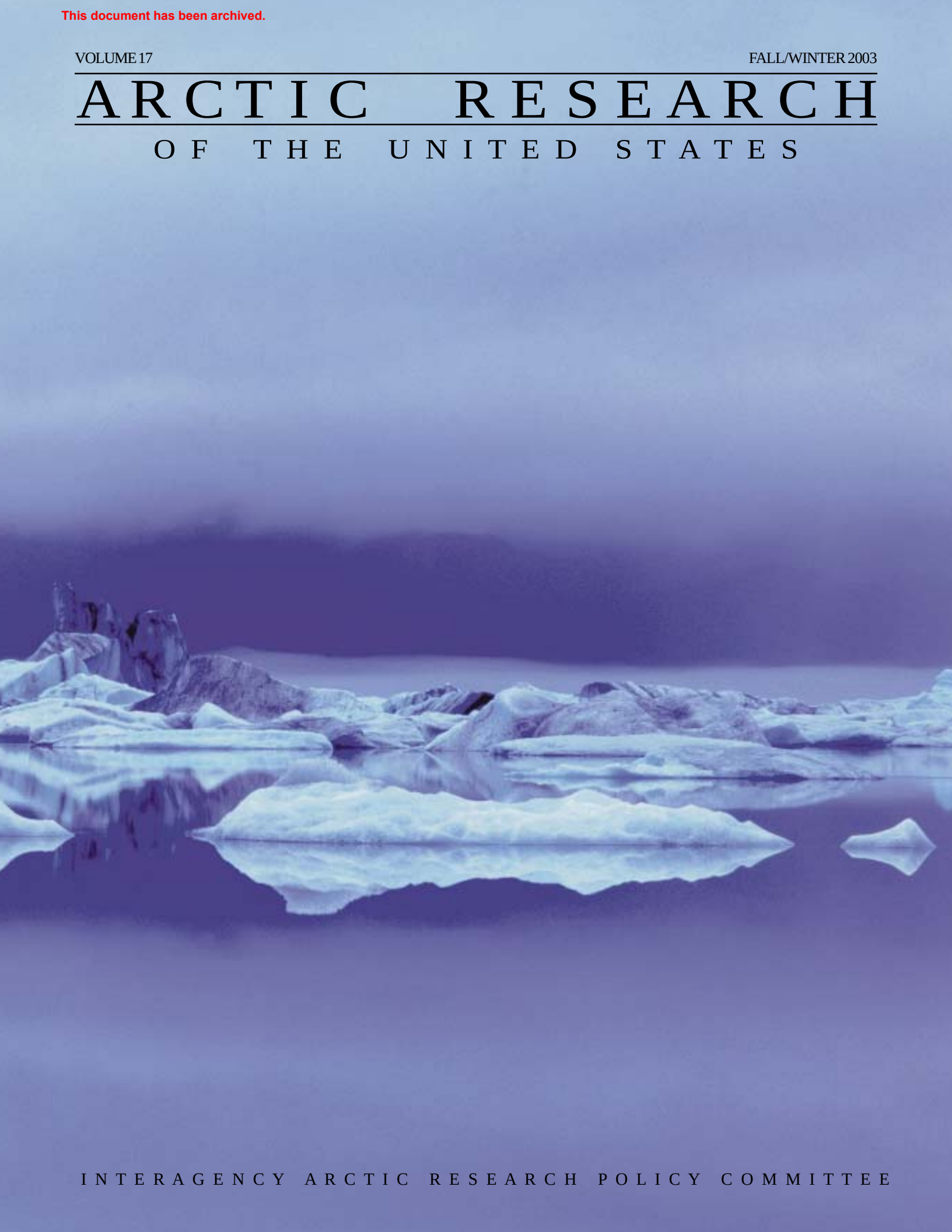
VOLUME 17 FALL/WINTER 2003

ARCTIC RESEARCH
OF THE UNITED STATES



INTERAGENCY ARCTIC RESEARCH POLICY COMMITTEE

About the Journal

The journal *Arctic Research of the United States* is for people and organizations interested in learning about U.S. Government-financed Arctic research activities. It is published semi-annually (spring and fall) by the National Science Foundation on behalf of the Interagency Arctic Research Policy Committee (IARPC). The Interagency Committee was authorized under the Arctic Research and Policy Act (ARPA) of 1984 (PL 98-373) and established by Executive Order 12501 (January 28, 1985). Publication of the journal has been approved by the Office of Management and Budget.

Arctic Research contains

- Reports on current and planned U.S. Government-sponsored research in the Arctic;
- Reports of IARPC meetings; and
- Summaries of other current and planned Arctic research, including that of the State of Alaska, local governments, the private sector, and other nations.

Arctic Research is aimed at national and international audiences of government officials, scientists, engineers, educators, private and public groups, and residents of the Arctic. The emphasis is on summary and survey articles covering U.S. Government-sponsored or -funded research rather than on technical reports, and the articles are intended to be comprehensible to a nontechnical audience. Although the articles go through the normal editorial process, manuscripts are not refereed for scientific content or merit since the journal is not intended as a means of reporting scientific research. Articles are generally invited and are reviewed by agency staffs and others as appropriate.

As indicated in the U.S. Arctic Research Plan, research is defined differently by different agencies. It may include basic and applied research, monitoring efforts, and other information-gathering activities. The definition of Arctic according to the ARPA is "all United States and foreign territory north of the Arctic Circle and all United States territory north and west of the boundary formed by the Porcupine, Yukon, and Kuskokwim Rivers; all contiguous seas, including the Arctic Ocean and the Beaufort, Bering, and Chukchi Seas; and the Aleutian chain." Areas outside of the boundary are discussed in the journal when considered relevant to the broader scope of Arctic research.

Issues of the journal will report on Arctic topics and activities. Included will be reports of conferences and workshops, university-based research and activities of state and local governments and public, private and resident organizations. Unsolicited nontechnical reports on research and related activities are welcome.

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Cover

Icebergs in the Russell Fiord Wilderness, Tongass National Forest, near Yakutat, Alaska. Photo by Howie Garber.

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ARCTIC RESEARCH

OF THE UNITED STATES

U.S. Arctic Research Plan

Biennial Revision: 2004–2008

United States Arctic Research Plan

Biennial Revision: 2004–2008

Introduction

The United States Arctic Research Plan was prepared by the Interagency Arctic Research Policy Committee (IARPC) and approved by the Chair of IARPC on July 10, 2003. The Plan is a consensus document that reflects the views of twelve IARPC agencies. It responds to recommendations of the U.S. Arctic Research Commission and to recommendations of scientists who provided advice to the IARPC agencies.

The Plan includes five special focus multiagency research programs agreed to by the Federal agencies and includes multiagency cross-cutting issues such as research support and logistics, facilities, international activities, and data and information. The Plan describes high-priority research needs of the agencies. The Plan also responds to environmental and strategic objectives of U.S. Arctic policy.

The Plan is a living document. In accordance with the Arctic Research and Policy Act, it is revised every two years.

Executive Summary

Background

The United States has substantial economic, scientific, strategic, and environmental interests in the Arctic. As required by the Arctic Research and Policy Act of 1984 (Public Law 98-373),* a comprehensive Arctic Research Plan is prepared by the Interagency Arctic Research Policy Committee and submitted to the President, who transmits it to Congress. Section 109(a) of the Act requires a biennial revision to the Plan. This document updates the Plan and elaborates on the requirements of Section 109(a).

United States research in the Arctic and this biennial revision are governed by U.S. national policy on the Arctic, research goals and objectives agreed upon by the Interagency Committee, and guidance provided by the Arctic Research Commission.

Guiding Vision

It is in the national interest of the United States to support scientific and engineering research to implement its national policy objectives, including:

- Protecting the Arctic environment and conserving its living resources;
- Promoting environmentally sustainable natural resource management and economic development in the region;
- Strengthening institutions for cooperation among the eight Arctic nations;
- Involving the indigenous people of the Arctic in decisions that affect them;
- Enhancing scientific monitoring and research on local, regional, and environmental issues (including their assessment); and
- Meeting post-Cold-War national security and defense needs.

Interagency Coordination

The Arctic Research and Policy Act requires cooperation among agencies of the U.S. Government with missions and programs relevant to the Arctic. It established the Interagency Arctic Research Policy Committee to "promote Federal interagency coordination of all Arctic research activities" [Section 108(a)(9)]. The Interagency Committee, chaired by the National Science Foundation (NSF), continues to provide the mechanism for developing and coordinating U.S. Arctic research activities.

Revision to the Plan

This revision to the United States Arctic Research Plan includes two major sections. The first of these presents the special focus Interagency Research Programs. For this biennial revision of the Plan, agencies agreed that the following five programs are ready for immediate attention as interagency focused efforts:

- Study of Environmental Arctic Change (SEARCH)
- Developing a Research Plan for a Sustainable Bering Sea
- Arctic Health Research
- Research on Resource Evaluation
- Research on Civil Infrastructure.

The second major section is the Agency Programs, which represent the objectives of Federal agencies, focusing on the period covered by this revision (2004–2008). They are presented in seven major categories, and where common activities exist they are presented as collective programs:

- Arctic Ocean and Marginal Seas
- Atmosphere and Climate
- Land and Offshore Resources
- Land–Atmosphere–Water Interactions
- Engineering and Technology
- Social Sciences
- Health.

Since the passage of the Act, the Interagency Committee, the Arctic Research Commission, and the State of Alaska have addressed issues related to logistics support for Arctic research. This revision considers issues related to surface ships and ice platforms; land-based and atmospheric facilities and platforms; coordination; and data facilities.

Budgetary Consideration

Appendix C presents a summary of each agency's funding for the 2002–2004 period. The total interagency Arctic budget estimate for FY 03 is $299 million; for FY 04 it is $300 million. Program descriptions reflect the general direction of agency programs.

* Amended on November 16, 1990 (Public Law 101-609); see Appendix E.

1. Introduction

1.1 National Needs, Goals, and Objectives

United States research in the Arctic and this biennial revision are governed by the U.S. Arctic Policy Statement of 1994, the Declaration on Establishment of the Arctic Council, research goals and objectives agreed upon by the Interagency Committee, and guidance provided by the Arctic Research Commission.

1.1.1 Guiding Vision

The national interest of the United States requires support of scientific and engineering research to implement its national policy objectives, including:

- Protecting the Arctic environment and conserving its biological resources;
- Assuring that natural resource management and economic development in the region are environmentally sustainable;
- Strengthening institutions for cooperation among the eight Arctic nations;
- Involving the Arctic's indigenous people in decisions that affect them;
- Enhancing scientific monitoring and research on, and assessment of, local, regional, and global environmental issues on Earth and in near-Earth space; and
- Meeting national security and defense needs.

U.S. Arctic research uses the northern polar region as a natural laboratory to study processes that also occur at lower latitudes. Where appropriate, this research is coordinated with the efforts of state and local governments and the private sector. The research is carried out in a manner that benefits from and contributes to international cooperation. Arctic research policy is subject to periodic review and revision. The role of the Arctic in meeting national needs and addressing key policy issues is further highlighted below.

1.1.2 Nonrenewable Resources

The U.S. imports approximately 50% of its petroleum. About 17% of our domestic oil production comes via the Trans-Alaska Pipeline System from the Prudhoe Bay region in Arctic Alaska. The Department of the Interior (USGS and MMS) estimates that at least 36% of the Nation's future reserves (undiscovered resources) of oil and natural gas liquids lie beneath northern Alaska and adjacent offshore areas. The State of Alaska reports that northern Alaska contains known gas reserves of 30.9 trillion cubic feet (tcf), which is about 18% of the Nation's gas reserve; currently plans are being discussed for a gas pipeline to transport this resource south. Gas hydrate resources exist in Arctic Alaska. The USGS estimates that 98% of these resources occur under Federal waters in the Beaufort Sea. In addition to oil and gas, the Arctic has large coal deposits. The U.S. Arctic has been estimated to contain about as much coal as the remainder of the United States. However, U.S. Arctic coal production is limited by the lack of infrastructure and will continue to be limited until the energy needs of Alaska grow substantially or Pacific Rim countries provide sufficient impetus for further coal development.

Minerals are also important Arctic resources. The Red Dog lead–zinc–silver mine, north of the Arctic Circle, is one of the largest zinc-producing mines in the world, producing 70% of the U.S. zinc output, according to data from the U.S. Geological Survey. The Arctic shelves also contain mineral deposits. At least one offshore tin mine has been brought into production in Russia. Dredging for sand and gravel on the Arctic Ocean shelves supports hydrocarbon development and other large coastal and offshore construction projects.

1.1.3 Renewable Resources

Arctic and Bering Sea waters support some of the most productive fisheries in the world. The Bering Sea supplies nearly 5% of the world's fishery products. An estimated 4 million metric tons of 43 commercial species are caught every year by fishing fleets from the United States, Russia, Japan, and other nations. Since the passage of the Magnuson Fishery Conservation and Management Act in 1976, American groundfish operations in Alaska have developed into an industry with an annual product value estimated at $2.2 billion. Dutch Harbor–Unalaska, Alaska, is the leading U.S. port in the quantity of commercial fish landings. Alaska leads all states in both total volume and total value of fish landings.

1.1.4 Global Change

A greenhouse effect occurs on Earth, because its atmosphere of water vapor, carbon dioxide, and other constituents traps outgoing long-wave radiation emitted from the Earth's surface. Without the greenhouse effect, the global surface air temperature would be about 33°C lower. Anthropogenic emissions of greenhouse gases and aerosols and land use changes alter the incoming and outgoing distribution of solar energy that powers weather and climate. Climate model projections of future global distributions of surface air temperature resulting from increased greenhouse gases indicate that the Arctic region will be expected to have a larger warming compared to tropical and marine latitudes (Serreze et al. 2000). (See Section 2.1.)

1.1.5 Social and Environmental Issues

Arctic populations live in close contact with their environment and are highly dependent on marine and terrestrial ecosystems. Contaminants pose a potential threat to the health of Arctic residents who rely on subsistence foods (fish, marine mammals, moose, and caribou). Heavy metals, organochlorines, soot, and other pollutants accumulate at high latitudes because of atmospheric and oceanic circulation patterns and subsequent concentration in food chains and organic soils (Schlosser et al. 1995). The effects of environmental change, including climate changes, can have impacts on Arctic ecosystems, on the response of wildlife to ecosystem productivity, and on the human use of wildlife.

Other issues of importance to Arctic residents include changes such as those resulting from large-scale development and population influx. Many of these changes are positive, such as increased educational and employment opportunities, better medical care, and the use of modern technology. Other changes, such as social and cultural disruption, are a cause for concern. Research addressing the phenomena of rapid social change, human–environment interactions, and the viability of small subsistence-dependent communities sheds light on the complex relationships between environment, economy, culture, and society.

High latitudes are also particularly susceptible to adverse conditions in the space environment, which can disrupt satellite operations, communications, navigation, and electric power distribution grids, leading to a variety of socioeconomic losses. These space environment effects, generally referred to as "space weather," are often associated with transient phenomena on the sun that may cause geomagnetic storms on Earth.

1.1.6 U.S. Goals and Objectives for Arctic Research

Arctic research is aimed at resolving scientific, sociological, and technological problems concerning the physical and biological components of the Arctic and the interactive processes that govern the behavior of these components. The objectives include addressing the needs for increased knowledge on such issues as using the Arctic as national defense, natural hazards, global climate and weather, energy and minerals, transportation, communications, renewable resources, contaminants, environmental protection, health, adaptation, and Native cultures.

More specific long-term goals have been developed by the Interagency Committee to further guide the revision of the Plan:

- Pursue integrated, interagency, and international research and risk assessment programs for the purpose of managing Arctic risks;
- Continue to develop and maintain U.S. scientific and operational capabilities to perform research in the Arctic;
- Promote the improvement of environmental protection and mitigation technology and the enhancement of ecologically compatible resource use technology;
- Develop an understanding of the role of the Arctic in predicting global environmental changes and perform research to reveal early signals of global changes as manifested in the Arctic;
- Develop the scientific basis for responding to social changes and the health needs of Arctic people;
- Contribute to the understanding of the relationship between Arctic residents and their use of wildlife and how this relationship might be affected by global climate change and transported contaminants;
- Engage Arctic residents, scientists, and engineers in planning and conducting the research and report results to these individuals and the public;
- Continue to document and understand the role of permafrost in environmental activities;
- Advance knowledge of the Arctic geologic framework and paleoenvironments;
- Contribute to the understanding of upper atmospheric and outer space phenomena, particularly their effects on space-borne

and ground-based technological systems;
- Develop and maintain databases and data and information networks; and
- Develop and maintain a strong technological base to support national security needs in the Arctic.

In addition to these goals and objectives for Arctic research developed by the Interagency Committee, the Arctic Research Commission has provided further guidance for U.S. Arctic research. This revision of the Plan is consistent with these Commission recommendations.

1.2 Budgetary Considerations

The Act does not provide separate additional funding for Arctic research. Agencies request and justify funds for these activities as part of the budget process. Table 1 presents a summary of each agency's Arctic research funding for the 2002–2004 period. The total interagency Arctic expenditure for FY 03 was $299 million; for FY 04 it is $300 million. Appendix C contains a detailed listing of existing Federal agency programs and budgets, divided by major subelements. The Plan contains the detailed agency budgets through FY 04. Program descriptions may be assumed to reflect the general direction of agency programs.

In the FY 04 Interagency Research and Development Priorities Memorandum (http://www.whitehouse.gov/omb/memoranda/m03-15.pdf), OSTP and OMB issued R&D Investment Criteria aimed at improving R&D program management and effectiveness. Approval and funding of all Federal R&D is contingent upon meeting the primary criteria of Relevance, Quality, and Performance. While individual Arctic research efforts will continue to be gauged by the R&D Investment Criteria, the next Arctic Research Plan will provide more information and references associated with the R&D Investment Criteria with respect to interagency coordination in this area.

Table 1. Arctic research budgets by individual Federal agencies (in millions of dollars).

Agency	*FY 02 Actual*	*FY 03 Estimated*	*FY 04 Estimated*
Defense	19.4	15.2	17.1
Energy	15.8	16.3	4.5
EPA	0.4	0.6	0.5
HHS	26.2	37.2	38.2
Homeland Security	10.4	5.9	8.2
Interior	47.2	55.7	53.9
NASA	38.5	36.1	37.5
NOAA	47.4	35.2	35.4
NSF	86.0	93.1	101.7
Smithsonian	0.5	0.5	0.5
USDA	3.3	3.0	2.9
Total	294.9	298.6	300.3

1.3 Interagency Coordination

The Arctic Research and Policy Act (Appendix E) requires cooperation among agencies of the U.S. Government with missions and programs relevant to the Arctic. It established the Interagency Arctic Research Policy Committee to "promote Federal interagency coordination of all Arctic research activities" [Section 108(a)(9)]. The Interagency Committee, chaired by the National Science Foundation (NSF), continues to provide the mechanism for guiding and coordinating U.S. Arctic research activities. The biennial revisions of the U.S. Arctic Research Plan serve as guidance for planning by individual agencies and for coordinating and implementing mutually beneficial national and international research programs.

Since the last revision of the Plan, significant progress has been made in implementing recommendations, and accomplishments continue to be identified. These include activities of the Interagency Committee and the Arctic Research Commission. Additional information can be found in the journal *Arctic Research of the United States* (Volume 16, Spring/Summer 2002), published by NSF on behalf of the IARPC.

The Act mandates coordination of U.S. Arctic research programs. Mechanisms for appropriate levels of coordination continue to evolve. Three levels of coordination and cooperation are needed for an effective national Arctic research program:
- Individual agency, and independent investigator, research programs;
- National coordination; and
- International collaboration.

Each element requires a mechanism for internal program development, review, and implementation,

and each needs to be linked to the other two. The national effort is performed through the Interagency Committee. A staff oversight group of the Interagency Committee provides coordination, assisted by working groups representing specific agency programs. These are reported in the subsequent sections.

Coordination with global change programs is an integral part of Arctic program development and implementation.

1.4 International Cooperation

The U.S. is now in its fourth year as a regular member of the Arctic Council, since concluding its two-year chairmanship of the Council on October 13, 2000, in Barrow, Alaska. Finland chaired the Council for the 2000–2002 period and passed the gavel to Iceland in October 2002. The Arctic Council is an eight-nation forum established in 1996 to bring together, in a senior policy setting, the environmental conservation elements of the former Arctic Environmental Protection Strategy (AEPS) and issues of common concern related to sustainable development. In addition to the eight nations (Canada, Denmark/Greenland, Finland, Iceland, Norway, the Russian Federation, Sweden, and the United States), many of the Arctic's indigenous communities are recognized as Permanent Participants of the Arctic Council.

The Arctic Council is entirely consistent with the objectives articulated in the U.S. Arctic Policy Statement of 1994 and offers an important vehicle for pursuing them. These policy objectives include:

- Protecting the Arctic environment and conserving its living resources;
- Promoting environmentally sustainable natural resource management and economic development in the region;
- Strengthening institutions for cooperation among the eight Arctic nations;
- Involving the indigenous people of the Arctic in decisions that affect them;
- Enhancing scientific monitoring and research on local, regional, and environmental issues; and
- Meeting national security and defense needs.

The United States has been an Arctic nation, with important interests in the region, since the purchase of Alaska in 1867. National security, economic development, human rights, and scientific research remain cornerstones of these interests. At the same time the pace of change in the region—particularly political and technological developments—continues to accelerate, creating interdependent challenges and opportunities for policy makers in Arctic regions.

U.S. Arctic policy reflects these elements of continuity and change. It emphasizes environmental protection, sustainable development, and the role of indigenous people, while recognizing U.S. national security requirements. It also is concerned with the need for scientific research—particularly in understanding the role of the Arctic in global environmental processes—and the importance of international cooperation in achieving Arctic objectives.

The Department of State's Office of Polar Affairs works in close consultation with the State of Alaska, Alaskan indigenous people, and Alaskan nongovernmental organizations (NGOs) on Arctic issues and policy making. Federal agencies continue to give careful consideration to local Alaskan needs, including the unique health, social, cultural, and environmental concerns of indigenous communities, when developing Arctic programs and policies. Alaskans will continue to be included as appropriate on U.S. delegations to Arctic-related meetings. U.S. Inuit, Aleut, Gwich'in, and Athabaskan populations are now represented as Permanent Participants on the Arctic Council, the Gwich'in and Athabaskans as a result of a ministerial decision in October 2000 in Barrow, Alaska. The Council now has six Permanent Participants.

The Arctic Council today includes five observer nations (Germany, France, the Netherlands, Poland, and the United Kingdom) with Arctic research and environmental interests. These nations have contributed to the environmental working groups of the Council and stated that they were interested in taking a more active role in the Council's work.

1.4.1 Environmental Protection

During its chairmanship the U.S. expanded its international cooperation in the area of Arctic environmental protection.

The United States remains fully engaged in the Arctic Council Action Plan to Eliminate Pollution in the Arctic (ACAP), which is focused on dealing

with threats identified in the Council's Arctic Monitoring and Assessment Program. The Environmental Protection Agency has provided leadership for an ACAP program to prevent production and remediate the effects of persistent organic pollutants in the Russian Federation.

The National Science Foundation and NOAA provide crucial leadership for the Arctic Climate Impact Assessment (ACIA), in cooperation with the Arctic Monitoring and Assessment Program, and for the Conservation of Arctic Flora and Fauna (CAFF) Working Group, in cooperation with the International Arctic Science Committee. The U.S. is financing all of the ACIA Secretariat, among other contributions.

U.S. engagement in prevention and remediation activities follows a decade of international cooperation to monitor and assess the levels of environmental pollution. Beginning in 1989, the eight Arctic countries first discussed the need for international cooperation to address environmental protection. In 1991, in Rovaniemi, Finland, they established the Arctic Environmental Protection Strategy (AEPS). In 1996, in Ottawa, Canada, the Arctic Council was created to address issues of sustainable development in the Arctic and to oversee and coordinate the programs previously established under AEPS. This nonbinding effort has primarily operated through four working groups to address environmental issues relevant to the circumpolar area:

- *Arctic Monitoring and Assessment Program (AMAP):* Assesses the health and ecological risks associated with contamination from radioactive waste, heavy metals, persistent organic pollutants, and other contaminants. Recommends targeted monitoring to collect current data from areas of special concern.
- *Conservation of Arctic Flora and Fauna (CAFF):* Studies the adequacy of habitat protection and ways to strengthen wildlife protection through an international network of protected areas and more effective conservation practices.
- *Protection of the Arctic Marine Environment (PAME):* Creates international guidelines for offshore oil and gas development in the Arctic, organizes and promotes the drafting of a regional action plan for control of land-based sources of Arctic marine pollution, and collects information on Arctic shipping activities.
- *Emergency Preparedness and Response (EPPR):* Provides a forum in which participants work to better prevent, prepare for, and respond to the threat of environmental emergencies in the Arctic. Activities include risk assessment and recommendation of response measures.

During the Finnish chairmanship of the Council, Council leadership conducted a review of the allocation of environmental work among the four working groups (AMAP, CAFF, PAME, EPPR) to remedy gaps and duplication, if any. It was established that the current structure of the Council is operating efficiently with few or no gaps or duplication. Having completed the review, the Council will move forward with its substantive work during the Icelandic chairmanship.

1.4.2 Sustainable Development

The Arctic Council Declaration describes sustainable development as "including economic and social development, improved health conditions, and cultural well-being." Further, the concept of sustainability is reflected in the description of environmental protection, which refers to "the health of the Arctic ecosystems, maintenance of biodiversity in the Arctic region, and conservation and sustainable use of natural resources."

At the Inari Ministerial meeting in October 2002, Ministers committed to developing the Arctic Council's Sustainable Development Framework Document, adopted by Ministers in 2000. It is intended that Ministers will adopt this at the next Arctic Council Ministerial in the fall of 2004 in Iceland.

1.4.3 Scientific Research

The United States continues to plan to further international scientific research through development of an increasingly integrated national Arctic research program. During the U.S. chairmanship the United States took steps to support international cooperation in monitoring, assessment, and environmental research, as well as social science research related to sustainable development. U.S. support for the Arctic Climate Impact Assessment remains a key example of promoting international collaborative research in the environmental sciences and in social science related to sustainable development.

The Interagency Arctic Research Policy Committee, with advice from the U.S. Arctic Research Commission, coordinates Federal efforts to produce an integrated national program of research, monitoring, assessments, and priority setting that

most effectively uses available resources. U.S. Arctic policy recognizes that cooperation among Arctic nations, including coordination of priorities, can make essential contributions to research in the region. To this end the Framework Document on Sustainable Development, support for the Survey of Living Conditions in the Arctic, and the AMAP assessment on the state of the Arctic environment provide important tools in influencing future research priorities.

1.4.4 Conservation

The United States works both nationally and internationally to improve efforts to conserve Arctic wildlife and protect habitat, with particular attention to polar bears, walruses, seals, caribou, migratory birds, and boreal forests.

Consistent with the Agreement on Conservation of Polar Bears, the U.S. and Russia signed an agreement in October 2000 to improve conservation of their shared population of polar bears. The Senate consented to the agreement in July 2003. Several official studies are ongoing, including a study of pollution contamination of seals around two villages in northern Alaska. The U.S. also works to better implement existing measures, such as the 1916 Migratory Bird Treaty and other conservation measures, to mitigate seabird bycatch by commercial fishing vessels.

1.4.5 Cooperation with the Russian Federation

Via the Department of State's Environmental Diplomacy Funds (EDF), the U.S. successfully concluded international projects that assess pollutants in Russia for the benefit of the entire Arctic region. The findings of these projects will have relevance not only in Russia, but in the entire Arctic region. U.S. financial and resource contributions to these projects have helped ensure a strong international presence on issues that ultimately affect our own Arctic inhabitants and ecosystems.

In addition to the broad-based cooperation within the Arctic Council, which, among other things, aids in establishing a more effective environmental regulatory infrastructure in Russia, other multilateral forums now exist to address specialized concerns. Through NATO, we engage the Russian military on defense-related environmental issues. On a trilateral basis, with Norway, we focus on the cleanup and consolidation of waste generated from military activities through the Arctic Military Environmental Cooperation (AMEC) process. Our support of the International Atomic Energy Agency's International Arctic Seas Assessment Program also has provided a conduit for monitoring and assessing radioactive contaminants in the seas adjacent to the Russian Arctic.

The former Soviet Union (FSU) had an extensive nuclear power program with numerous supporting waste management activities that involved ad hoc storage of low- and intermediate-level radioactive wastes by shallow land burial and in surface water impoundments, as well as storage of high-level wastes. The Mayak, Tomsk, and Krasnoyarsk sites all lie within a few kilometers of the edge of the West Siberian Plain and Basin. Past and continuing disposal of wastes at Mayak, Tomsk, and Krasnoyarsk to surface waters (for example, the Ob and Yenisey Rivers) and surface water impoundments, and by deep well injections at Tomsk and Krasnoyarsk, have the potential to contaminate the Arctic Ocean, the western Siberian oil and gas fields, and the regional water resources.

1.5 Revision to the Plan

This sixth revision to the United States Arctic Research Plan includes two major sections:

- Section 2. Special Focus Interagency Research Programs; and
- Section 3. Agency Programs.

The Agency Programs section includes discussion of representative programs of Federal agencies, focusing on the period covered by this revision (2004–2008). Examples of programs are presented in seven major categories, and where common activities exist they are presented as collective activities. Individual agency mission accomplishments were discussed in the Spring/Summer 2002 issue of *Arctic Research of the United States* and will be updated in 2004. Several overall themes transcend essentially all integrated and research mission components.

Section 4 presents current activities related to field operational support necessary for implementation of the proposed interagency programs and research mission activities.

2. Special Focus
Interagency Research Programs

The Interagency Committee's research policy states:

> The IARPC agrees that a more comprehensive approach to funding of research and baseline programs is required to ensure a long-term, viable research and development presence in the Arctic. This presence will ensure support of the national needs, which include renewable and nonrenewable resource development, environmental protection, and partnerships with the private sector and residents of the Arctic. It will complement other national and international scientific programs, such as Global Change. To this end the IARPC agencies agree to develop an integrated interagency program sufficient for meeting national needs.

For this biennial revision of the plan, agencies agreed that the following three programs are ready for immediate attention as multiagency focused efforts:

- Study of Environmental Arctic Change (SEARCH)
- Developing a Research Plan for a Sustainable Bering Sea
- Arctic Health Research.

Two new programs will be undertaken during this planning cycle:

- Research on Resource Evaluation
- Research on Civil Infrastructure.

These coordinated, multiagency programs are being designed to:

- Focus research activities in concert with national policy;
- Build on individual agency efforts in reconnaissance, monitoring, process studies, and modeling;
- Facilitate research and logistics coordination through regionally focused programs;
- Take maximum advantage of remote sensing and new technologies;
- Strengthen interagency data and information management;
- Draw on the strengths of the academic, industrial, and government research communities in planning and implementing programs;
- Support and enhance programs to acquire long-term measurements of key parameters and environments; and
- Enhance international research collaboration.

The U.S. has a substantial economic, strategic, and environmental stake in the Arctic. Domestic energy reserves and the growth in Bering Sea fisheries harvests are two examples of our dependence on Arctic resources. Sound management decisions for sustainable development of Arctic resources hinge on enhanced understanding of the environment, leading to better forecasts. In addition, there is a strong international commitment to collaborate.

Benefits to the Nation from Arctic research include improvements in:

- Knowledge of fishery resources and controlling dynamics;
- Models and data for assessing past climates and global change and their effects;
- International cooperation in a strategic region;
- Forecasts of weather, ice, and ocean conditions;
- Protection of the Arctic environment;
- Understanding of the causes, effects, and limits of air and water pollution; and
- Protection and understanding of cultures and cultural resources.

2.1 The Study of Environmental Arctic Change

2.1.1 Introduction

The following discussion is drawn from the Science Plan for the Study of Environmental Arctic Change (SEARCH) program, a research program sponsored by the Interagency Arctic Research Policy Committee. The Science Plan was prepared by the SEARCH Project Office, Polar Science Center, Applied Physics Laboratory, University of Washington, Seattle. For more information, see http://psc.apl.washington.edu/search/Library/SEARCH_Science_Plan.pdf.

As discussed in detail in the SEARCH Science Plan, observed changes in the atmosphere, in the oceans, and on land in the Arctic are affecting virtually every part of the Arctic and now have potential impacts, both direct and indirect, on human society. These changes include a decline in sea-level atmospheric pressure [typically a 2-mb decrease in multiyear averages (Steele and Boyd 1998) over the Arctic with a peak change of 4 mb near the center of the basin (Walsh et al. 1996), or on the order of one standard deviation in AO Index]. Other observed environmental changes include:

- Reduced sea ice extent [3% per decade (Parkinson et al. 1999)] and thickness [–42% in the last 25 years (Rothrock et al. 1999)].
- Shift in the balance between Atlantic and Pacific waters and changes in salinity and temperature (e.g. Morison et al. 2000). The revealing changes in upper ocean temperatures and salinities are five times the RMS variability in the 1970s and exceed extreme values measured in the corresponding locations in the previous 50 years (EWG 1997, Steele and Boyd 1998).
- Sea level rise in the Russian Arctic. There are 2- to 20-cm increases in sea level in the Russian marginal seas over a 50-year period, with interannual variations on the same order (Pavlov 2001). Proshutinsky et al. (2001) argue that this is driven by changes in atmospheric forcing of the barotropic circulation.
- Permafrost warming (0.5°C) and thawing in the intermittent permafrost region of Alaska (Osterkamp and Romanovsky 1999) and warming and thawing of permafrost in the Russian Arctic (Pavlov 1994) since the late 1980s.
- Decreasing permafrost temperatures in eastern Canada (Wang and Allard 1995).
- Below-average Northern Hemisphere snow cover in recent years by reductions in spring snow cover since the mid-1980s (Robinson et al. 1993, 1995).
- Decreasing mass of small Arctic glaciers (Dyurgerov and Meier 1997, Dowdeswell et al. 1997).
- Drying trend, increased forest fires (Oechel and Vourlitis 1996, Stocks 1991), and southern pest infestations in Alaska.
- Long-term increase in river runoff (Petersen et al. 2003).
- Large increase in Bering Sea jellyfish populations. According to Brodeur et al. (1999) the biomass of large jellyfish in the Bering Sea has soared in the 1990s.
- Whale migrations shifting with decreased ice extent (Tynan and DeMaster 1997, Treacy 1998).
- Increase in Barents Sea cod size with temperature increases (Bogstad and Gjosaeter 1994, Brander 1994).
- More terrestrial plant growth. According to the SEARCH Science Plan, studies point to increased plant growth (Mynemi et al. 1997), northward advances of the tree line (D'Arrigo et al. 1987, Nichols et al. 1996), increased fire frequency (Oechel and Vourlitis 1996, Stocks 1991), and thawing and warming of permafrost (Pavlov 1994, Osterkamp and Romanovsky 1996, 1999).

Because of the interplay of natural and human-caused factors, we do not know if the recent complex of changes is part of a pattern of natural variability or the beginning of a long-term shift. We also do not know what climate and ecosystem processes may be involved or what the long-term impacts may be. We do know that environmental changes in the Arctic can affect other global systems in major ways, mainly by changing the amount of solar radiation reflected from the earth's surface (snow and ice reflect energy that is absorbed by earth and open water) and by reducing the global thermohaline circulation by capping the sub-Arctic seas with fresh water and melted sea ice flowing from the Arctic Ocean.

2.1.2 Arctic Oscillation

SEARCH scientists hypothesize, and statistical analysis and modeling studies tend to confirm,

that many of the changes listed in Section 2.1.1 are related to a strengthening of the atmospheric polar vortex [e.g., SEARCH Science Plan 2001, Morison et al. 2000, Zhang et al. 1998, 2000, Maslowski et al. 2000) as characterized, for example, by the Arctic Oscillation (AO), which is a natural mode of atmospheric variation. The strengthened west-to-east motion of the atmosphere associated with an increased AO brings more warm air to the Greenland Sea, Scandinavia, and Russia.

The cause for the 1990s increase in the AO is an important research question. Some modeling studies (Fyfe et al. 1999, Shindell et al. 1999) suggest the AO is strengthened by the anthropogenic (human-caused) rise in greenhouse gases, but the recent changes are larger and earlier than these models suggest. Therefore, while anthropogenic climate change may explain part of the observed environmental changes, a significant part of the change is likely an extreme example of natural variability. This large-scale pattern of change interacts with more localized natural and anthropogenic factors to change the climate at any one location. We do not know if the recent complex of changes is part of a cyclic pattern of natural variability or the beginning of a long-term shift. We also do not know if these changes can themselves reinforce or slow environmental change.

2.1.3 Goals

SEARCH is a broad, interdisciplinary, multi-scale interagency program with a core goal of understanding the complex of recent and ongoing intertwined changes, with a view toward prediction. In addition to understanding how changes in the Arctic are interrelated to each other, SEARCH will investigate the links between Arctic change and global processes and will assess the impacts that Arctic change may have throughout the Northern Hemisphere. SEARCH will evaluate the possibility that changes in the Arctic can anticipate changes elsewhere on the globe.

To be most effective in understanding the Arctic's many systems and their interplay, many resources and kinds of expertise must be brought together. SEARCH is the first interagency effort to combine funding sources, disciplines and knowledge from across the United States and around the world to address an issue of this type. The effort is designed to bring researchers together to share knowledge and learn from one another. It is unique, given the complexity of the Arctic environment.

2.1.4 Critical Science Questions

The recent changes in the Arctic are complex, but a key idea of SEARCH is that many of the changes can be thought of as an interrelated complex of pan-Arctic change related to the atmospheric circulation of the whole Northern Hemisphere (SEARCH Science Plan). As discussed above, it is relatively straightforward to argue that a strengthened polar vortex can drive the observed complex of change through the effect of wind stress and the transport of heat and moisture. A critical question is to what extent the response of the Arctic can in turn affect the Northern Hemisphere atmospheric circulation through effects on albedo or the freshwater cycle and global thermohaline circulation (SEARCH Science Plan). Based on observations by the indigenous populations of the Arctic, which bear much in common with the scientific observations, it seems certain that the complex of change has ecological and social dimensions as well (SEARCH Science Plan). For example, people that depend on sea ice for transportation and subsistence gathering report firsthand the effects of decreases in ice extent. The SEARCH program will test these hypotheses in order to understand the changes seen to date, track the changes into the future, and help society to adjust to future changes. Science questions related to these hypotheses will guide the efforts of SEARCH. For example:

- Are the changes seen in recent decades in the Arctic climate system consistent with natural variability, or are such changes at least partially attributable to human activity?
- What is the interplay among atmospheric circulation, ozone loss, and UV radiation?
- Can climate changes in the Arctic be predicted or assigned a probability?
- How will hemispheric or global climate affect or be affected by changes in the Arctic (atmosphere, ocean, land surface, and hydrology)?
- How will seasonal weather patterns in the Arctic and mid-latitudes be affected by changes in the Arctic?
- What are the likely effects and consequences of environmental Arctic change on the health and well-being of Arctic residents?
- What are the likely effects and consequences of environmental Arctic change on ecosystems and key species of the Arctic?
- How might Arctic-driven environmental changes affect societies and U.S. national security?

2.1.5 Major Activities

The changes of the last few years come at a time when many of the large-scale observing systems of the past have declined or been eliminated. For example, the large-scale hydrographic surveys and the ice camps maintained by the Soviet Union for many years have stopped (EWG 1997). Many of the weather stations in the United States, Canada, and Russia have been eliminated. Therefore, according to the SEARCH Science Plan, a major emphasis of SEARCH is developing a long-term large-scale program of observations, the related analysis and modeling, and activities to apply what is learned. SEARCH includes four major types of activities:

- A long-term observational program to detect and track the environmental changes;
- A modeling program to synthesize observations, test ideas about the coupling between the different environmental changes observed, and predict their future course;
- Studies to test hypotheses about critical forcing and feedback processes; and
- An application component to understand the impact of the physical changes on ecosystems and societies and to distinguish between climate-related changes and changes due to other factors such as resource utilization, pollution, economic development, and population growth.

To achieve the goals of SEARCH, the agencies supporting it will invest not only in the four areas described above, but also in "infrastructure" activities such as:

- Development of new observing technologies;
- Creation of new computer-based models;
- Management and rescue of environmental data; and
- Construction and maintenance of field facilities.

2.1.6 Observation and Modeling

There is a need for the deployment of a comprehensive and sustained Arctic environmental observing system. This system will require remote and in-situ systems focused on land, sea, air, and ice. It must provide the critical information on the physical and biotic environment needed to meet the needs of SEARCH. The observing system must be strongly coupled to modeling and data assimilation efforts to ensure that the system's data are useful and used. This comprehensive system must evolve to meet new requirements, comply with new strategies, and incorporate new technologies. Once new observing technologies have been developed and proven in the field, a pathway will be needed to make these technologies operational. This pathway must include consideration of funding requirements, data quality and continuity, and data application.

The observing system and models will provide useful information at different geographic scales from local to regional to global. The use of satellite-based remote sensing is critical for providing the large-scale overview and finer-scale information when possible. Locally intensive observations will rely more heavily on in-situ observations. Whenever possible, these should be made with autonomous sensors or samplers. Continuous use of in-situ data for calibration or validation of remotely sensed data is essential and will require a multiagency approach.

2.1.7 Summary of Agency Participation

Each participating agency will contribute to SEARCH in ways consistent with its mandates, strategies, and scientific capabilities. Each will undertake specific parts of SEARCH and share data, information, and understanding to achieve the overall SEARCH goals. Results from SEARCH and other programs will provide the scientific underpinning for Arctic regional and global assessments of climate variability and change and associated impacts. Table 2 describes the major types of activity that each agency expects to undertake to support SEARCH. Table 3 lists specific priorities for 2004 and currently known agency funding requests.

2.1.8 Major Programs to be Conducted Under SEARCH

Meeting the goals of SEARCH and providing answers to the critical science questions will require the coordinated application of the capabilities and resources of all of the participating agencies. In addition, collaboration with organizations and scientists from other countries will be required to deal with the pan-Arctic nature of these questions.

The SEARCH Science Plan defines a comprehensive, multidisciplinary approach to understanding environmental change in the Arctic and its connections to other regions. The complexity of the overall plan requires that it be divided into

Table 2. Agency activity areas.

National Science Foundation	Environmental processes research and observation, model development, observing technology development, social sciences research, Native-led observatories
National Aeronautics and Space Administration	Space-based and airborne measurements of atmospheric and land/ocean surface processes; model-based research
Department of Commerce/National Oceanic and Atmospheric Administration	Sustained in-situ ocean and atmospheric observations, data- and model-based analyses, forecast services, impact assessments
Department of Defense/Office of Naval Research, Cold Regions Research and Engineering Laboratory	Research and technology development leading to predictive capability for environmental conditions that affect defense operations
Department of Energy/Atmospheric Radiation Measurement Program—North Slope of Alaska/ Adjacent Arctic Ocean Site	Research on atmospheric processes, quantification of surface radiation budgets, environmental modeling
Department of the Interior/Bureau of Land Management, Fish and Wildlife Service, National Park Service, U.S. Geological Survey, Minerals Management Service	Use of protected and managed land areas for long-term terrestrial in-situ observations; assessment of impacts of environmental change on glaciers, vegetation, fish, and wildlife; development of best management practices
Department of Agriculture/Agricultural Research Service, Natural Resource Conservation Service, Forest Service	Impacts of high-latitude environmental change on plant germplasm, agricultural pests, soil quality, and boreal forests; assessments of environmental change on agricultural potential and forest resources.
Smithsonian Institution	Research to understand current and past responses of society to environmental change, and development of interagency outreach program
Department of Homeland Security/U.S. Coast Guard	Logistics support for ocean and sea ice research and observations
All	Integrated modeling and/or assessment efforts, joint studies, collaborative publications

smaller thematic areas suitable for effective implementation. A series of "programs" are to be developed that include efforts in one or more of the four thematic areas included under SEARCH (ocean, atmosphere–cryosphere, biosphere, and human society). These programs will develop in their own way with expert scientists preparing the scientific approach and agency managers developing implementation and funding mechanisms.

Ocean Thematic Area

The highest-priority program to be identified under SEARCH is the Arctic/Sub-Arctic Ocean Fluxes (ASOF) program, which has had a year of intense planning and coordination at national and international levels.

The descent of cold, dense waters across the Greenland–Scotland Ridge and in the Labrador Sea is a principal means by which the deep ocean is ventilated and renewed. Most projections of greenhouse-gas-induced climate change anticipate a weakening of the thermohaline circulation (THC) in the North Atlantic in response to increased freshening and warming in the subpolar seas. The thermohaline circulation is a global process that transports warm surface water from the equator to the higher latitudes and returns cold deep water. A reduction in upper ocean density at high northern latitudes may reduce the rate at which water sinks and thus may weaken the THC and possibly change the climate of eastern North America and western Europe (e.g. Rahmstorf and Ganoploski 1999). Projections of greenhouse-gas-induced climate change indicate a weakening of the THC in the North Atlantic in response to increased freshening and warming in the polar/subpolar region (Delworth and Dixon 2000). These changes reduce high-latitude upper-ocean density and therefore weaken the THC (see, for example, Manabe and Stouffer 1993, Rahmstorf and Ganopolski 1999, Wood et al. 1999). The ASOF program is focused on the response of the ocean's thermohaline circulation to changes in the flux of Arctic ice or fresh water to the North Atlantic. ASOF is designed to detect changes in freshwater flux and thermohaline circulation and assess the potential for resultant climate change.

In FY 04, NSF, NASA, NOAA, Interior, and

Table 3. Agency priorities and funding for FY04.

National Science Foundation	Field measurement programs for improving models and understanding processes; develop new technologies; implement environmental observatories (facilities for making measurements, with a changing mix of measurements); develop new models and data assimilation techniques; lead the interagency effort on human dimensions research	$6.0 million
National Aeronautics and Space Adminstration	Provide the perspective from space under the NASA Earth Science Enterprise; evolve from observation only to include modeling and data assimilation; recalibrate existing sensors for use in the Arctic; build long-term, consistent data sets and support data management and rescue efforts; in the future, aim for more analysis and modeling with targeted in-situ field campaigns to support existing or already planned satellites	$4.0 million SEARCH related*
Department of Commerce/ National Oceanic and Atmospheric Administration	Focus on sustained observations of atmosphere, sea ice, ocean, and marine biota; undertake related data management and data rescue efforts; support modeling and data assimilation; develop applications and products for the public and policy/decision makers	$2.0 million
Department of Defense/ Office of Naval Research, Cold Regions Research and Engineering Laboratory	Continue DOD mission-focused research with secondary objective of supporting SEARCH when possible; continue tracking and modeling sea ice and snow; analyze historical Arctic Ocean and terrestrial data and recent Arctic atmospheric and hydrological data; develop new observing technologies; continue observations in the Bering Strait region; evaluate future DOD missions under possible future environmental conditions in the Arctic and globally	Will use existing funds to begin
Department of Energy/ Atmospheric Radiation Measurement Program— North Slope of Alaska/ Adjacent Arctic Ocean Site	Continue Atmospheric Radiation Measurement Program at the North Slope/Adjacent Arctic Ocean site; investigate flux of thermal and solar radiation through the atmosphere with emphasis on the role of clouds; build and maintain database; apply knowledge to climate models; maintain facilities at Barrow and Atqasuk; complete original site design to include Barrow, Atqasuk, and Oliktok Point as funds permit	$3.2 million SEARCH related*
Department of the Interior/ Bureau of Land Management, Fish and Wildlife Service, National Park Service, U.S. Geological Survey, Minerals Management Service	Conduct studies to understand impacts of environmental change on the lands and resources managed by DOI; discriminate natural from anthropogenic causes and determine need for management actions; provide protected locations and facilities for establishment of environmental observing sites; continue research on conservation of trust species under conditions of a changing Arctic; undertake long-term ecological observations; perform associated data management and rescue tasks	$10.8 million
Department of Agriculture/ Agricultural Research Service, Natural Resource Conservation Service, Forest Service	Conduct research on environmental changes occurring in high latitudes that may affect the sustainable production of food, fiber, and other renewable resources; contribute information concerning impacts on these resources and resource use to interagency human dimensions research	$2.9 million SEARCH related*
Smithsonian Institution	Develop mechanisms to present the SEARCH program and results to a broad national audience, communicate scientific discoveries and understanding, advertise needs and and capacities to the public; enhance existing programs and activities to include Arctic science elements; entrain commercial and charitable organizations to develop educational and outreach materials	Will use existing funds, donations and contributions from other agencies to begin
Department of Homeland Security/U.S. Coast Guard	Provide icebreaker, helicopter, and other logistic support for SEARCH scientific activities in the Arctic	Will use existing funds and cost reimbursements

* Funds appropriated for activities other than SEARCH but whose results can contribute to the SEARCH hypotheses and science questions.

DOD/ONR will support ASOF, as will several international collaborators.

Atmosphere/Cryosphere Thematic Area

In November 2001 the agencies participating in SEARCH sponsored a major science workshop to develop the purpose and scope of a proposed new program, now titled Atmospheric and Cryospheric Change in the Arctic (ACCA).

The Arctic atmosphere and cryosphere have undergone changes during the last thirty years that include a lowering of surface atmospheric pressure, increases in surface air temperature in large regions, decreased ice extent [3% per decade (Parkinson et al. 1999)], and a decrease in ice thickness [42% in 25 years (Rothrock et al. 1999)] (Walsh et al. 1996, Serreze et al. 2000), but our present level of knowledge is inadequate to understand, quantify, or predict the interactions among these changes. Changes over the past decade have resulted in a trend toward increasing strength of the Icelandic low. The positive phase of the NAO is associated with mutual strengthening of the Icelandic Low and Azores High, with corresponding impacts on Northern Hemisphere climate. As discussed above and in the SEARCH Science Plan, the simultaneous increase in NAO or AO and the arguably related changes in the Arctic indicate that changes in the Arctic are connected to the atmospheric circulation of the whole Northern Hemisphere.

The ACCA program will seek to improve understanding of these interactions, leading to formulation of effective strategies to minimize the impacts of climate change. In FY 04, NSF, NASA, NOAA, DOE, and DOD will provide support for the ACCA program.

Biosphere Thematic Area

The SEARCH Science Steering Committee (SSC) is developing a framework for a science program focused on environmental change and associated impacts on marine and terrestrial biota. Key objectives of the biospheric component of SEARCH will be to understand how climate variability and change affect ecosystems and key species and to understand how human management and use of living resources may have to adapt.

In 2004 the NSF, NOAA, and DOI will develop and undertake an implementation plan that will coordinate and enhance biospheric research in the Bering Sea, in cooperation with the interagency Bering Sea research program (see page 21). Simultaneously, NSF, NOAA, DOI, and NASA will evaluate how to transform existing terrestrial ecological monitoring sites, such as an existing north–south transect in the Alaska National Wildlife Refuge, into more comprehensive terrestrial environmental change monitoring sites.

Human Society Thematic Area

To assess the effects of environmental change on indigenous people and other residents, a research program examining the dynamics of linkages between human populations and the biological and physical environment of the Arctic is required. Under SEARCH, experts in the social and economic sciences are leading a dialogue with physical and biological scientists to develop the needed research effort. In addition, the NSF will support research activities in two areas: the study of societal conflicts that arise when "common pool" Arctic resources are affected by environmental changes such as changes in ice extent, increased temperatures, thawing permafrost, and ecological changes that result from physical changes; and pilot projects to involve networks of local residents in performing and documenting environmental change observations.

Synthesis, Integration, and Outreach Activities

In 2004 the agencies that comprise SEARCH will begin what will become a continuing set of activities designed to address the complex goals of SEARCH. By bringing together the data, information, and understanding that each has achieved, the inherently multidisciplinary SEARCH hypotheses and science questions can be addressed. The Smithsonian Institution will organize and lead an interagency task team that will develop outreach activities based on information supplied by the various agencies.

Currently the United States, through both NOAA and the National Science Foundation, is providing leadership and financial support to the Arctic Climate Impact Assessment (ACIA), a whole-Arctic activity under the auspices of the Arctic Council. SEARCH will support the ACIA assessment to be completed in 2004 and also will participate in future assessments undertaken by the Intergovernmental Panel on Climate Change (IPCC) in 2005 and beyond.

2.1.9 Resource Requirements for Continuing Implementation of SEARCH

The SEARCH program is planned as a long-term effort to document and understand environ-

mental change and associated impacts. Given this long-term perspective, SEARCH can be successful even though all activities do not begin at the same time. Agency planning processes are complex and require coordination. Over the next several years the participating agencies will further define their individual roles in SEARCH and seek to obtain the resources needed to implement those roles.

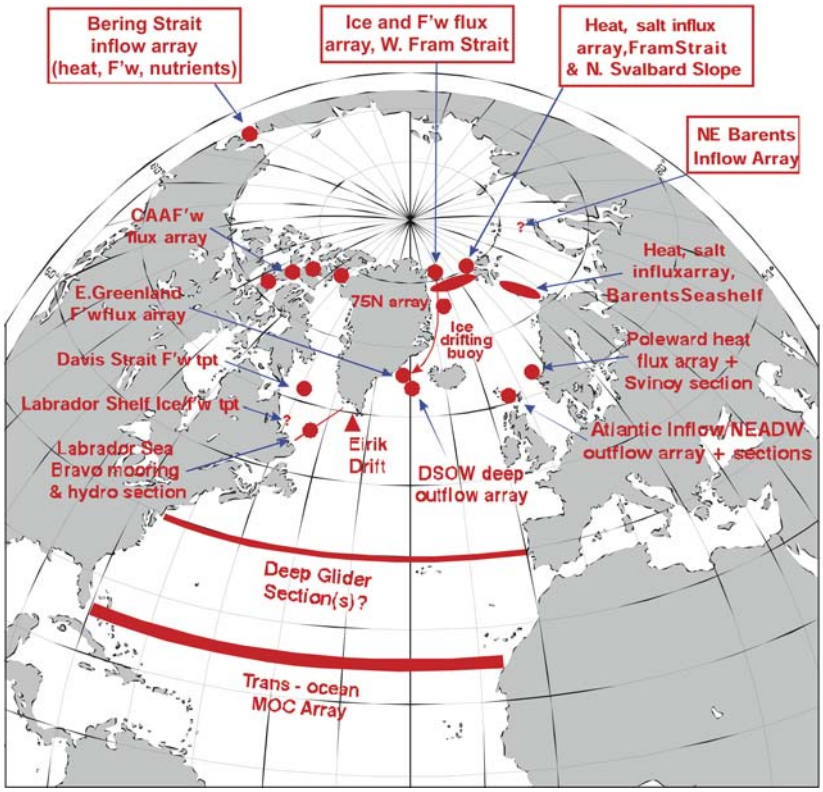
2.1.10 Interagency Management of the SEARCH Program

From its inception the Interagency Working Group (IWG) of the Interagency Arctic Research Policy Committee has been responsible for developing the SEARCH program within the agencies. The responsibilities of the IWG are to:

- Approve membership and "terms of reference" for the Science Steering Committee (SSC);
- Review and approve science and science implementation plans prepared by the SSC and its subsidiary bodies;
- Solicit science advice from the SSC and develop responsive programs and plans;
- Discuss and coordinate agency plans for budget requests to support activities related to SEARCH and provide appropriate interagency assistance;
- Review agency activities that address SEARCH hypotheses and science questions and coordinate agency activities;
- Facilitate international efforts needed to address the SEARCH science questions;
- Identify opportunities for and promote coordination of development and use of facilities needed for SEARCH;
- Identify, encourage, and support activities to integrate and synthesize the results of science supported by SEARCH funds; and
- Identify, encourage, and support outreach and education activities based on the results of activities supported by SEARCH funds.

The SEARCH SSC will continue to provide scientific planning. In particular, it will develop the scientific bases for the thematic programs to be implemented under SEARCH and will be instrumental in devising means for synthesizing and integrating the diverse information that SEARCH will generate. The SSC will provide scientific liaison to international science groups and aid the IWG's efforts to achieve international implementation mechanisms.

Distribution of the observing sites that make up the prototype ASOF Array. The justification for each is described on the SEARCH website (http://psc.apl.washington.edu/search/).



2.1.11 Initial Focused Programs to be Conducted as Part of SEARCH

Arctic/Sub-Arctic Ocean Fluxes

The intention is to establish a coordinated, circum-Arctic system of ocean flux measurements to cover all of the gateways that connect the Arctic Ocean with sub-Arctic seas. Because decreases in the flow through one Arctic gateway may be balanced or reinforced by changes in the transport through another, it is necessary to make measurements in these critical passages at the same time.

The research should not be entirely restricted to "Arctic gateways," however. The proposed ASOF observing system extends south to 25ºN. At least initially the appropriate emphasis in making long observational series is seen to lie in generating the data sets and time series needed to develop the predictive skill of climate models.

Atmospheric and Cryospheric Change in the Arctic

Purpose and Rationale. Atmospheric and Cryospheric Change in the Arctic (ACCA) will focus

on integrating the following three topics:

- Improved predictive understanding of Arctic atmospheric and cryospheric processes through continued model development and data assimilation;
- Coordination, maintenance, and enhancement of Arctic climate and radiation measurement networks; and
- Variations in the fluxes of heat, fresh water, and contaminants into, within, and out of the Arctic and sub-Arctic regions.

ACCA is motivated by the need to understand the climate change that has been observed in the Arctic and to identify the impacts that this change may have on the global climate system. The primary means for addressing the need will be through model development. The data needed for model validation require the establishment and maintenance of field measurement networks adequate to assess regional meteorological and radiation parameters and to detect variations in the regional fluxes of heat, water vapor, fresh water, and climatically active atmospheric contaminants. The models and measurement systems are inherently linked, inasmuch as each system drives the others. Hence, coordination will be essential.

Science Drivers. ACCA will address the above concerns by focusing research on the following key climate-related questions:

- Which of the atmospheric and cryospheric changes that have occurred in the Arctic during recent decades reflect long-term, as compared to interannual or decadal, changes?
- Which of these changes reflect significant teleconnections with lower-latitude climate?
- What mechanisms have driven the recent and ongoing atmospheric and cryospheric changes?
- What are some future Arctic climate change scenarios and their probabilities of occurrence?
- What are possible, or probable, impacts of Arctic climate change on the global ocean and on lower-latitude climate?

Strategy. An integrated approach based on enhanced observational systems, field-based process studies, numerical modeling, and data assimilation will be necessary to address these issues. Climate models can be used to assess future climate change, but they must be able to simulate past and present conditions. This requires the assimilation of long-term data sets into the models and an improved understanding of the relevant processes. Currently, ongoing climate change can only be documented and characterized through observations obtained over decadal time periods and large geographical regions. A minimal strategy to accomplish this will require the following:

- A distributed observation network to obtain long-term observations of sufficient quality and continuity to address questions of climate; this includes satellite observations and distributed networks of climate and radiation measurements;
- Modeling and data analyses using climate models that adequately represent Arctic processes, coupled with assimilation techniques that optimize the integrated information return from models and observations;
- Process studies that are based on field data and assess processes that impact climate and whose understanding is essential to successful development and application of climate models; and
- Coordination activities to maintain a focus on key issues and to ensure that policy makers and the public are informed in a timely fashion about key findings.

These topics can be grouped into general categories, falling under observation network, and modeling and data analyses.

Reliable long-term measurements are limited in the Arctic. Technological advances now make it possible to greatly enhance new data acquisition using existing facilities, such as drifting and land-based remote stations, through the use of telemetry. New technologies also allow the use of satellites in enhanced data acquisition. Several such facilities, supported by Federal agencies, exist in the Arctic:

- The International Arctic drifting Buoy Program (IABP) provides measurements of sea level pressure, ice drift, and surface temperature.
- The Barrow Alaska Environmental Observatory (NOAA Climate Monitoring and Diagnostics Laboratory, DOE Atmospheric Radiation Measurement Program, and NSF Arctic System Science Program) measures UV, visible, and IR radiation; cloud cover and height distribution; aerosols; heat and water vapor fluxes; CO_2; and other air chemistry parameters.
- The Greenland Climate Network assesses climate and glaciological parameters across the Greenland ice sheet.
- The North Pole Environmental Observatory, a remote drifting station, measures meteorological, snow, sea ice, and upper ocean parameters.

- Manned and autonomous surface and upper air stations measure a broad variety of atmospheric parameters.
- Satellite monitoring documents the vertical structure of the atmosphere in addition to snow and ice cover (SSM/I and others).
- The Network for the Detection of Stratospheric Change (NDSC) measures stratospheric parameters.

These facilities need to be expanded and coordinated, and the measurements prioritized, in order to support a set of core Arctic measurements.

Understanding Arctic climate sufficiently to allow prediction depends on the use of climate models. These depend in turn on the availability of observations for model validation. Establishment of data priorities for assimilation into models is essential. The following issues will be paramount in ACCA.

- Application of statistical techniques to data sets in order to test hypotheses concerning high-latitude climate processes;
- Inclusion of realistic cryospheric behavior, including sea ice rheologies and cloud radiation feedback, in climate models;
- Development of optimal techniques for data assimilation into models;
- Quantitative comparisons of the existing ocean–ice–atmosphere models; and
- Evaluation of the role of air chemistry in Arctic change, with an emphasis on aerosols, CO_2, and ozone.

Process studies address deficiencies in our modeling of large-scale climate processes and should be selected based both on model deficiencies and on observed conditions. These studies are likely to involve a combination of field observations and theoretical research and require well-defined strategies for assimilation of the results into models. Cloud radiation feedback mechanisms and upper ocean turbulent heat fluxes, neither of which are well documented in the Arctic but both of which are crucial to understanding climate, are examples of such processes.

Future Programs

Terrestrial Biotic Systems. As discussed in the SEARCH Science Plan and above, changes have occurred in non-glaciated terrestrial biotic systems in response to a predominately warmer physical environment during the past decade (Mynemi et al. 1997).

The changes in terrestrial environmental variables are by no means a simple, direct response to regionally warming atmospheric temperature trends. There is a high degree of biocomplexity inherent in the myriad direct and indirect climate, hydrologic, soil, and ecosystem feedback mechanisms. Increased understanding of the vulnerability of Arctic terrestrial systems to projected continued warming is important for making decisions concerning changes in land use, maintenance of existing and future infrastructure, mitigation of environmental impacts, and the sustainability of Arctic communities, particularly those depending on a subsistence lifestyle.

A central question arises from the recent trend of climate warming and terrestrial system change: Are the changes related? How much of the changes are due to natural variability and how much is humar-induced? There have been cycles of atmospheric temperature change for thousands of years and fluctuations in terrestrial systems on the same time scale. The difficulty in making connections is twofold: correlating the most recent warming trend to observed changes in terrestrial systems and tying either the warming or the terrestrial changes to anthropological causes. The data simply do not exist, and the understanding of the feedback processes is insufficient to produce reliable evidence of either relationship. Having admitted that the problem is unsolvable at present does not exclude the possibility that it can be solved with a coordinated approach using available techniques and in a reasonable time frame. SEARCH provides the framework for accomplishing that goal because it allows coordinated observations of changes within the system while taking a system-level view of the biocomplexity of the Arctic on a sufficiently long time scale to begin to identify feedback processes acting in response to both natural and anthropogenic causes and effects.

SEARCH will facilitate the needed coordination to produce a research outcome that builds on the earlier efforts. The research program will include:

- Long-term data collection from environments on the decadal time-scale, e.g., existing ecological monitoring sites in the Alaska National Wildlife Refuge (DOI/FWS);
- Limited manipulative experiments to induce changes in terrestrial processes in response to climate change; and
- Modeling studies designed to integrate knowledge about processes and feedbacks in order to build a predictive capability.

Marine Biotic Systems. The Bering Sea ecosystem is among the most productive of high-latitude seas. SEARCH-related activities in the Bering Sea are described in Section 2.2. Bering Sea research

has a regional focus, while the SEARCH effort takes a pan-Arctic approach.

The approach to implementing the marine biotic systems research effort will focus on three principal tasks:

- Build an interdisciplinary, integrated observation and knowledge base for the Bering Sea region;
- Synthesize available information into conceptual models that identify potential linkages among natural and human-induced stressors to achieve new insights and guide future research; and
- Perform integrated, ecosystem-level assessments for the Bering Sea region that link ecological, cultural, economic, and health challenges to physical change in the environment, recognizing both natural phenomena and human activities that impact marine ecosystems and indigenous populations.

Human Social and Economic Systems. Where researchers have studied evidence of past and contemporary cultures, it is clear that survival in the Arctic has depended on adaptability. Changes in the Arctic have been tied historically to both local and global processes. In addition to changes driven by seasonal extremes and variability, human activity within the region has caused significant environmental, economic, social, and cultural change (for example, colonization, marine mammal hunting, the fur trade, the gold rush, and urbanization). Arctic residents today have the capacity to foster or discourage some of the most extensive and precipitous changes in the region (for example, large-scale oil development, logging, alteration of fire regimes, and the redirection of freshwater flow to the Arctic Basin).

Some physical changes that originate in the Arctic could propagate to lower latitudes, changing air and sea temperatures and affecting economies. For example, major Atlantic and Pacific fisheries could depend on ocean conditions that are influenced by Arctic processes that are affected, in turn, by changes in climate.

The Arctic is extremely vulnerable to climate change and its potential impacts. The special report on the regional impacts of climate change by Working Group II of the Intergovernmental Panel on Climate Change (IPCC) noted that over the period of IPCC assessment, climate change will contribute to major physical, ecological, sociological, and economic changes already begun in the Arctic. A considerable interdisciplinary effort is needed to collect and analyze information on the implications of these environmental changes for human populations.

To assess the effects of observed environmental change on indigenous people and other residents, a research program examining the dynamics of linkages between human populations and the biological and physical environment of the Arctic is required. That research program should incorporate an integrative, interdisciplinary approach including the following:

- The biophysical basis for future human impacts on the functioning of the Arctic system;
- Recent and past patterns of habitat use (including land, water, and ice) and resource use (including subsistence, land tenure, domestication, farming, fishing, and resource extraction) where human consequences of global change are expected;
- Patterns of human response and adaptation to environmental change (including settlement decisions, shifts in resource use, migration, diversification, impacts of environmental change on human health, and economic transitions);
- The basis for sustainability, viability, resilience, and vulnerability in future interactions between humans and their environment; and
- Development and implementation of an educational framework that offers feedback and learning opportunities for local stakeholders, scientists, and decision makers.

2.2 Developing a Research Plan for a Sustainable Bering Sea

The Bering Sea, located between the Aleutian Archipelago and Bering Strait, is a marginal sea that connects the North Pacific to the Arctic Ocean. The Bering Sea region is productive and ecologically diverse. Its multiple habitats are ideal as homes to a rich variety of biological resources.

The ecological riches of the Bering Sea have attracted and supported aboriginal cultures for millennia. Today, Bering Sea resources continue to support the economic survival, subsistence, and cultural foundation for Alaska Natives. In addition, the Bering Sea commercial fishery is a key economic force in the region. About 50% of all fisheries landings in the United States in 1998 came from the Bering Sea (see http://www.pmel.noaa.gov/foci/overview.html). Walleye pollock comprise much of the fish landings. Bristol Bay supports the world's largest sockeye salmon fishery, and snow crab landings represent the largest crustacean fishery in the U.S.

2.2.1 Changes in the Bering Sea

The Bering Sea is a seasonally ice-covered, sub-Arctic sea located at the southern extreme of seasonal sea ice cover, and thus it is likely to be exceptionally sensitive to variations in climate that impact the extent and duration of sea ice. Sea ice is a forcing mechanism that influences the temperature and salinity of the water column, its hydrographic structure, and the availability of light for photosynthesis. As such, sea ice affects the timing, amount, and fate of primary production, the survival of larval fish, and the spatial distribution of fish and their predators. Thus, changes in the dynamics of sea ice, if they occur, can have profound influences on the ability of a region to support diverse ecological communities and fisheries.

Recent and rapid changes in the physical and biological characteristics of the Bering Sea have raised concerns (Overland et al. 2004). Changes in the abundance of salmon, crab, and groundfish may result in significant economic impacts. Continuing declines in some populations of marine birds and pinnipeds have prompted protective measures such as fish trawling closures around critical feeding areas used by the endangered Steller's sea lion. There have been unexplained blooms of phytoplankton never before recorded in the Bering Sea, and between 1989 and 2000 an exponential increase in the biomass of large gelatinous zooplankton occurred, which has since collapsed (Hunt et al. 2002).

There is a clear need to better understand the causal relationships between climate, primary and secondary production, and the population dynamics of upper-trophic-level organisms. Greater understanding about how these factors influence each other is vital for determining the relative roles of climate variability and fishery harvests in structuring the Bering Sea ecosystem and for understanding the region's resiliency in the face of change.

2.2.2 Arctic Research Commission Charge

The Arctic Research Commission, in its 2001 and 2003 Reports to Congress (http://www.arctic.gov), targeted integrated research and assessment of the Bering Sea as key research priorities. The Commission observed that concern about the Bering Sea has engendered large and intense research synthesis and planning efforts. These efforts share a commitment by scientists from diverse disciplines and organizations to come together to define the most important research needs and to share research results. Significant research efforts have produced important results. The Commission concluded:

- Greater integration of key Bering Sea research programs is required.
- Current research has not enabled managers to predict ecological responses to management decisions implemented within the Bering Sea region.
- An integrated research program and a concerted effort are required to synthesize existing and new information for an integrated assessment.

2.2.3 Enhancing Research

Continued research is critical to better elucidate the mechanisms and processes of change in the Bering Sea as well as the Arctic. To meet the needs for an integrated assessment in the Bering Sea, Federal partners will develop a strategic plan to clarify and connect scientific questions to management needs.

Since natural ecosystems, science, and management are all dynamic processes, an iterative

approach will be used to ensure linkages among decisions that need to be made, new knowledge that will be obtained, and ongoing changes that will influence outcomes. The importance of this process was reflected by the Polar Research Board of the National Research Council of the National Academy of Sciences, which published a study on the Bering Sea ecosystem that included a set of recommendations emphasizing the vital link between science and management, including:

- Adopting a broad ecosystem perspective for scientific research and resource management;
- Adopting an adaptive management approach for Bering Sea resources;
- Evaluating how well management and research institutions are able to address emerging problems;
- Providing appropriate management solutions; and
- Developing research programs to help policy makers solve short- and long-term ecological problems.

Building an Iterative Bering Sea Research Strategy

The Interagency Arctic Research Policy Committee authorized the establishment of a Bering Sea Interagency Working Group to work toward an integrated assessment, and it subsequently reaffirmed this commitment by expanding the focus on research. The Bering Sea IWG is benefiting from past efforts in defining research goals and establishing a conceptual framework. In addition, an NSF-sponsored meeting (Bering Sea Research, September 2002 in Laguna Beach, California) included members of the SEARCH and North Pacific Research Board leadership to ensure coordination among groups during the development of the research recommendations presented above.

Components of Strategic Integrated Research

The Bering Sea Research Strategy includes five key components, each of which influences the others in an iterative framework. They include:

- Definition of a sustainable Bering Sea: Based on dialogue among interested parties, key concerns, common interests, and desired outcomes from management actions will be determined. In this process the essential characteristics of the Bering Sea are defined. This will provide the necessary framework around which to structure integrated assessments. Interviews were conducted with Federal and state officials and commercial and environmental interests.
- Conceptual synthesis: Existing data will be integrated to identify potential relationships among forcing functions, ecosystem changes, sources of stress, and ecological end points of concern identified in the goals. The process is interactive, iterative, and interdisciplinary, and it addresses the influences of multiple natural and human stressors on ecological and human systems. The purpose is to learn more from existing data, generate multiple working hypotheses about likely causal relationships, and define essential research needs.
- Research Plans: Based on the conceptual synthesis, research questions will be refined and further research designed to produce integrated research and assessments. The expected outcome is a dynamic research plan available to Federal agencies and others that capitalizes on existing research efforts and defines new research within a structured framework for integrating research activity and interpreting results.
- Research implementation: New research will be initiated to evaluate predictive relationships among natural and human influences on key values to be sustained. The research will investigate processes, trends, and effects, as well as monitor the impacts of management decisions. New information is fed back into goal setting, synthesis, and planning for re-evaluating goals, refining conceptual models, and developing updated research plans.
- Ecological forecasting: To be useful to living-resource managers, the results of research must lead to the ability to provide forecasts of future ecological states. Research will be conducted to build coupled physical–biological models and to develop science-based products that provide value to resource managers. A long-term goal of this research is to specify an ecological forecasting system that could be used in an operational setting for resource management.

The strategy is intended to be dynamic and to involve interplay among research findings and environmental observations, desired management outcomes, goal setting, and new insights that lead to new research. Strategy development will progress concurrently with ongoing research. The outcome over the next several years is expected to include conceptual synthesis and a first-stage integrated assessment and research plan.

2.3 Arctic Health

The Arctic Research Commission has recommended:

> "a comprehensive, inter-agency study of Arctic Health. NIH has agreed to be the focal point for this effort focused primarily on the environmental health questions outlined by the Arctic Monitoring and Assessment Program and on the study of incidences and trends in the major causes of morbidity and mortality in the Arctic. NIH should lead this effort with the assistance of other agencies especially EPA and NOAA. The potential effects of anthropogenic contaminants such as persistent organic pollutants, heavy metals and radionuclides are a growing concern in the Arctic. The effects of both communicable diseases such as tuberculosis, systemic diseases such as diabetes and cancer and external causes of illness and death such as alcoholism and accident likewise have profound effects in the Arctic." (*Report on Goals and Objectives for Arctic Research,* U.S. Arctic Research Commission, 2003.)

The Arctic Research Commission also expressed interest that such a plan address health concerns from two standpoints: What are the health concerns that people of the Arctic worry about, such as pollution? What are the actual causes of morbidity and mortality in the Arctic?

2.3.1 Epidemiology and Health Surveillance

Research Goal: To understand the epidemiologic parameters of diseases important to Arctic residents, providing data that will inform and guide programs to prevent, diagnose, and treat such diseases, ranging from acute infectious illnesses to chronic conditions dependent on diet and lifestyle.

Infectious Diseases

Centers for Disease Control and Prevention's Arctic Investigations Program. The Arctic Investigations Program, Anchorage, Alaska, is a division of the National Center for Infectious Diseases. Its mission is prevention and control of infectious diseases, with a focus on diseases of high incidence and concern among the indigenous populations of the Arctic and sub-Arctic regions and on emerging and re-emerging infectious disease problems. The Centers for Disease Control's long-term plan, *Preventing Emerging Infectious Diseases: A Strategy for the 21st Century*, focuses on four goals:

- Strengthening surveillance and response nationally and internationally;
- Supporting research to understand and combat infectious threats;
- Enhancing public health epidemiologic and laboratory capacity in the U.S. and internationally; and
- Working with partners in public health to implement, support, and evaluate disease prevention activities.

The plan targets certain high-priority categories of emerging infectious disease problems and special groups of people who are at increased risk for antimicrobial resistance, food- and waterborne diseases, vector-borne and zoonotic diseases, diseases transmitted through blood transfusions or blood products, chronic diseases caused by infectious agents, vaccine development and use, people with impaired host defenses, diseases of pregnant women and newborns, and diseases of travelers, immigrants, and refugees. For the 2004–2008 planning period, the Arctic Investigations Program will target vaccine-preventable diseases, antimicrobial resistance, chronic diseases caused by infectious agents, and bioterrorism response.

National Institute of General Medical Sciences. The National Institute of General Medical Sciences, through a partnership with the Indian Health Service, is supporting several projects by the Alaska Native Tribal Health Consortium. Three studies, funded in part by the National Institute of Allergy and Infectious Diseases, examine infectious diseases:

- Determine the prevalence and serotype of chronic hepatitis B, which may aid in understanding modes of communication of the disease;
- Determine the rates of re-infection with *Helicobacter pylori* after treatment, since infection rates are high among Alaska Natives; and
- Work to prevent pneumococcal disease, which is a high priority because of the incidence of otitis media in Native populations.

National Institute on Drug Abuse. The National Institute on Drug Abuse supports efforts to enhance Alaska's research capacity. One current initiative examines women's health and gender differences among Alaska Native women. Recent drug abuse research suggests that the identification of subtypes of women drug users based on individual and contextual variables may

be essential to understanding unsafe sexual practices among drug-using women.

Other future research plans include expanding the substance abuse and health and social consequences research portfolio, including infectious diseases, violence, and crime, and the development of prevention and treatment strategies.

National Institute of Dental and Craniofacial Research. The National Institute of Dental and Craniofacial Research goals and objectives include support that will lead to the prevention and control of dental caries among children in the Pacific Northwest and Alaska. Alaska Native children are disproportionately affected by early childhood caries, compared to all U.S. children. The cultural practice of pre-mastication of solid food for infant feeding amplifies the transmission of oral secretions from adult to child. The prevention of early *S. mutans* acquisition and subsequent caries in infants and toddlers requires efforts starting at birth. A community-based controlled clinical trial will determine if the serial use of chlorhexidine and xylitol in mothers can reduce the vertical transmission of cariogenic bacteria between Alaska Native mothers and infants. The treatment regimen is coordinated with medical care to perinatal Alaskan Native women. If successful, this novel preventative intervention could impact the prevalence of caries among population groups at high risk for childhood caries.

National Institute of Allergy and Infectious Diseases. The National Institute of Allergy and Infectious Diseases promotes the development of vaccines, diagnostic tests, and drug therapies to prevent and control these diseases.

NIAID is supporting a three-year pilot intervention trial in three Alaska Native villages with high numbers of asymptomatic carriers to determine if *Haemophilus influenzae* type b vaccine can be given to persons of all ages to eliminate or reduce colonization in Alaska Native villages in a region with high rates of *Haemophilus influenzae* type b, despite ongoing vaccination of children. The researchers hope to determine what treatment most effectively eliminates the *Haemophilus influenzae* type b reservoir from a village, such as *Haemophilus influenzae* type b conjugate vaccine with and without rifampin (the standard treatment). Mass vaccination with *Haemophilus influenzae* type b conjugate vaccine may be possible.

Occupational Injuries

National Institute for Occupational Safety and Health. The Centers for Disease Control and Prevention's National Institute for Occupational Safety and Health, Division of Safety Research Alaska Field Station, in collaboration with the Indian Health Service, the State of Alaska, the Alaska Native Tribal Health Consortium, and the Alaska Native Health Board, will continue studies on the epidemiology, risk factors, and prevention strategies for occupational injuries in Alaskan communities. It has mounted two other initiatives in Arctic research. The commercial fishing industry contributes high numbers of fatal and severe non-fatal injuries. The National Institute for Occupational Safety and Health is examining vessel stability and the deck environment surrounding the deployment and retrieval systems of fishing equipment (including the use of cranes, winches, lines, nets, crab pots, and crab pot launchers) from a mechanical and safety engineering perspective.

Alaska experienced a downward trend in occupational fatalities during the 1990s (from 78 in 1990 to 42 in 1999, a decrease of 46%). The U.S. Congress supported a Federal initiative beginning in FY 00 to reduce aviation-related injuries and fatalities and to promote aviation safety in cooperation with the air transportation industry in Alaska, a partnership of four Federal agencies: the Federal Aviation Administration (FAA), the National Transportation Safety Board (NTSB), the National Weather Service (NWS), and the National Institute for Occupational Safety and Health (NIOSH). The goal is to reduce the number of aircraft crashes and injuries in Alaska by at least 50% by the end of 2009. The initiative involves five objectives:

- Gather and analyze aircraft crash, injury, and fatality data involving Alaska commuters and air taxies, and identify risk factors;
- Bring together aviation industry groups to characterize the problems;
- Develop aviation safety education plans for pilots, companies, and the flying public;
- Evaluate the effectiveness of and changes in flight safety practices; and
- Evaluate progress and suggest additional improvements.

The Alaska Field Station will collaborate in the integrated surveillance system for disease and injury in the Arctic, linking to the International Circumpolar Surveillance system.

Nutrition

National Institute of General Medical Sciences. The National Institute of General Medical Sciences, through a partnership with the Indian Health Service, is supporting two projects by the

Alaska Native Tribal Health Consortium regarding nutrition:

- The Alaska Native diet and assessment of the nutrition of subsistence foods; and
- Maternal nutrition during pregnancy among Alaska Natives.

Disabilities

National Institute of General Medical Sciences. For rural, subsistence, or working class families, disabilities can have profound effects on entire families. The National Institute of General Medical Sciences, through a partnership with the Indian Health Service, is supporting a study that examines the prevalence of disabilities.

Chronic Diseases

National Institute of Alcohol Abuse and Alcoholism. The goal of the National Institute of Alcohol Abuse and Alcoholism is to identify the causes and consequences of abusive and chronic alcohol consumption and to develop effective treatment and prevention strategies for adverse consequences of drinking. In the next five years NIAAA plans to:

- Test the efficacy of several pharmacological adjuncts to alcoholism treatment and examine genetic, biological, and behavioral characteristics of Alaska Natives receiving treatment for alcoholism;
- Involve Alaska Natives in developing and conducting research projects;
- Learn if there are specific differences in the development of alcohol problems in various Alaska Native groups;
- Study maternal drinking and fetal alcohol spectrum disorders in the Arctic, working with local communities, the Substance Abuse and Mental Health Services Administration, and the Department of Education;
- Determine whether and how alcohol availability and other control policies affect alcohol-related consequences in communities of the Arctic region;
- Identify risk and protective factors as predictors of sobriety and the sobriety process in Alaska Natives, particularly as influenced by the indigenous culture;
- Develop culturally and linguistically appropriate psychometric instruments for prevention strategies with Alaska Natives; and
- Support forums to identify strategies for moving validated scientific research findings into clinical practice.

National Institute of Child Health and Human Development. The National Institute of Child Health and Human Development and the National Institute of Alcohol Abuse and Alcoholism recently started a program to support community partnerships to investigate the role of prenatal alcohol exposure in the risk for sudden infant death syndrome and adverse pregnancy outcomes. The program is aimed at communities at high risk for prenatal maternal alcohol consumption, such as American Indian and Alaska Native communities.

National Cancer Institute. The National Cancer Institute is involved in several Arctic health research projects:

- Alaska Native Tumor Registry. The Alaska Native Tumor Registry was initiated in 1974 as a collaboration between the National Cancer Institute, NIH, and the CDC using procedures developed by the National Cancer Institute's Surveillance, Epidemiology and End Results Program. From 1984 to 1988 the Alaska Native Tumor Registry functioned as a hospital registry for the Alaska Native Medical Center. In 1989 the National Cancer Institute entered into an interagency agreement with the Alaska Native Medical Center through the Indian Health Service, with technical assistance provided by the University of New Mexico. In 1999 the Alaska Native Tumor Registry became an official part of the Surveillance, Epidemiology and End Results Program. All patients are tracked and notified of recommended follow-up appointments. Accurate information on the unique cancer patterns occurring in this population is useful for provider education and training, program planning, studies of cancer etiology, evaluation of screening programs, and the development of interventions to improve patient care and programs for cancer prevention and risk reduction. Research studies in progress related to the Alaska Native Tumor Registry include:
  - Serum polychlorinated by-phenyl levels in breast cancer patients and controls;
  - Prospective study of breast cancer and organochlorines in serum and fat tissue in the breast;
  - *Helicobacter pylori* and cancer and other diseases of the stomach;
  - Prevalence of colorectal cancer genes in (formalin-fixed) tissue among colorectal cancer patients;
  - Familial aggregation of nasopharyngeal cancer; and

- Biomarkers expressed in tumor tissue of Alaska Native breast cancer patients.

- Network for Cancer Control Research among American Indian and Alaska Native Populations: The National Cancer Institute, through its Surveillance Research Program, Division of Cancer Control and Population Sciences, supports the Network for Cancer Control Research between American Indian and Alaska Native Populations. Established in 1990, this network of researchers working among American Indians and Alaska Natives developed a National Strategic Plan for Cancer Prevention and Control Research in 1992. The National Cancer Institute shares support for network meetings with the Mayo Comprehensive Cancer Center.

National Institute of Neurological Disorders and Stroke. The National Institute of Neurological Disorders and Stroke anticipates funding a cooperative agreement that will support the development of a state-wide, population-based Alaska Native Stroke Registry at the Alaska Native Medical Center. It would create a model registry to conduct research into the epidemiology and management of stroke among Alaska Natives, support research strategies to reduce the burden of stroke in the population, and strengthen the research capabilities of the faculty at the Alaska Native Medical Center.

The primary goals of the Alaska Native Stroke Registry are to:

- Define the natural history and clinical course of stroke among Alaska Natives, including incidence and prevalence, risk factors, clinical management, and health outcomes such as residual physical disability and mortality;
- Develop research programs to prevent stroke and improve the quality of stroke care provided to Alaska Natives to minimize stroke sequelae; and
- Enhance opportunities for multidisciplinary research collaborations between the Alaska Native Medical Center and institutions with established programs in stroke research.

National Heart, Lung, and Blood Institute. A study supported by the National Heart, Lung, and Blood Institute is a working partnership between the Native-owned corporation that manages the health care of the Native Alaskans of Norton Sound and investigators from the Strong Heart Study, a 14-year study of cardiovascular disease in American Indians. These Eskimo villages are remote and isolated, and traditional lifestyle is being eroded by mechanization and a westernized diet. There has been relatively little outside genetic influence, and they, like the American Indians of the lower 48 states, are beginning to show a marked increase in the prevalence of atherosclerosis and coronary artery disease.

The aims of the five-year (FY 00–04) $7.8 million study are to document cardiovascular disease and cardiovascular disease risk factors among 1200 Alaska Natives who are members of approximately 40 families. This family-based, cross-sectional study will document recognized and emerging risk factors and prevalent cardiovascular disease in each individual through a standardized interview, a physical exam, laboratory measurements, and a review of centralized medical records. The investigators will assay contemporary samples and serum specimens, which have been stored at the Anchorage Centers for Disease Control and Prevention office antedating this study by 10–20 years, for specific markers of inflammation and serologic responses to six measures of infection (*Chlamydia pneumoniae*, hepatitis A virus, herpes simplex virus types 1 and 2, *Helicobacter pylori*, and cytomegalovirus). This is the first project to identify and map genes that contribute to the risk of cardiovascular disease in this unique and understudied population.

Substance Abuse and Mental Health Services Administration. Since the Substance Abuse and Mental Health Services Administration does not do research, the information provided here describes the HHS's research agenda. Currently there are five programs/projects to report:

- Circles of Care Program: Supported by SAMHSA's Center for Mental Health Services, this program provides grants for tribes and urban Indian communities to plan, design, and assess culturally specific mental health service system models for American Indian and Alaska Native children and their families.
- Child Mental Health Initiative: This is the Cooperative Agreement for the Comprehensive Community Mental Health Services for Children and Their Families Program. Community Mental Health Services provides grants for state and tribal governments to develop systems of care for children (and their families) with serious emotional disturbances.
- Anchorage Comorbidity Services Project. This project, funded through a $15 million congressional earmark and jointly administered by the SAMHSA's Center for Substance Abuse Treatment and Community Mental

Health Services, supports the development and evaluation of an optimally integrated system of emergency and long-term services for individuals in south-central Alaska who have co-occurring substance abuse and mental disorders.

- Alaska Fetal Alcohol Syndrome/Alcohol-Related Birth Defects Program. The overall goal of this program is to improve the practice of identifying, preventing, and treating fetal alcohol syndrome and alcohol-related birth defects by improving Alaska's system of care for those individuals already affected by prenatal exposure to alcohol.
- National Center for Excellence. Supported by the Center for Substance Abuse and Prevention and funded at $3.8 million per year for five years, the Center for Excellence coordinates activities to ensure that advances in both science and practice are synthesized and efficiently disseminated to the field.

Agency for Toxic Substances and Disease Registry. Environmental contamination in the Great Lakes continues to be a threat to human health. The present concern is atmospheric transport of toxic chemicals to the Great Lakes from various sources, specifically the Arctic region. This research program will continue, with more emphasis on developing biomarkers for exposure and health effects. These studies will provide valuable information on exposure pathways, body burden levels, and potential adverse health outcomes from exposure to toxic chemicals in the environment. The lessons learned from the Great Lakes can be useful for researchers as they continue their work in the Arctic.

2.3.2 Information: Acquisition, Assembly, and Dissemination

Research Goal: To develop a responsive system for handling health information transfer in the Arctic, ranging from telemedicine systems utilized in health care delivery, to an Internet-based health information network for researchers and the general populace, especially Native and other populations (such as the Circumpolar Health Information Center).

National Institute of General Medical Sciences

The National Institute of General Medical Sciences, through a partnership with the Indian Health Service, is supporting several projects by the Alaska Native Tribal Health Consortium.

One applied study investigates the degree of concordance of diagnosis of effects of telemedicine vs. live diagnosis. This study is important because of the challenges of delivering care to rural Alaska.

National Institute of Mental Health

Since 1986 the National Institute of Mental Health has supported the American Indian and Alaskan Mental Health Research Center. This center conducts research and promotes research training and leadership development appropriate for Native communities, disseminates research findings to communities and practitioners, and aids organizations in developing skills to conduct mental health research. The center has initiated activities in the following areas:

- Development of a web-based treatment manual system: Working with the Cook Inlet Tribal council, the nonprofit arm of the Cook Inlet Region Corporation, a manual is being developed to address the continuum of care needed for Alaskans with alcohol, drugs, and mental disorders. Care programs address the range of needs from the homeless to women at risk of having their children taken away for abuse or neglect.
- A research evaluation to examine factors associated with success in disseminating the State of Alaska-funded rural human service program for serious emotional problems or disturbances.

National Cancer Institute

In 1997 the National Cancer Institute assisted the Network and Mayo in establishing the Native CIRCLE, a clearinghouse for information and resources developed through research. Many useful, culturally sensitive materials, including school curricula, videos, pamphlets, and survey instruments, are catalogued and made available to researchers and communities for application in the areas of smoking prevention, cancer screening, and dietary change.

National Institute of Child Health and Human Development

The National Institute of Child Health and Human Development will identify and develop strategies for designing outreach programs to increase sudden infant death syndrome awareness and to reduce sudden infant death syndrome risk in American Indian communities. The meeting will provide a forum for health care professionals to interact with

community leaders, including small group discussions with public health nurses, community health representatives, elders, and fathers. Some of the issues and strategies to be discussed include:

- Developing a community-owned project;
- Incorporating the indigenous culture and traditions (such as encouraging the use of cradle boards and using talking circles);
- Using elders to educate young parents;
- Using public health nurses, community health representatives, and home visiting programs such as Healthy Start;
- Focusing education on women's health pre- and post-pregnancy; and
- Focusing on alcohol and smoking issues.

The National Institute of Child Health and Human Development plans to use information gleaned from these meetings to develop materials, coalitions, and an infrastructure that the communities can use when developing and conducting the outreach programs. As a result of these interactions, representatives from the tribes and individual communities are expected to tailor informative action plans for community-driven SIDS risk reduction strategies that meet the unique needs of their own members.

National Institute of Diabetes and Digestive and Kidney Diseases

The National Institute of Diabetes and Digestive and Kidney Diseases, via the National Diabetes Education Program, promotes a public awareness campaign: "Move-IT! Reduce your Risk of Diabetes." This campaign is targeted to Native youth to encourage physical activity to reduce their risk of type 2 diabetes.

National Center for Research Resources

To educate and inform the Alaskan public about health science research so they can make healthier lifestyle choices, the National Center for Research Resources supports the Imaginarium's Health Outreach Caravan, which forms partnerships with the scientific, public health, educational and cultural communities; develops mobile, hands-on, interactive, and culturally appropriate health-related programs; and develops a Health Science Teen Volunteer Corps across remote, culturally unique regions of Alaska to facilitate linkages between biomedical scientists, village elders, and local community and school programs.

Health Resources and Services Administration

From FY 00 through FY 02, the Health Resources and Services Administration funded the Alaska Federal Health Care Access Network to support the creation and operation of a tele-health network that provides 230 village clinics in Alaska with the capacity to conduct telemedicine consults. These clinics serve more than 200,000 residents in remote areas throughout Alaska. As well as clinical services, the network provides access to continuing education of the indigenous population, with videoconferencing, transmission of data, and voice communications.

National Institute on Drug Abuse

Since 1994 the National Institute on Drug Abuse has been funding projects at the University of Alaska Anchorage dealing with the spread of AIDS and other infectious diseases, substance abuse, and related mental health problems. Out of this work has come a large five-year project, in conjunction with the University of New Mexico, the first-ever systematic study of ethically important aspects of rural health care for stigmatizing illnesses. Key concepts in this research include rurality, ethics, psychosocial issues, stigma, and barriers to optimal care. The project will make significant contributions to health services research in the Arctic and other frontier and rural areas, as well as leading to a better understanding of rural health problems and their solutions. The National Institute on Drug Abuse plans to include studies of a previously unseen problem—rural runaway youth—a group at extreme risk for substance abuse, mental health, and infectious diseases, as well as violence and other forms of abuse.

National Institute of Dental and Craniofacial Research

The National Institute of Dental and Craniofacial Research, through the University of Washington Northwest's Alaska Center, supports the development of a web-based tool (EthnoDent) that focuses on reducing cultural barriers between providers and multicultural patients (including Native Americans and Alaska Natives) in the area of children's oral health. This instructional tool will reduce disparities in children's oral health by enhancing the provider's attitudes and skills in communicating with multicultural families.

2.3.3 Infrastructure and Capacity Building

Research Goal: To build up the capacity of Arctic institutions and organizations for competitive participation in the research enterprise (their ability to

obtain research grants) through training efforts, and support of facilities or center-type grants.

National Institute of Mental Health

The National Institute of Mental Health, along with the National Institute of Neurological Diseases and Stroke and the National Center for Research Resources, is presently collaborating in the joint sponsorship of the Alaskan Basic Neuroscience Program at the University of Alaska Fairbanks. This program is part of the Specialized Neuroscience Research Program at Minority Institutions initiative, intended to establish and enhance competitive research programs in basic neuroscience at minority institutions. The research projects will examine themes of interest to Alaskan peoples, including circadian rhythms, hibernation mechanisms, and neural development and repair.

National Cancer Institute

The National Cancer Institute supports the Native American Student Research Program, a collaboration between the Indian Health Service, the Oregon Health Sciences University, and the tribe-operated Northwest Portland Area Indian Health Board. Spanning six years, this cancer control research and training program for American Indian and Alaska Native graduate and post-doctoral students, has provided training to 53 trainees of diverse Native groups, including Alaska Natives. A substantial proportion of the trainees have been awarded National Cancer Institute funds to carry out community-based cancer control activities among Native groups.

National Institute of Neurological Diseases and Stroke

A specialized neuroscience research program at the University of Alaska establishes an Alaskan Basic Neuroscience Program to expand, facilitate, and stimulate neuroscience research, to facilitate the development of collaborative research, and to stimulate the active participation of Alaska Native students.

National Center for Research Resources

The National Center for Research Resources continues to develop Alaska's research capacity through the funding of the Institutional Development Award program, a science education health outreach program, and co-funding of a neuroscience research program. The NCRR is supporting the University of Alaska's Center of Biomedical Research Excellence. The Alaska Native Health Research Center has formed a partnership with the University of Alaska research faculty and Alaska Native communities and tribal health corporations to increase the university's research capacity. The specific goals are to enhance research productivity and increase community education by identifying risk and protective factors affecting the weight and health of Alaskan Natives, and the relationship between genetics, healthy behavior, and obesity, an important risk factor for cardiovascular disease and non-insulin-dependent diabetes.

Fogarty International Center

The Fogarty International Center is soliciting grant applications for its new program entitled Health, Environment and Economic Development. The program, co-funded by the Fogarty International Center, four other NIH institutes and centers, and the U.S. Geological Survey (USGS), intends to support research collaborations to examine the relationships among health, significant trends in economic development, and the natural environment. The first planning grants will be awarded by the end of FY 03, followed by specific projects in FY 05.

National Institute of Allergy and Infectious Diseases

The National Institute of Allergy and Infectious Diseases supports a demonstration and education outreach program at the University of Washington aimed at increasing organ donation and transplantation among Alaska Natives.

2.3.4 International Circumpolar Collaborations

Research Goal: To promote the collaborative efforts of scientists across the eight circumpolar nations in order to facilitate comparison of environmental monitoring results, disease rates, and dissemination of medical care. This will lead to a more comprehensive understanding of the effects of environmental pollution, climate change, and cultural impacts on Arctic populations

The Fogarty International Center is continuing to support a Fogarty International Research Collaboration Award, awarded to researchers at Stanford University and the Vavilov Institute of General Genetics of the Russian Academy of Sciences, to study diversity in human DNA sequences. The purpose of the study is to characterize the genetic ancestry of Native American

groups to provide insight into the migration of populations to the New World from northeast Asia. The grant aims to develop models of molecular variability in individuals from a worldwide array of samples, including approximately 50 previously collected samples from six different Siberian peoples (Buryats, Tuvinians, Yakuts, Evenks, Chukchis, and Eskimos). This will help explain the rate and distribution of genetic mutation, genetic divergence, and eventually, demographic changes.

Finally, NIH, together with NSF and the Department of State, will continue to support collaborative research projects, some of which are relevant to the Arctic, between U.S. scientists and their counterparts from the Former Soviet Union through the U.S. Civilian Research and Development Foundation. During 2002–2004, two projects related to the Arctic bring together researchers from the Shirshov Institute of Oceanology of the Russian Academy of Sciences, Oregon State University, and Science Applications International Corporation to study the interrelationships between marine biology, geology, and environmental sciences.

2.4 Research on Resource Evaluation

This is a new section of the U.S. Arctic Research Plan. In its 2003 *Report on Goals and Objectives for Arctic Research*, the Arctic Research Commission provided the following statement and recommendation:

> "The Alaska National Interest Lands Conservation Act of 1980 (ANILCA §1010) directs the Secretary of the Interior to "assess the oil, gas, and other mineral potential on all public lands in the State of Alaska in order to expand the data base with respect to the mineral potential of such lands." The Department of the Interior conducted and published several of these assessments. However, for the last several years the program has not added to the information on the resources on Alaska public lands. The environmentally sound and sustainable use of the resources on the vast area of federal lands in Alaska (about 66% of the State's area) is essential for both the state and the nation. Resource exploitation provides the nation with needed materials and energy while providing expanded economic opportunities for the population of the State.
>
> The Arctic Research Commission requests that the Department of the Interior resume its resource evaluation activities and cooperate with the other Federal Agencies, the State of Alaska and institutional partners to provide widely available and comprehensive coverage of all federal lands in Alaska."

The Department of the Interior has continued to assess the energy and minerals of Alaska, and its bureaus have published numerous reports on this subject. However, with the renewed interest in information on the oil, gas, and other mineral potential on public lands in the State of Alaska, the Department of the Interior will initiate discussions with Interior bureaus and other departments to determine the feasibility of resuming publication of an annual report on these topics. IARPC expects to work with the Department of the Interior to develop this initiative in the context of funding that is made available during the period of this revision to the U.S. Arctic Research Plan (2004–2008).

2.5 Research on Civil Infrastructure

This is a new section of the U.S. Arctic Research Plan. In its 2003 *Report on Goals and Objectives for Arctic Research*, the Arctic Research Commission provided the following statement and recommendations:

> "Understanding climate change in the Arctic is an important goal, as the SEARCH Program has recognized. It is at least equally important, however, to begin the task of finding ways to cope with the effects of climate change, particularly on Arctic infrastructure. The effects of infrastructure problems on human life in the Arctic are particularly noted above in the section on Arctic Health. These difficulties are compounded by climate change. The destabilization of structures by changes in permafrost, changes in coastal communities caused by changing in sea level and in the frequency and strength of storm induced wave action, changes in weather patterns requiring changes in aircraft operation and many others require

a strong commitment to engineering research in the Arctic. The Commission is encouraged by arrangements between the U.S. Army's Cold Regions Research and Engineering Laboratory (CRREL) and the University of Alaska to bring the nation's most able engineering talent to bear on these problems. CRREL is recognized around the world as an international treasure of expertise in Arctic engineering.

The Commission recommends continuing support for the U.S. Army Cold Regions Research and Engineering Laboratory and encourages their participation in infrastructure research in Alaska.

Accurate and precise geospatial (map) data are essential for many purposes including air navigation, wilderness travel, and mineral and energy exploitation. Similarly, they are fundamental requirements for the effective construction of civil infrastructure projects. The Department of the Interior through its USGS Geospatial Data Clearinghouse provides geospatial data and, in particular, digital elevation models based on a variety of measurement techniques, primarily observations from aircraft and spacecraft. Complete coverage of the 48 contiguous states has been available for years. Full coverage of the U.S. Arctic region at high precision (1m × 1m × 1m) does not exist and is critically needed.

The Commission recommends that the Department of the Interior take steps to acquire and make available precise geospatial data for maps of the U.S. Arctic."

The USGS has initiated the National Map Program in Alaska through the Alaska Geographic Data Committee's (AGDC) Alaska Digital Ortho-Imagery Initiative. The AGDC comprises over 45 Federal, state, local government, university, and nongovernmental institutions, including private industry. The AGDC developed a set of technical requirements and a strategic plan with required funding and timelines that would provide high-resolution ortho-imagery and high-resolution DEMS for the entire state. Work on the AGDC initiative was formally begun in FY 02 with the acquisition of interferometric synthetic aperture radar (IFSAR) imagery (for DEM production) and high-resolution color aerial photography for the Northeast Study Area of the National Petroleum Reserve of Alaska. DOI invested approximately $1 million in FY 02 for this pilot study through USGS contracts with private industry, supplemented with funding from the BLM.

In FY 03 the USGS and BLM expanded the coverage over NPRA. The strategy is to focus the work on areas of the state where high-resolution data are required to support priority DOI and AGDC member's planning and management needs. IARPC and the Department of the Interior will work to develop this program in the context of funding that is made available during the period of this revision to the U.S. Arctic Research Plan (2004–2008). IARPC also will encourage continuing support for the U.S. Army Cold Regions Research and Engineering Laboratory's participation in infrastructure research in Alaska.

3. Agency Programs

3.1 Selected New Opportunities for Arctic Research

The following sections describe some new opportunities for Arctic research. The focus is on selected new agency programs and is not intended to be a comprehensive listing of all programs in a given research area.

3.1.1 U.S. and the Arctic Council

U.S. agencies are continuing to examine how best to contribute data to ongoing research programs being conducted through the Arctic Council's working groups and also whether there is scope for new research on issues relating to environmental contaminants, pollution, human health, and biodiversity. Given the Council's mandate with respect to sustainable development, there is also scope for renewed emphasis on research in the social sciences.

3.1.2 Remote Sensing

NASA has completed a major re-survey of the Greenland ice sheet, through its Program for Arctic Regional Climate Assessment (PARCA), resulting in the completion of a wide range of remote-sensing-based data sets covering the ice sheet. These are in the process of being made available, with coordination from the National Snow and Ice Data Center (see Section 3.5.1 for details about PARCA). Data sets include surface topography derived from satellite radar and airborne laser observations, meteorological observations from automatic weather stations, ice thickness from radar sounding, surface accumulation from ice cores, and passive-microwave-derived estimates of surface melt. This combined data set represents a new benchmark for the current state of the Greenland ice sheet.

NASA also supports the development of geophysical "pathfinder" data sets that will be useful to a broad community of scientists. Following a re-competition of NASA's Pathfinder program, the following projects with Arctic interests have been completed. These projects include the development of a historical synthesis (1978–2000) of snow cover data from microwave and optical instruments, to be used for modeling purposes; a pilot study of Alaskan glacier extent measurements to quantify global warming impacts using satellite high-resolution optical and infrared data sets (the Global Land Ice Measurements from Space project, or GLIMS, led by USGS); and the development of snow and ice cover products for polar research applications using NASA's scatterometer data.

NASA has entered a new data-rich era of satellite observations of the Arctic, with the launch of the Earth Observing System suite of sensors. ICESat will make observations of cloud and ice surface heights, the latter being comparable with airborne laser altimeter observations of Greenland, one of the goals being to determine whether the rapid thinning of many parts of the margin of the Greenland ice sheet is continuing. The NASA satellites Terra and Aqua are providing a wide range of data types that will enrich our capability to understand Arctic processes. Two examples are AMSR, which is an advanced passive microwave sensor of high potential value for sea ice studies, and MODIS, which is a high-spectral-resolution visible and infrared imaging sensor that will enhance our ability to observe surface albedo and temperature in polar regions.

3.1.3 In-situ Sensing

NOAA has supported a temporal and spatial study of Alaskan clouds based on the use of a ground infrared imager. Measurement of clouds is fundamentally important to studies of Arctic climate variability and change. The infrared cloud imager records calibrated images of sky radiance. This project is a first step toward studying the relationship between the Arctic Oscillation and cloudiness at various Arctic locations.

3.1.4 Fisheries Management

NOAA is also undertaking studies of the development of physical, chemical, and plankton data-

bases for the Bering and Chukchi Seas. In addition NOAA is carrying out an analysis of physical and ecosystem model outputs in relation to changing populations of Stellar's sea lions. NOAA also funds programs that focus on traditional ecological knowledge addressing scientific and coastal communities informational needs.

3.1.5 Cultural Exchange

Work continues on planning for the Russia–United States International Beringian Park in the Bering Strait region. This park would preserve the unique environmental and cultural heritage of adjacent regions of Alaska and Siberia. Current plans call for continuing the highly successful past efforts on research, cultural exchanges, and publication projects.

3.1.6 Data

Common to all programs is the need for consistent data management among the Federal agencies. The Arctic Data and Information Program describes this activity (see Section 4.2).

3.1.7 U.S.–Russia Collaboration

The ending of the Cold War and the opening of relations with the former Soviet Union offer an unprecedented opportunity to develop bilateral research programs on Arctic scientific issues of common concern to the U.S. and Russia. Several bilateral agreements already exist to promote cooperative efforts in the areas of environmental protection, oceans research, basic science, fisheries management, and energy technology. An extensive amount of data has been exchanged with the former Soviet Union and now Russia over the last several years, which include data from north of the Arctic circle. These data are distributed among the U.S. national data centers. A steady stream of Russian scientists and science officials have visited the U.S., offering plans and proposals for collaborative work. Proposals for specific projects with Federal agencies have resulted. Many agencies have taken the initiative to develop their own contacts and programs in Russia. Revelations about environmental contamination in the Russian Arctic and efforts to preserve and disseminate scientific data from the former Soviet Union have been the principal motivations behind much of this activity.

Studies of Russian, U.S., and Canadian Arctic history continue to demonstrate the ties that have linked Arctic people, cultures, and regions for the past 15,000 years.

Under the Environmental Working Group (EWG) of the U.S.–Russian Joint Commission on Economic and Technological Cooperation, the U.S. and Russia have developed methods and procedures for using national security data for environmental problems of mutual interest. A key success of the EWG has been the creation of a series of Arctic climatology atlases using information derived from both Russian and U.S. national security data. Four CD-ROM atlases (available at http://nsidc.org/data/ewg/index.html) covering winter and summer oceanography, ice, and meteorology have been released with 40-year gridded time histories. The oceanographic atlases have more than doubled the Arctic oceanographic information available to the world's scientific community.

3.1.8 Oil Pollution Control

Title V of the Oil Pollution Act of 1990 established the Prince William Sound Oil Spill Recovery Institute (OSRI), with interagency participation led by NOAA and including the Department of the Interior, the Department of Transportation, and three state agencies (Fish and Game, Environmental Conservation, and Natural Resources). During the 1990s the State of Alaska coordinated with OSRI in developing an Arctic–sub-Arctic oil spill research plan. OSRI's programs are funded through the approximately $1 million in annual interest earnings it receives from a $22.5 million fund dedicated for OSRI and maintained within the Oil Spill Liability Trust Fund. In 2002, Congress approved extension of OSRI through September 2012, with its funding to continue from the interest earnings as described above. OSRI programs are detailed at their web site (www.pwssc-osri.org). OSRI is located in Cordova, Alaska, and is administered through the Prince William Sound Science Center (www.pwssc.gen.ak.us), a non-profit research organization founded in 1989 to facilitate and encourage ecosystem studies in the Greater Prince William Sound region.

3.1.9 Permafrost Degradation

Renewed concern for the potential damage to infrastructure and the environment due to permafrost degradation has been sparked by ongoing initiatives to provide access to the National

Petroleum Reserve in Alaska (NPR–A) for non-renewable resource development, as well as increased DOD interest for potential National Missile Defense facilities in Alaska and other Arctic regions.

Roads, airfields, buildings, and pipelines founded on permafrost are at risk of damage when the ground warms or thaws. This degradation causes frozen ground to lose its strength, with consequences ranging from a reduced service life to outright structural failure. The thawing of ice-rich permafrost produces irregular settlement and slope instabilities that permanently alter the terrain and have catastrophic consequences on the infrastructure.

Permafrost degradation is not a hypothesized outcome of global warming; engineers have been dealing with the effects of permafrost degradation for some time. Factors such as microclimate, local hydrology, glacial history, geomorphology and materials, and increased snow depth can promote, and in some cases control, degradation at specific sites.

In addition to the impact to infrastructure, permafrost warming and thawing have dramatic effects on vegetation, topography, and hydrologic processes, which in turn have serious ecological and land use implications. Warming may increase the release of trapped methane. The degradation process may result in an increase in the mobility of methane locked in existing permafrost deposits. The impact is initially localized and is highly dependent on the nature of the contaminants and the geological and hydrological conditions of the site.

The issue of permafrost degradation impacts virtually all elements of the existing infrastructure and future Arctic building programs, land use, and contaminant mobility, and it raises concerns regarding the exposure of other cold-regions nations to this threat. Although this problem has been recognized by the engineering community, knowledge of the extent of permafrost areas at risk, predictions of the rate of degradation and the resultant damage to specific structures, and a strategy for dealing with progressive damage are all lacking.

3.1.10 Contaminant Behavior and Impact in Northern Polar Regions

NOAA is involved in several contaminant behavior programs that are examining the deposition flux rates and fate of atmospheric mercury at Barrow, Alaska, and tracing persistent organic and trace element pollutants in the Alaskan Arctic. The latter is the Alaskan component of a larger effort entitled “Study of Atmospheric Deposition in the Arctic; A Paired Study of a Site in Alaska and a Site in the Russian Far East.” The scientific objectives are to gain insight into the sources, occurrence, and environmental fate of persistent organic pollutants, to contrast the occurrence of persistent organic pollutants and trace elements in this region with other Arctic airsheds, and to provide data in a form compatible with existing AMAP data to be used in assessing the potential risks to the environment and human inhabitants in the Arctic.

In March 2000, NOAA’s CMDL added continuous measurements of spectral aerosol optical depth at Barrow by the addition of a sunphotometer. Atmospheric aerosols are created as airborne pollutants and soil dust, which enter the Arctic from Eurasia. The data gathered are used to distinguish varying types of aerosols. Asian dust observed at Barrow is thicker optically than Arctic haze and is composed of larger particles.

The Climate Monitoring and Diagnostics Laboratory’s clean air sector at Barrow, Alaska, is also involved in monitoring gaseous elemental mercury in the Arctic environment. This is a byproduct of coal combustion, waste incineration, and certain types of manufacturing. Mercury concentrations in certain Arctic mammals are the highest in the North American Arctic (Arctic Monitoring and Assessment Program 1997). A reduction in atmospheric mercury occurs when there are sunlight, low temperatures (less than 20°C), and an underlying snowpack. The concentrations of bioavailable mercury in the Barrow snowpack are the highest ever measured anywhere in the world. If the mercury events found at Barrow are prevalent throughout the coastal Arctic, this region would represent a deposition zone for mercury air pollution.

3.2 Arctic Ocean and Marginal Seas

3.2.1 Ice Dynamics and Oceanography

NOAA, NSF, NASA, and DOD work cooperatively to carry out observations and modeling of the freshwater dynamics connecting the Arctic and the Atlantic. Concentrated activity occurs where the Arctic and Atlantic Oceans meet and interact. Improved observations of water masses and fluxes of water, salt, ice, and tracers between the Arctic and the Atlantic will help us understand this changing state and anticipate its future.

NOAA is continuing to study the variability of thermohaline circulation and freshwater storage in the Arctic Ocean. The Arctic Ocean and its marginal seas are key areas for understanding the Arctic climate system and its change through time. Changes in the freshwater balance would influence the extent of sea ice cover; changes in the surface albedo, energy balance, temperature, and salinity of water masses; and biological processes in the Arctic. (Also see Section 2.1.)

3.2.2 Ocean and Coastal Ecosystems and Living Resources

NOAA has undertaken several programs focusing on ocean ecosystems, including analyses in the Bering Sea region to study climate variability and its impacts on ecosystems and a study of the trophic pathways on the Chukchi–Beaufort shelf. Microalgae grow on the undersurface of sea ice as well as within the sea ice matrix and are a well-known feature of Arctic ecosystems. They contribute a poorly known proportion of the total primary production in Arctic seas. Ice algae are important to microbial food webs and the dissolved and particulate carbon and nitrogen pools of the Arctic Ocean. Novel techniques to quantitatively trace carbon fixed by ice algae and water column phytoplankton through pelagic and benthic food webs using conservative fatty acid signatures are being used. The results of this work will help us understand trophic dependencies and carbon budgets in Arctic food webs and predict the effects of environmental change caused by global warming and further reductions in sea ice.

NOAA's Arctic Research Office has supported projects to examine possible connections between Arctic climate and oceanic change and the declining Steller's sea lion population. The areas of interest include impacts of climate change on the Bering Sea ecosystem over the past 500 years, retrospective studies of climate impacts on Alaska Steller's sea lions, the nature of North Pacific regime shifts and their impacts on Steller's sea lions, ocean climate variability as a potential influence on Steller's sea lion populations, North Pacific climate variability and Steller's sea lion ecology, interannual variability of biophysical linkages between the basin and shelf in the Bering Sea, and climate-related processes and killer whale abundance as factors in Steller's sea lion population trends in the Aleutian Islands. The National Marine Mammal Laboratory's Alaska Regional Office and the Protected Resources Management Division are responsible for research on the management of 22 species of marine mammals that commonly occur in Alaska, including Steller's sea lions.

NOAA's Resource Assessment and Conservation Engineering Division and Resource Ecology and Fisheries Management Division is promoting a full-scale program to provide information on the run characteristics of Yukon River Chinook salmon. Over 1100 fish will be radio-tagged near the river mouth and tracked to upriver spawning areas in order to provide information on stock composition and timing, nation of origin, migration patterns, and locations of previously undocumented spawning areas.

NOAA's Pacific Marine Environmental laboratory (PMEL) conducts fisheries oceanography and ecosystem studies in the Bering Sea and the western Gulf of Alaska. Fisheries–Oceanography Coordinated Investigations (FOCI) is a cooperative program among PMEL, NMFS's Alaska Fisheries Science Center, NOS's Coastal Ocean Program, and the University of Alaska. FOCI's goals are to increase understanding of the Alaskan marine ecosystem, to document the role of walleye pollock in the ecosystem, to determine factors that affect pollock survival, and to develop and test annual indices of pre-recruit pollock abundance. FOCI is also investigating decadal variability and climate change of the North Pacific and western Arctic, particularly in light of the declining Steller's sea lion population. (Also see Section 2.1.)

3.2.3 Marine Geology and Geophysics

The Arctic continental margin and deep ocean basin constitute one of the least understood

geological regions of the world, partly because much of the offshore area is covered with sea ice. A better understanding of the tectonic history, geologic structure, sediment processes and distribution, and climatic and glacial history of the deeper basin will require extensive geophysical and geological research and the integration of newly collected data on an international scale.

Objectives

- Develop and perfect new techniques for deployment of instruments in the harsh Arctic environment (for example, seismic tomography, geophysical arrays, hydraulic piston coring, and scientific deep drilling);
- Initiate Arctic marine geological and geophysical studies to provide information on past and present climate change and the history of the ice cover, support rational development of natural resources, and address fundamental questions of global geologic history and regional tectonic development;
- Define the geologic framework, deep structure, and tectonic history and development of the Bering Sea region;
- Develop the capability for systematic and comprehensive collection of geologic data in the ice-covered offshore regions using remote sensing and other technologies, such as the nuclear submarine; and
- Determine modern sediment transport by sea ice, icebergs, and other processes; characterize the seafloor sediments by coring and reflection methods; and establish a well-dated stratigraphy.

3.2.4 Underwater Research

In 2002 NOAA funded the development of an ROV, the *Global Explorer*, to investigate life under the ice, in the water column, and on the seafloor of the deep Canada Basin and the Northwind Ridge. This program, called Arctic 2002, was a collaboration between NOAA's Ocean Exploration Office and Arctic Research Office, the Canadian Department of Fisheries and Oceans, JAMSTEC, and institutes in China.

Objective

- To take censuses of marine life in the unexplored regions of the Arctic. Baseline transects are needed to be able to quantify changes in the ecosystems over space and time.

3.3 Atmosphere and Climate

3.3.1 Upper-Atmosphere and Near-Earth Space Physics

The goal of this research is to study upper-atmospheric and near-Earth space phenomena unique to the Arctic regions. These include the aurora, particle precipitation, auroral convection and currents, polar mesospheric clouds, Joule heating, and geomagnetic storms and substorms. These phenomena are intimately linked to the Arctic environment and culture, particularly as Arctic inhabitants become more dependent on modern technology and the Arctic economy becomes more firmly planted in technical systems.

Many of these phenomena are driven by particles and fields originating on the sun. Particles from the sun impact Earth's magnetosphere, which is connected to the upper atmosphere and ionosphere through magnetic field lines that converge in the polar regions. A large fraction of the energy entering the magnetosphere is deposited in the polar upper atmosphere. Arctic ionospheric disturbances interrupt the performance of GPS navigation systems, surveillance systems, and high-frequency radiowave propagation.

The state of the space environment near Earth and its response to solar inputs has come to be known as space weather. The study of Arctic phenomena represents a critical element in understanding the way the space weather system works.

The Arctic region is also extremely sensitive to climate variability and change. Warming of the atmosphere at lower altitudes is occuring in conjunction with cooling of the upper atmosphere, a change that is believed to be manifested in the increasing occurrence rate of polar mesospheric clouds. These effects are being studied intensively as part of the U.S. Global Change Research Program. (See Chapter 12, p. 260 of the Strategic Plan for the U.S. Climate Change Science Program.)

Objectives

- Observe the global-scale response of the polar regions through a coordinated program involving a polar network of ground-based optical, radio, and magnetic observatories and space-based measurements;
- Develop special research tools to address key problems, including establishing a Relocatable Atmospheric Observatory and upgrading the existing incoherent scatter radars, the array of HF radars in the Arctic, and the arrays of optical, radio, and magnetic remote sensors, and also including establishing a coordinated rocket program, promoting the use of special facilities, and making use of research aircraft;
- Maintain active theoretical programs and promote the evolution of models to describe the unique physics of the atmosphere and ionosphere in Arctic regions;
- Understand solar phenomena that affect Earth's environment;
- Understand electromagnetic waves, fields, and particles in near-Earth space; and
- Develop an understanding and the ability to make long-term predictions of radiowave propagation in and through Earth's ionosphere.

3.3.2 Climate and Weather

NOAA is currently supporting a program to study the recent changes in sea ice and snow cover and their impact on the Arctic Oscillation. Changes are occurring in the Arctic that appear to have begun in the late 1960s and increased in the 1990s. These include tropospheric warming, reduction in ice extent, and increased variability in snow cover (Moritz et al. 2002). Much scientific interest has focused on the Arctic Oscillation (AO). A paradox is that the main shifts in the AO are seen in mid-winter, while many of the surface changes are seen in spring and summer. A second issue is whether the reductions in sea ice and snow cover in the western Arctic actually have an impact on the atmosphere. The goal of this project is to determine the impact of the Arctic Oscillation on low-level wind and temperature fields in spring in the Arctic and to evaluate the magnitude of feedback from sea ice and snow anomalies to the atmosphere in spring and summer.

The Arctic Climate Impact Assessment (ACIA) is a four-year project of the Arctic Council and the International Arctic Science Committee that started in 2001 and will be completed by the end of 2004. Funding for ACIA is from the eight Arctic-rim nations, with the United States (through NSF and NOAA's Arctic Research Office) being the lead country for the assessment. The goal of the ACIA is to examine the possible impacts of climate change on the environment and its living resources, on human health, and on relevant economic sectors. About 180 authors have been selected for the assessment from all Arctic countries. Further information on ACIA can be found on its web page at http://www.acia.uaf.edu/.

3.3.3 Tropospheric and Stratospheric Chemistry and Dynamics

NOAA scientists from the Aeronomy Laboratory and the Climate Monitoring and Diagnostics Laboratory play prominent roles in the international scientific assessment of the ozone layer.

NOAA scientists from the Climate Monitoring and Diagnostics Laboratory (CMDL) conduct monitoring and research of atmospheric constituents that are capable of forcing change in the climate of the Earth and atmospheric constituents that may cause depletion of the global ozone layer. The programs consist primarily of long-term measurements of solar radiation and atmospheric trace gases such as carbon dioxide, methane, carbon monoxide, halogenated compounds, nitrous oxide, surface and stratospheric ozone, and aerosols, and at sites remote from local and regional air pollution. The long-term measurements are supplemented by field campaigns using aircraft, ships, and even trains traveling the Trans-Siberian Railroad.

Global measurements show that atmospheric concentrations of chlorofluorocarbon-12 and the bromine-containing halons are continuing to increase in spite of the Montreal Protocol. Industrial production of CFC-12 ended in 1995 in the "developed" countries, but production in economically developing countries (for example, Russia and China) will continue until 2010.

3.4 Land and Offshore Resources

3.4.1 Energy and Minerals

The geologic framework of the Arctic is very poorly understood because of the complexities of its geology, its remoteness, and its relative lack of exploration. The remote frozen environment requires long lead times for energy and mineral development. Additional information is necessary to allow the discovery, assessment, and mapping of new and dependable sources of oil, gas, coal, and strategic minerals. These resources are important for national security and independence, as well as for local use and economics.

Objectives

- Reinstate systematic mineral appraisal activities and expand programs to provide periodic assessments of the undiscovered oil and gas and strategic mineral resources in the Arctic on both broad and local scales;
- Evaluate unconventional energy resources (for example, gas hydrates);
- Identify energy and mineral resources for local use;
- Use new technologies to develop a more modern and complete geologic database, increase geologic mapping, expand modeling efforts, and design derivative maps to address broader earth-science questions; and
- Evaluate the economic, environmental, cultural, and social implications of resource extraction and transport.

3.4.2 Coastal and Shelf Processes

Specific questions about where to build causeways, man-made islands, and other structures can be answered only after basic process information is collected, interpreted, and analyzed carefully. Studies of coastal erosion and sediment transport in the Arctic are needed to understand the long-term history of the coastal area in order to intelligently manage the coastal region. The study of archeological sites can provide important information on the history of coastal platforms, erosion rates, and land–shelf interactions.

Objectives

- Map beach, littoral, and nearshore sediment and subsea permafrost and determine its associated physical and chemical properties;
- Define the processes controlling the formation and degradation of the seasonally frozen sea floor;
- Implement long-term measurements of tides, winds, waves, storm surges, nearshore currents, sediment distribution patterns, and archeological sites to understand coastal erosion and sediment transport processes; and
- Investigate the direct and indirect effects of ice on coastal erosion (the influence on waves and currents) and on sediment transport (contact with beach sediments, keel gouging, and entrainment in frazil ice).

3.4.3 Terrestrial and Freshwater Species and Habitats

The Arctic supports many species of birds, mammals, fish, and plants, which are important resources to the Nation, as well as to Alaska Natives. Some of these resources are harvested commercially or for subsistence purposes (for example, food, shelter, fuel, clothing, and tools), and others provide recreation. To assure that biological resources are protected for future generations, management agencies must have adequate data and information on the biology and ecology of these species, as well as information on environmental attributes of importance to vital biological processes (for example, feeding and breeding).

Objectives

- Determine the history, abundance, biodiversity, and distribution of fish and wildlife populations and identify their habitat requirements;
- Develop new techniques and technologies for studying and managing biological resources in the often-remote and cold-dominated Arctic environments, including recovery of ecosystems damaged by wildfires and other natural and human-induced causes; and
- Improve methods for detecting and determining the effects of human activities on the environment.

3.4.4 Forestry, Agriculture, and Grazing

Enhanced knowledge of Arctic and sub-Arctic ecosystems, their controlling processes, and pro-

ductivity will lead to improved forest, cropland, and soil management practices for sustaining renewable resource productivity. The goals are to promote self-sufficiency and economic benefits for local inhabitants.

Objectives

- Conduct research covering northern boreal forest ecosystems and their controlling processes, focusing on forest landscape and stream ecosystem sustainability and long-term productivity in the face of episodic disturbance, global change, and atmosphere, landscape, forest, stream, and management interactions;
- Conduct soil and plant science research to enhance management practices in the face of development and low-temperature, permafrost, and wildfire impacts;
- Prepare coordinated soil resource information (maps and databases) of the Arctic circumpolar region and continue to coordinate this effort with China, Russia, Canada, Greenland, Germany, Norway, Sweden, and Finland and with the Joint Cryosol Committee of the International Permafrost Association and the International Union of Soil Science;
- Conduct animal science research focused on integrated pest management and Holarctic ruminant parasites; and
- Provide technology for enhancing the economic well-being and quality of life at high latitudes.

3.5 Land–Atmosphere–Water Interactions

3.5.1 Glaciology and Hydrology

NOAA has supported a program to study the hydrologic response of Siberian major rivers to climate change and variation (Yang et al. 2002). Arctic rivers are an important component in global ocean and climate systems, and these studies have shown changes in the hydrologic regimes of the major rivers in Siberia over the past several decades. This project, at the University of Alaska Fairbanks, is a comprehensive assessment of change and variability in Siberian river systems and their connections to surface climate and atmospheric circulation.

The Program for Arctic Regional Climate Assessment (PARCA) is a NASA project with the goal of measuring and understanding the mass balance of the Greenland ice sheet. Primarily remotely sensed data have been used in the project, complemented by targeted in-situ measurements, primarily on ice cores and at automatic weather stations (AWS).

Before PARCA in 2000, we could not determine whether the ice sheet was increasing or decreasing in volume, and mass-balance errors were equivalent to a thickness change of about ±10 cm/yr for the entire ice sheet. Since then, analysis of repeat surveys by satellite radar altimeter (1978–1988 and 1992–1999) and by aircraft laser altimeter (1994–1999), and volume-balance estimates from comparison of total snow accumulation with total ice discharge, all show that the entire region of the ice sheet above about 2000 m in elevation has been close to in balance (within 1 cm/yr) for at least the past few decades but with smaller areas of quite rapid change that can largely be explained by temporal variability in snow accumulation rates (Davis et al. 2000). Some areas, however, appear to be undergoing thinning in excess of 1 m/yr, which may be ongoing adjustments to events since the last glacial maximum or they may indicate changes that began only recently. In particular, most surveyed outlet glaciers are thinning in their lower reaches, and a large area of ice sheet in the southeast has also thinned significantly over the past few decades, at rates that increase to more than 1 m/yr near the coast. Only part of this thinning can be explained by increased melting associated with recent warmer summers, indicating that ice discharge velocities must also have increased (Krabill et al. 2000, Abdalati et al. 2001, Thomas et al. 2001).

Future PARCA research will address these issues, focusing on near-coastal snowfall and ablation and on the dynamics of thinning outlet glaciers. In addition to understanding coastal thinning, a major goal of future PARCA research will be the development of models that reliably hindcast temporal variability in snowfall and surface ablation over the ice sheet, using analyses from operational weather forecasting models to provide ongoing maps of accumulation and ablation rates over both polar ice sheets. This will best be achieved by developing appropriate

capabilities for Greenland, where the existing database is far richer than for Antarctica.

This work will also help prepare for the interpretation of future measurements of elevation change by the Geoscience Laser Altimeter System (GLAS) aboard NASA's ICESat, which was launched on January 12, 2003. ICESat is a three-year mission (five-year goal) to measure elevation changes on the Earth's great ice sheets to an accuracy of approximately 2 cm. These data will greatly enhance our ability to ascertain where the Greenland ice sheet is growing and where it is shrinking. These data will be combined with ancillary data to investigate the mechanisms for that shrinkage.

NASA has also supported an assessment of the current state of balance of major Canadian ice caps. This makes use of survey work from the mid-1990s, from which changes in surface topography can be assessed. Initial results indicate that all of the ice caps for which analyses have been completed show some signs of thinning, primarily at the edges. The level of thinning is consistent with what has been observed in the more temperate regions of the Greenland ice sheet but don't show a strong dynamic component.

3.5.2 Permafrost, Landscape, and Paleoclimate

Additional knowledge is needed about the temperature, distribution, thickness, and depth of permafrost throughout all geomorphic provinces of the Arctic, including the continental shelf. Modern geologic processes that are responsible for the present morphology and land surface need to be better understood.

Objectives

- Undertake a comprehensive program to extract paleoclimatic records from permafrost terrains and lake sediments;
- Reconstruct the late Glacial and Holocene climate history in the Arctic via borehole monitoring and other technology;
- Improve the ability to assess and predict the degree and rate of disturbance and recovery of permafrost terrain following natural or human-induced changes;
- Improve our understanding of the effects of thawing of permafrost on the hydrology, ecosystem characteristics, and productivity of boreal forest ecosystems;
- Model the response of the hydrologic and thermal regimes of the active layer and permafrost to greenhouse-gas-induced warming in the Arctic and sub-Arctic at different locations;
- Provide information on the moisture and thermal regime of the active layer and on degradation of permafrost due to climate warming;
- Develop results leading to the ability to predict future climate-induced changes to the Arctic landscape;
- Understand how possible climate-induced alterations to permafrost systems may influence carbon metabolism, turnover, and storage; and
- Reconstruct the late Glacial and Holocene climate history in the Arctic.

3.5.3 Ecosystem Structure, Function, and Response

Research is needed to improve our understanding of the influence of climate on land and freshwater processes and vice versa. Resource managers and decision makers need reliable environmental impact and health risk assessments.

Topics of particular importance include heat balance relationships, landscape alteration, impacts of wildfire, identification of biological indicators of change, development of a basis for (and clarification of) current and recent contaminant levels, sources and sinks of carbon and trace gases, and long-term trends in biological diversity.

Objectives

- Distinguish ecological changes due to natural causes from changes due to human activities and evaluate management techniques for the conservation and restoration of ecosystems;
- Identify and evaluate the responses of key biological populations and ecological processes to increased CO_2 and to different climatic conditions; monitor the changes in ecotone boundaries, which might serve as integrative indicators of change; and select biological indicators for use in a monitoring program designed to detect, measure, and predict the extent of change;
- Provide opportunities for international cooperation at Long-Term Ecological Research sites and biological observatories in the Arctic;
- Identify factors contributing to reductions in regional and global biological diversity;
- Integrate process, community, ecosystem,

and landscape features into a dynamic description that is realistically linked to both finer and coarser scales of resolution;
- Determine the CO_2 flux from tundra and the responses of vegetation to elevated levels of CO_2; and
- Determine the environmental factors controlling methane fluxes.

3.6 Engineering and Technology

Engineering and technology provide one of the best and possibly most direct avenues for improving and extending the infrastructure so critical to quality of life in the Arctic. In addition, enhanced engineering capabilities and advanced technologies can make crucial contributions to addressing environmental quality challenges and achieving environmentally sustainable development of natural resources. The harsh and unique environment of the Arctic makes advancement in these areas particularly difficult and limits the ability to simply borrow or evolve the engineering and technology advances developed for nonpolar conditions. Only concentrated, specific efforts will produce the advanced technical capabilities the Arctic requires. Engineering and technology development programs that address the priority Arctic engineering research needs are necessary to support these efforts.

Recent concerns of Arctic infrastructure damage due to permafrost degradation have highlighted the inability of current engineering and technology design criteria to address changes in the permafrost foundation over the life cycle of these structures. These deficiencies impact the existing infrastructure in Alaska and future Arctic building programs, including structures such as roads, pipelines, buildings, airfields, and hazardous material storage tanks. These same concerns have been raised regarding the exposure of other cold-regions nations to this threat, particularly in countries of the former Soviet Union.

Cooperation between government agencies, academia, and the private sector provides an excellent opportunity to leverage resources and assure that the advanced technologies developed by government and academia can be practically and effectively applied. Development of goals that meet both commercial and technological interests will help assure that technologies developed will move rapidly into the marketplace.

Objectives

- Develop engineering data and criteria for building, operating, and maintaining strategic and operational facilities and infrastructure in the Arctic, including the effects of permafrost degradation;
- Ensure that current engineering practices include assessment of potential impacts of warming climate on permafrost and other Arctic systems commensurate with the design life of the projects;
- Provide the capability to conduct logistics operations and research support and development in the Arctic;
- Undertake assessment of the potential impact of weather changes associated with climate warming on transportation and maintenance of lines of communications;
- Develop environmentally compatible engineering technologies for the Arctic;
- Develop enhanced understanding of cold-regions performance of new structural materials and systems;
- Provide design criteria for ship operations in ice-infested waters;
- Provide mapping and prediction of ice conditions, along with GIS-based monitoring systems, for port and harbor management;
- Provide engineering data and criteria for water resources activities and environmental impact permitting;
- Provide GIS database and mapping capability for land use, water resources, and monitoring of environmental degradation;
- Ensure that the best available, safest, and pollution-free technologies are used in the development of oil and gas in the Arctic and outer continental shelf;
- Ensure, through technology transfer and retrospective case studies, that future resource exploration and development in the Arctic take advantage of both tried and proven methods, as well as incorporating innovative new technology with minimal environmental impact;
- Provide enhanced engineering criteria and techniques to use naturally occurring materials, such as snow and ice, for ice road and island

construction, reducing costs and minimizing environmental impacts;
- Develop methods for mining and mine closure that are environmentally compatible in Arctic environments;
- Advance the technology for recovering fossil fuels in the Arctic, including onshore extraction and production methods;
- Develop criteria for exploiting frozen ground conditions to minimize environmental impact (tundra snow and ice roads) and enhance system performance (for example, ground-penetrating radar);
- Prevent the discharge of oil, chemicals, and other hazardous materials into the marine environment;
- Ensure quick, effective detection and cleanup of pollution discharges;
- Provide the ability to predict and map movement of pollutants in ice-infested waters;
- Develop Arctic-appropriate cleanup technologies for contaminants and remediation of sites resulting from past military and resource development;
- Evaluate enhanced marine transportation for resupply of coastal and Arctic villages;
- Develop and maintain effective surface transportation and air support facilities in the Arctic; and
- Develop mechanisms for technology transfer between government, academia, and private industry.

3.7 Social Sciences

The historic, current, and future presence of human populations in the Arctic has made the social sciences a top priority and a valuable tool for Arctic research. How have various groups adapted to environmental, economic, and social change? What predictions about future adaptations can be made on the basis of the historic and prehistoric record? How can traditional knowledge enhance scientific understanding of the Arctic environment? These are just a few examples of questions that arise when considering the role of societies in Arctic research. In addition, Arctic communities have themselves become active partners in research projects responding to local needs and concerns.

In an effort to coordinate research plans among Federal agencies, an Interagency Arctic Social Sciences Task Force was established within the Interagency Arctic Research Policy Committee (IARPC). The Task Force prepared and implemented a *Statement of Principles for the Conduct of Research in the Arctic* (see Appendix F), which addresses the need for improved communication and increased collaboration between Arctic researchers and northern people. The principles have fostered greater awareness of local concerns among Arctic researchers and have helped to place a high value on the full participation of Arctic residents in research and environmental issues.

International Arctic Social Science and Health Research

International scientific organizations that have recognized the importance of Arctic social sciences include the International Arctic Social Sciences Association (IASSA), the International Arctic Science Committee (IASC), and the International Union for Circumpolar Health (IUCH). The United States has actively participated in these organizations.

The Arctic Council also admitted two new indigenous groups, the Arctic Athabaskan Council and the Gwich'in Council International, as Permanent Participants. They join the Aleut International Association, the Inuit Circumpolar Conference, the Saami Council, and the Russian Association of Indigenous Peoples of the North (RAIPON), bringing the number of Permanent Participants on the Council to six. RAIPON was elected to replace the Saami Council as chair of the Board of the Indigenous Peoples' Secretariat in November 2000.

The program of the Arctic Council's Sustainable Development working group depends in part on the work of social science research. Research is at the heart of the Survey of Living Conditions in the Arctic: Inuit, Saami and the Indigenous Peoples of Chukotka. The Arctic Telemedicine project, the International Circumpolar Surveillance project on infectious diseases in the Arctic, and the project on Arctic Children and Youth all depended, in part, on the contributions of social science research. The Council anticipates that additional projects underway on timberline forests, capacity building, reindeer husbandry, and ecological and cultural tourism will benefit from the contributions of social science research.

Social science research is also a significant contributor to the environmental protection agenda of the Arctic Council. Social science research, for example, is an integral component of the new Arctic Climate Impact Assessment (ACIA) and an element of the monitoring programs for toxic pollutants under AMAP's subgroup on Human Health.

Social and Health Sciences

NSF continues to provide support for peer-reviewed research projects dealing with decision, risk and management frameworks, risk and health perceptions, co-management of resources, and collaborative research with indigenous communities. Arctic social scientists work with Arctic communities in a collaborative fashion. For example, NSF's Arctic Social Sciences Program contributed to the establishment of the Alaska Native Science Commission (ANSC), an organization that provides essential linkages between researchers and local communities, facilitating communication and cooperation.

NSF plans to continue to emphasize the partnership approach in the Arctic through enhanced outreach to Arctic communities, recognizing that cooperative community relations and education form a central tenet of responsible research conduct.

Human Dimensions of Global Change

The NSF supports opportunities for research on the Human Dimensions of Global Change (HDGC). HDGC research focuses on the interactions between human and natural systems, with emphasis on the social and behavioral processes that shape and influence those interactions. NOAA's Economics and Human Dimensions program supports research investigating human responses to variations in the climate system. The program currently focuses on the potential use and constraints to the use of climate forecast information for decision making across a range of sectors. Although NOAA's Economics and Human Dimensions program does not focus on any particular region, the role of indigenous knowledge and how it might interact with newly developed climate forecast information, as well as the ways in which Native communities adapt to their regional climate, is of interest to the program.

The Human Dimensions of the Arctic System (HARC) initiative, launched under the NSF Arctic System Science program, will focus on the dynamics of linkages between human populations and the biological and physical environment of the Arctic, at scales ranging from local to global.

Education, Training, and Outreach

NSF and Federal agencies are committed to training young scientists and to developing educational components that link social scientists with students and other members of Arctic communities. The Smithsonian Institution conducts research and education programs in the North Pacific, Russia, Canada, and the North Atlantic region and provides museum and exhibit training in Washington, D.C., and Anchorage, Alaska. A new Arctic Studies Center publication series, *Contributions to Circumpolar Anthropology*, has been initiated and will include an English translation of a material culture atlas of Siberia, a Native history of the Bering Strait region, and archival studies of the Jesup North Pacific Expedition and works on the Yamal, Siberian archaeology, and the history of Eastern Arctic archaeology.

Programs such as NSF's Faculty Early Career Development (CAREER) program support innovative research and teaching by junior faculty members. Research Experience for Undergraduate (REU) supplements and sites provide on-site research training to college and university students.

The RAPS (Resource Apprenticeship Program) of the Department of the Interior has provided summer jobs for Alaska Natives through the NPS, BLM, and FWS. Other programs, such as the Cooperative Education Program and the NOAA Sea Grant Program, also support students in Alaska. The BLM Heritage Education National Program is developing materials on archaeological and historical places in Alaska to support education of America's children and to foster a sense of stewardship of cultural heritage.

The USDA Forest Service has participated in an increasing number of programs within the region to promote Alaska Archaeology Week activities (lectures and field trips) and other opportunities for education that foster stewardship and the conservation of heritage resources. The Forest Service is continuing a comprehensive program of cultural resource presentations, subsistence awareness sessions, and site monitoring and protection.

Resources Management

Over 66% of the area of Alaska is managed by Federal agencies. Cultural and natural resources are protected by law, and good management can only be built on accurate baseline data. Although cultural resources, historic and prehistoric sites, artifacts, and landscapes require documentation

and protection, renewable resources, especially fish and game, are also culturally defined through subsistence needs. In 1989, Alaska's subsistence laws were declared unconstitutional because they discriminated against non-rural residents. As a result, Federal land management agencies assumed responsibility for subsistence management on Federal lands. The DOI Fish and Wildlife Service (and its Office of Subsistence Management) is the lead Federal agency in this responsibility. Subsistence is defined as fulfilling both household economic needs and cultural needs, including social communication, food sharing, and maintenance of cultural knowledge and identity. Management of marine resources, such as fish and most species of marine mammals, is led by the DOC National Marine Fisheries Service.

3.7.1 Cultural Resources

The Arctic is a major repository of human experience. Archaeological remains go back some 15,000 years, providing a record of human adaptation to environmental change of unparalleled richness. The Arctic is also home to numerous indigenous cultures. Their traditional and local knowledge base can provide long-term information about northern ecosystems and wildlife, of considerable value in resource management.

The National Park Service and the Smithsonian have been working together in Anchorage for several years on regional archeological assessments, and SI cooperation with NSF and NEH has resulted in several important exhibitions and publications. A number of agencies support research on archaeology, history, and Native culture (BIA, BLM, USFS, NPS, SI, NSF). Finds of artifacts and bones give evidence of past economies and baseline data for pollution monitoring, and historical and ethnographic descriptions tell of more recent conditions. Coastal resources (fish, seals, walrus, whales) supported the largest human populations in Alaska, and changing shorelines and maritime conditions are reflected by these sites.

Objectives

- Document and analyze the origins and transformations of Arctic cultural systems, ethnic groups, and languages;
- Study and analyze traditional knowledge systems, resource uses, and subsistence economics;
- Research paleoenvironmental changes, including ancient sea levels, in concert with cultural historical investigations; and
- Help develop explanatory models integrating cultural systems with local, regional, and global environmental changes.

Repatriation

Repatriation has also become a major priority for museums and research institutes since the passage of NAGPRA (Native American Graves Protection and Repatriation Act) in 1990. This act requires Federal agencies to document Native American human remains, associated grave goods, and items of "cultural patrimony." Agencies must report their holdings of such materials to Native American groups and consult about their repatriation. The National Park Service has a major role in NAGPRA for coordination and guidance at the national level. It can be expected that repatriation will be a major effort for at least a decade.

Repatriation at the Smithsonian has resulted in returns of most of its collections of human remains from Alaska, and consultations are beginning with regard to cultural objects. At the same time a new program, the Smithsonian Alaska Collection Project, has been initiated by the Arctic Studies Center. The project will involve consultation with various groups of Alaska Natives over cultural materials they would like to see brought to the Arctic Studies Center office in Anchorage for study, exhibition, and publication on the Internet.

3.7.2 Rapid Social Change and Community Viability

The impacts of technological and economic development on northern societies, both Native and non-Native, have been profound. While standards of living have often been improved, there have been concurrent changes in traditional cultural values. Chronic unemployment, family violence, substance abuse, and societal breakdown in general have reached epidemic proportions.

One of the recent losses contributing to community instability lies in the area of historical knowledge. While the elders remain important in transmitting knowledge, much information on the past two centuries of community history lies in museums and archives far from northern villages. With NSF assistance, the Smithsonian has been pioneering new methods of "knowledge repatriation" on St. Lawrence Island, through collaborative identification, publication, and local dissemination of historical community records that have never before been available to village residents.

Objectives

- Gain insight into the short-term and long-term effects of rapid social change on Arctic cultures and societies;
- Develop culturally relevant educational programs;
- Develop practical applications of social and behavioral science to benefit Arctic residents;
- Determine linkages between social and behavioral science and health; and
- Determine ecological thresholds as they relate to economic development and community viability.

3.8 Health

Health can be defined as a combination of physical, psychological, social, and spiritual well-being. Unique cross-cultural interdependencies due to harsh environmental conditions in the Arctic highlight this definition. Consequently Arctic health research must take into account complex human and environmental interactions.

Health research in the Arctic focuses on basic and applied biomedical topics (such as molecular biology and genetics), the effects of cultural change on Native populations, the epidemiology of disease, adaptations of humans to extreme environmental conditions, environmental health risks, contamination, and health care delivery in remote and isolated communities. Health concerns in the Arctic are intimately linked to international health issues. Western culture can impact Native people adversely by introducing lifestyle and dietary changes and new infectious agents. Research designed to study these effects and techniques for disease prevention is urgently needed. Health research in the Arctic is done, individually or collaboratively, by the Centers for Disease Control and Prevention, the Indian Health Service, the National Institutes of Health, and the Department of Defense. Nonclinical research on social and behavioral aspects of health is supported by the National Science Foundation's Arctic Social Sciences Program. (For more information, see Section 2.3.)

4. Research Support, Logistics, Facilities, Data, and Information

4.1 Research Support and Logistics

IARPC and Federal agencies will use new resources targeted for Arctic logistics to enhance the U.S. leadership role in Arctic research. The focus on logistics entails:

- Establishment, development, and maintenance of national Environmental Observatories;
- Technology and instrument development;
- Expansion of marine platforms and aircraft support capabilities;
- Integration of research, education, and Arctic community interests; and
- Further international collaboration in the support of research.

The use of the new resources will be guided by the Arctic Research Commission's report *Logistics Recommendations for an Improved U.S. Arctic Research Capability* [available from the Arctic Research Consortium of the United States (ARCUS) at http://www.arcus.org]. The general recommendations of the report are:

- Ensure access to the Arctic over the entire year;
- Increase the availability and use of remote/autonomous instruments;
- Protect the health and safety of people conducting research in the Arctic;
- Improve communications and collaboration between Arctic people and the research community; and
- Seek interagency, international, and bilateral logistics arrangements.

Planning will be done in partnership with Native groups and other advisory bodies and will respond to merit-reviewed proposals.

The NOAA/CMDL Barrow Observatory, a manned atmospheric baseline facility located six miles northeast of Barrow, has been in continuous operation since 1973. The Barrow Observatory focuses on research relating to atmospheric constituents that are capable of forcing change in the climate of the earth through modification of the atmospheric radiative environment, as well as those that may cause depletion of the ozone layer. This facility conducts scores of continuous monitoring activities, including hosting 21 cooperative programs with universities and other government agencies. NOAA operates a three-station network of solar UV measurements with sites at Barrow, St. Paul Island, and Nome. The Barrow Observatory has expanded its research activities over its lifetime and expects to be monitoring climate change in the Arctic through the next century, as long as the requirement continues. Information on CMDL and the Barrow Observatory can be found at http://www.cmdl.noaa.gov.

Another major logistics issue in the Arctic is developing full access and capability to conduct research on all aspects of the Arctic Ocean. The U.S. plans to facilitate this by funding research use of the new USCGC *Healy* and improved sensors for the Arctic drifting buoy program, moorings, and autonomous underwater vehicles.

For both marine and terrestrial research the U.S. will improve basic health and safety by providing access to a pool of emergency beacons, satellite phones, and GPS receivers. There is also a need to better integrate traditional knowledge of Arctic residents with research to broaden our capability in the Arctic. The U.S. plans to increase the duration of measurements (especially during the winter) by providing remotely operated instruments linked with individual researchers in their labs, with other Environmental Observatories, and with distance learning centers.

4.1.1 Oceans

One of the largest single improvements made to U.S. logistical capability in the Arctic comes with the access to the USCGC *Healy*. For the first time, a U.S. research vessel capable of accessing the whole Arctic Ocean is available. In FY 01, NSF supported approximately 90 days of science cruises,

and the first full operational year began in FY 02, supporting four cruises north of Alaska. The maximum number of days of 200 were used in 2003, with 10 days allocated to NOAA, and a similar level of tasking is anticipated in FY 04 and FY 05.

While the *Healy* provides an enormous step forward in capability, it has catalyzed demand, and in 2002 two cruises that could not be accommodated on the *Healy* were supported by the *Polar Sea*. Better coordination between national research icebreakers has become a high priority, and the Forum of Arctic Operators is developing an approach to make scheduling information more widely accessible, with the goal of improved capacity of sharing research icebreaker scheduling information.

At the same time as the *Healy* becomes available, access to U.S. Navy submarines that are capable of operating in the Arctic has largely ended. The submarines provided a unique capability to access the whole Arctic Ocean under the icepack year-round. While the U.S. Arctic Research Commission pursues options to revive or replace this capability, NSF has begun to fund the development and testing of a long-range AUV to begin building a capability to range throughout the Arctic Ocean, perhaps in conjunction with the *Healy* or ice camps.

North Pole Environmental Observatory

The North Pole Environmental Observatory is a Long Term Observatory in the Arctic Ocean. Operations will be based out of Alert, Canada, involving an annual campaign of mooring deployments and servicing and hydrographic stations on a transect from Alert to the North Pole.

An international research team supported by the NSF established a temporary camp at the North Pole, laying the groundwork for a five-year project to take the pulse of the Arctic Ocean and learn how the world's northernmost sea helps regulate global climate. The team deployed a system of floating buoys and has anchored devices to the ocean floor to collect data on everything from the salinity of the water in the Arctic Ocean to the thickness and temperature layering of its ice cover. This is the first time such a congregation of drifting buoys has been placed at the North Pole.

4.1.2 National Ice Center

The National Ice Center (NIC) is a unique interagency organization with oversight from the Department of Defense (DOD), Department of Commerce (DOC), and Department of Homeland Security (DHS) and responds to both Defense and U.S. national interests as outlined in Annex II to the 1995 Navy–NOAA Umbrella Memorandum of Agreement (MOA). The Naval Ice Center (NAVICE) comprises the largest component of NIC and represents the Naval Meteorology and Oceanography Command through the Naval Oceanographic Office. The second leg of the triad, DOC, is represented under the National Oceanic and Atmospheric Administration's (NOAA) Office of Satellite Data Processing and Distribution. The U.S. Coast Guard's (USCG) Director of Operations Policy represents the third member of the triad, DHS.

NIC's mission is to provide the highest-quality operational global, regional, and tactical-scale sea ice analyses and forecasts, tailored to meet the requirements of U.S. national interests. It provides this support to U.S. armed forces, U.S. government and international agencies, academic and scientific institutions, and civil interests. Weekly global and regional-scale ice extent and coverage products are produced in support of mission planning, vessel operations, and scientific research. More frequently produced tactical-scale ice analyses and forecasts are tailored to customer-specified spatial and temporal requirements. Sea ice features of most frequent interest to operations include ice edge position, ice thickness, ice concentration, areas of compression or heavy deformation, and the location and orientation of open water or thin-ice-covered leads and polynyas. All NIC ice extent and coverage products are derived from a blend of remotely sensed and in-situ oceanographic and meteorological data.

NIC ice analyses are crucial to both the safety of navigation in ice-covered waters and as a U.S. contribution to international global climate and ocean observing systems. Real-time raster and digital ice products are distributed via the Internet using the NIC home page (http://www.natice.noaa.gov) and over military networks comprising the Defense Information Infrastructure.

The U.S. Interagency Arctic Buoy Program (USIABP), managed by NIC, collects and distributes surface meteorological and ice drift data. A historical quality-controlled archive of these data is available from the World Data Center–A or via the Internet (http://iabp.apl.washington.edu) from the Applied Physics Laboratory of the University of Washington.

The NIC science program, operating with fiscal support from ONR, NOAA, and NASA, is aimed

at expanding the use of NIC's products within the science community and providing a route for the migration of scientific techniques (such as algorithms) into the operational environment but was recently expanded to include five post-doctoral fellows. The NIC Science Plan (available at http://www.natice.noaa.gov) summarizes the activities, interests, and goals of this polar science program. Current areas of in-house research include improvements to the next generation of ice forecast models, study of Antarctic hydrography, evaluation of passive and active microwave remote sensing algorithms, refinement of data assimilation techniques, and improvements to long-term sea ice forecasting techniques.

4.1.3 Land-Based Facilities

Continuing and Expanding Long Term Observations

The response to NSF's first announcement of opportunity for Long Term Arctic Observations indicated that there is significant need in this area. NSF is now supporting unsolicited proposals to conduct service observations to be made available to broad communities particularly to facilitate long-term observations at sites where there is already a significant history of observations. It is envisioned that this area would increase substantially under SEARCH.

Toolik Field Station

Significant improvements have been made to the laboratories, power system, communications system, and living conditions since FY 99. The University of Alaska has, with NSF's encouragement and with significant input from the user community, developed a long-range development plan that has been approved by the landowner, BLM. While work towards the goals in the plan have slowed, it is hoped that in the next five years it could be completed to provide a safe and efficient work environment for approximately 40 projects and up to 120 scientists annually.

Barrow

Approximately 25–30 NSF projects are active each year, and greater collaboration has developed between NSF projects and other agencies. Plans for the future include building the information technology infrastructure on the recently funded T1 link and providing alternative access to the Barrow Environmental Observatory.

Summit, Greenland

NSF is supporting a series of atmospheric and snow chemistry measurements at Summit, Greenland, in collaboration with NOAA. European-supported projects also continue at Summit, coordinating their activity with NSF through the station operator. However, efforts to develop a joint U.S.–European management of the station have not yet succeeded because of European administrative decisions, but progress is expected in 2004.

Circum-Arctic Environmental Observatory Network

The Circum-Arctic Environmental Observatory Network is an initiative to provide stronger collaborations among existing observatory operators so that they can leverage each other's strengths, particularly in the area of long-term observations and data standards. It is expected that U.S. observatories (Barrow, Toolik, Summit, North Pole) will learn from their international counterparts, mostly European, as they implement new capabilities.

Bering Strait Environmental Observatory

The Bering Strait Environmental Observatory is a Long Term Observatory, located on Little Diomede in the Bering Strait. This project is establishing an onshore environmental observatory at Diomede Village, Alaska, in the center of Bering Strait. The strategic location of this observatory on Little Diomede Island will permit rapid, flexible collection of chemical, biological, and physical data on the transport of nutrient- and organic-rich waters of north Pacific origin into the Arctic Ocean through this narrow strait. An interactive, web-based communication system will facilitate the use of the data by end users in education and research and in local communities in the Bering Strait region. Finally, because of the importance of benthic communities on the shallow Bering and Chukchi shelves to Arctic biogeochemical cycling, a 15-year record of benthic biological and chemical sampling will be continued at two highly productive sites directly north and south of Bering Strait. Ships of opportunity transiting Bering Strait will be used as sampling platforms. Additional information is available at http://eco53.bio.utk.edu.

Aircraft Support

DOC/NOAA has available hangar facilities for two H-1N helicopters at Fort Richardson, Anchorage, Alaska. These facilities have some additional space for field equipment, scientific instruments,

and Arctic gear. NOAA fleet ships have previously worked above latitude 60°N, ice and weather permitting. NOAA aircraft have flown Arctic research projects while based out of Elmendorf AFB, Eielson AFB, and Thule AFB. NSF, ONR, and the New York Air National Guard have taken over the SPAWAR Arctic Logistics infrastructure at Thule.

Cold Regions Research and Engineering Laboratory

A memorandum of understanding between the National Science Foundation and the U.S. Army Corps of Engineers has been implemented that allows NSF-supported engineering and scientific researchers to use USACE laboratory facilities. Many of these state-of-the-art facilities are dedicated to cold regions research and engineering thrusts and are described below. An aggregation of unique facilities that are nationally and internationally recognized exists at the Cold Regions Research and Engineering Laboratory (CRREL). The main complex is in Hanover, New Hampshire. In addition, a permafrost research tunnel and additional coldrooms are located near Fairbanks, Alaska. Industry and academia often use CRREL's unique experimental facilities.

At the Hanover campus the main laboratory houses 24 low-temperature research laboratories capable of achieving temperatures as low as –50°F, special-purpose ice test facilities, cleanrooms, a chemical laboratory, and two specialty low-temperature materials laboratories. The Material Evaluation Facility can simulate snow and icing conditions and static and cycling temperatures ranging from –50° to 120°F and has the capability to conduct full-scale tests on automotive vehicles. The High Performance Materials Laboratory is used for strength and thermal testing of many types of materials, including construction, road, bridge, and composite materials. Specialized testing machines, such as the Split Hopkinson Pressure Bar, enable low-temperature, high-strain materials evaluation to temperatures as low as –80°C. Other equipment includes thermal cycling chambers that allow for thermal cycling from –100° to 100°C and a specially fabricated UV–radiometry system for exposing testing materials to controlled doses of radiation.

The 73,000-square-foot Ice Engineering Facility has three special-purpose research areas: a large low-temperature towing tank, a 100-foot-long refrigerated flume for modeling rivers, and a large hydraulic model room for studying ice effects on civil works facilities, primarily locks and dams. The Ice Engineering Facility also houses a snowdrift wind tunnel.

The Frost Effects Research Facility (FERF) allows full-scale research on the impact of freeze–thaw cycles on pavements, foundations, and utility systems. This 29,000-square-foot facility contains a 182- by 75-ft soil testing area that can be maintained at temperatures below 30°F and 12 large test cells where soil can be frozen and thawed at temperatures ranging from as low as –35°F to as high as 120°F. Six to eight natural freeze–thaw cycles can be simulated in a single year. The newest addition to the CRREL's experimental capability, the Heavy Vehicle Simulator (HVS), is housed in this facility. The HVS can simulate the effect of heavy vehicles on roads and pavements.

At the Alaska campus in Fairbanks, CRREL has a research permafrost tunnel and maintains a 133-acre permafrost research site. The CRREL facilities in Alaska include two coldrooms capable of –30°F temperatures, a heavy equipment maintenance shop, a woodworking shop, a soils laboratory, a shock laboratory, and several Small Unit Support Vehicles (SUSVs) used as research vehicles.

The Technical Information Analysis Center (TIAC) serves DOD and the Nation as the most comprehensive source of cold regions information in the world. The 24,000-square-foot TIAC provides a gateway to the world's information and research resources for cold regions science and engineering. The Cold Regions Science and Technology Information Analysis Center (CRSTIAC) serves as the Nation's corporate repository for cold regions science and engineering data. This center houses the CRREL library, which contains 30,000 books, 160,000 reports, 450 journals, 450 rolls of microfilm, 250,000 pieces of microfiche, 40 CD-ROM reference titles, and topographic maps of all 50 states. The Bibliography on Cold Regions Science and Technology, comprising 53 volumes dating from 1951, is prepared for CRREL by the Library of Congress and contains approximately 250,000 citations, including cumulative author and subject indexes.

4.1.4 Atmospheric Facilities and Platforms

Because of the strategic location of the Arctic for observing space-related phenomena, an extensive infrastructure has been established over the past four decades to observe the Arctic upper atmosphere and ionosphere. The Arctic is the site of many ground-based radio, radar magnetic, and

optical observing sites. These sites and many other smaller facilities have been an important aspect of the Arctic social structure, providing economic benefits in remote regions and educational opportunities for indigenous people.

Among the major upper-atmospheric research facilities in the Arctic are the Sondrestrom Radar in Greenland, the High Frequency Active Auroral Research Program (HAARP) radar in Alaska, the Poker Flat Rocket and Research facility near Fairbanks, the Resolute Bay Observatory in Canada, the Longyearbyen Optical Station in Norway, and the SuperDARN radar network with sites spanning the Western Hemisphere Arctic. These and other smaller sites are operated in collaboration with international partners, including academic and research institutions in Canada, Denmark, Norway, and Japan.

NASA is establishing a Network for Detection of Stratospheric Change (NDSC) program at Thule and Sondrestrom, Greenland, to provide long-term data on a variety of stratospheric constituents. NASA and NSF cooperated in a program called the Program for Arctic Regional Climate Assessment (PARCA). This involved satellite and airborne surveys of different regions of the ice sheet to establish patterns of ice sheet thickening and thinning, along with ground-based surveys to establish reference data for interpreting airborne and satellite observations. Ground observations included the deployment of automatic weather stations and the analysis of shallow snow pits and deep ice cores. The results have, for the first time, shown clear regional patterns in the mass balance of the ice sheet.

4.1.5 Central Coordination and Logistics Information Clearinghouse

Arctic Logistics Information System (ALIAS)

The advent of the World Wide Web has changed our expectations for access to information. In planning and conducting Arctic research, investigators have to cope not only with the extreme polar climate that makes the region difficult and inhospitable to the unprepared, but also with sparse, independently minded populations, poor communications, and many languages. NSF has initiated a project to create a website to provide scientists with key information to assist in planning and executing research programs. An electronic bulletin board, ALIAS, on the Internet (http://www.arcus.org/ALIAS/index.html) is designed to provide information on logistics resources throughout the Arctic.

This key development has a potentially large payoff in terms of logistical cost, researcher time, and safety, with more than 150 NSF-funded projects in the field each year. The benefit will be felt not only by the NSF research community, but also by other Federal agencies and practically all researchers in the Arctic, with the potential of commercial applications and investment.

The Department of the Interior supports an Alaska Office of Aircraft Services (OAS), which coordinates aircraft services on a reimbursable basis.

4.1.6 Data Facilities

Archiving and distribution functions for data required in support of Arctic research are distributed among all the U.S. national data centers. Arctic data are held in global archives at the National Climatic Data Center (climatology and meteorology), at the National Oceanographic Data Center (oceanography), at the National Geophysical Data Center (seismology, geomagnetism, marine geology and geophysics, solar and ionospheric studies, ecosystems, topography, and paleoclimatology), and at the National Center for Atmospheric Research (upper atmosphere and ionospheric studies). Data sets for a vast array of cryosphere-specific variables in the Arctic (sea ice, snow cover, permafrost, etc.) are archived and distributed through the National Snow and Ice Data Center (NSIDC) and the World Data Center–A (WDC–A) for Glaciology in Boulder, Colorado. These include satellite-derived measurements, in-situ observations, and ancillary information that have been supported by NASA, NOAA, and NSF. Global satellite data archives for polar-orbiting satellites are held by NOAA/NESDIS/National Climatic Data Center (NCDC) in Asheville, NC. Included in these archives are:

- Global infrared and visible digital imagery from the advanced very-high-resolution radiometer (AVHRR) instruments;
- Atmospheric temperature and moisture data and derived soundings from the high-resolution infrared radiation sounder (HIRS) instruments; and
- Global passive microwave data from the special sensor microwave/imager (SSM/I).

Electronic access to recent AVHRR and HIRS data is available through the NESDIS Satellite Active Archive (http://www.saa.noaa.gov). Global satellite data archives for the Defense Meteorological Satellite Program (DMSP) Operational Linescan System (OLS) data are held by the National Geophysical Data Center.

The National Oceanographic Data Center (NODC)/WDC–A is the lead agency in the United Nations Intergovernmental Oceanographic Commission (IOC) Global Oceanographic Data Archaeology and Rescue Project (GODAR). Its goal is to locate and rescue historical oceanographic data that are in jeopardy of being lost, including Arctic oceanographic data.

The Alaska SAR Facility (ASF) also operates a NASA/EOSDIS, which receives and processes polar imagery from SARs onboard Canadian (Radarsat) and European (ERS-2) satellites. The ASF also carries out a range of tasks in support of the data, including calibration and the development of data analysis tools. A major data analysis project underway at the ASF involves implementation of the Radarsat geophysical processor system (RGPS), designed to generate high-level products, including ice drift, ice deformation, and ice thickness.

NOAA's Environmental Services Data Directory (NESDD) is a vital window into the U.S. national data archives, providing a means for scientists to locate the data they require.

4.1.7 Safety Support to Individual Projects

Several of the key recommendations in the *Logistics Recommendations for an Improved U.S. Arctic Research Capability* [available from the Arctic Research Consortium of the United States (ARCUS) at http://www.arcus.org] concerned improving the safety of researchers in the Arctic, under the general recommendation that a U.S. Federal program should "protect the health and safety of people conducting research in the Arctic." Specific recommendations were to:

- Sponsor Arctic travel skills and survival courses. NSF, through its contractors, offers three to four field training courses to 60 Arctic researchers annually.
- Supply portable satellite communications. IRIDIUM has become the standard for polar field communications. NSF has reached the goal of providing each field program that requires satellite voice communications with that capability. The next goal is to provide data communications with reasonable bandwidth.
- Support researchers in Russia. Approximately half of the Arctic falls within Russia or its economic zone. Access to the Russian Arctic for fieldwork has always been difficult, but after the initial opening up in the early 1990s, work in Russia is now difficult again and subject to increased risk compared to western standards. NSF has taken a leadership role in examining options that might open Russia to U.S. scientists.

4.2 Arctic Data and Information

4.2.1 Arctic Data

The Alaska SAR Facility has continued to serve the polar research community as the facility for archiving and distributing SAR data. Some of the major projects served this year include the Radarsat Geophysical Processing System project; operational support with near-real-time data (averaging less than three hours turnaround) for the National Ice Center; and the NOAA Coast Watch and Alaska Demonstration projects. In addition to these projects, ASF supports other projects, which together represent an estimated user community of 1400 individual PIs and co-PIs.

ASF has facilitated research and applications development through involvement with the science community, participating in workshops, attending conferences, and producing and distributing new products.

ASF continues to serve as the interface with the Canadian Space Agency, ensuring that data restrictions are appropriately enforced and that data are available to the users of Radarsat-1, whose mission life has exceeded its design life by more than two years. ASF also plans to continue reception of ESA's ERS-2 SAR data and to negotiate with ESA and NASA to participate in the reception, archive, and distribution segments of their future missions (Envisat, CryoSat, ALOS).

The National Snow and Ice Data Center (NSIDC) Distributed Active Archive Center (DAAC) provides access to cryospheric data for both northern and southern hemispheres, with the present emphasis on the Arctic. NSIDC is chartered and partially funded by NOAA, through the Cooperative Institute for Research in Environmental Sciences (CIRES), to provide snow and ice data services. The center is under contract to NASA's Earth

Observation System Data and Information System (EOSDIS) project as a DAAC, providing snow and ice data and information services. The DAAC processes, archives, and distributes sea ice and snow cover data from visible, infrared, and passive microwave sensors, in particular from the special sensor microwave imager (SSM/I), the moderate-resolution imaging spectrometer (MODIS), and advanced very-high-resolution radiometer (AVHRR) sensors, and related in-situ data. The DAAC's passive microwave data sets include a 20-plus-year time series of sea ice extent and concentration for both polar regions. The record will be augmented by the advanced microwave scanning radiometer (AMSR) on board the Aqua platform, which was launched in April 2002. Altimetry and aerosol data sets from the Geoscience Laser Altimeter System (GLAS) instrument on ICESat will also be distributed by the NSIDC DAAC. ICESat was launched in January 2003.

Non-EOS satellite data include the Near Real Time Ice and Snow in EASE grid (NISE) daily product, gridded passive microwave brightness temperatures and sea ice data on CD-ROM, AVHRR polar subsets at 1.25- and 5-km grids, and other in-situ data. Information on all NSIDC DAAC data sets may be found at http://www.nsidc.org/.

NSIDC was chartered by NOAA's National Environmental Satellite, Data, and Information Service (NESDIS) in 1982 to provide a focus for cryospheric data management activities. NSIDC operates under a cooperative agreement between NOAA and the University of Colorado's Cooperative Institute for Research in Environmental Sciences. Within NOAA, NSIDC is affiliated with the NESDIS National Geophysical Data Center. NSIDC is also the home of the World Data Center for Glaciology, Boulder. The majority of funding for NSIDC data management activities comes from NASA for operating a Distributed Active Archive Center (DAAC) for cryospheric data collected by the Earth Observing System (EOS) program.

The NSIDC DAAC provides access to EOS satellite data, as well as ancillary in-situ measurements, baseline data, model results, and algorithms relating to cryospheric and polar processes. NSIDC archives and distributes snow and ice products from the moderate-resolution imaging spectroradiometer (MODIS) instrument aboard the NASA TERRA and Aqua satellites. MODIS snow cover extent, sea ice extent, and sea ice surface temperature products are available in orbital and gridded formats. These products extend the existing 30-year record of passive-microwave-derived snow and sea ice products at greatly improved spatial and spectral resolution. Other DAAC products are the Near Real Time SSM/I EASE-Grid Daily Global Ice Concentration and Snow Extent, and global brightness temperatures from the Defense Meteorological Satellite Program's special sensor microwave imager. In addition to work with data sets, NSIDC compiles the *DAAC Yearbook*, a collection of articles on applications of DAAC data, written for the general public. (The *DAAC Yearbook* is available from NSIDC User Services, University of Colorado, Boulder, Colorado 80309-0449; nsidc@nsidc.org.)

As part of a larger joint NOAA/NASA program, NSIDC works closely with NOAA's NESDIS Long Term Archive team to develop a prototype long-term archive of snow and ice data, metadata, and products from EOS satellites. This effort will determine the resource requirements for a level of service to the user community that is comparable to the current level of service provided by NSIDC for EOS cryospheric data and by the National Geophysical Data Center for Defense Meteorological Satellite Program data and products.

The Arctic System Science (ARCSS) Data Coordination Center (ADCC) at NSIDC will provide ARCSS data and information to the scientific community well into the twenty-first century, consistent with mission objectives and appropriate peer reviews. The ADCC is the permanent archive and access point for data collected by investigators in the NSF's ARCSS program and serves as a catalyst for ARCSS integration through data and information management. Of note is ADCC's work to develop an automated system for climate model output data requests. ADCC averages well over 600 megabytes of data and information downloaded per month. These data sets are mostly in-situ and small data groupings rather than NSIDC's more typical large, multisensor collections.

NSIDC's participation in the joint U.S.–Russian Environmental Working Group's Arctic Climatology Subgroup to produce Arctic Atlases on CD-ROMs has strengthened connection to data repositories in Russia.

Investigators associated with NSIDC bring a polar scientist's perspective to data management. Work is being conducted under approximately 30 grants at any time, and topics range from studying variation in the timing and extent of snowmelt on the Greenland and Antarctic ice sheets with passive microwave data to documenting Inuit

knowledge of climate change. NSIDC also seeks to synthesize and interpret research for the general public. For example, "State of the Cryosphere" web pages (http://nsidc.org/sotc) present aspects of snow cover, sea ice, glaciers, and sea level changes as they relate to climate change.

NSIDC served as co-chair of a World Climate Research Programme (WCRP) Task Group to develop a Climate and Cryosphere (CliC) Science and Coordination Plan. The plan, which lays a path for the coordination of the cryospheric elements of existing projects of the WCRP, was adopted in March 2000, and a joint Arctic Climate System (ACSYS) –CliC Science Steering Group was established. The CliC project addresses interactions among all land and oceanic components of the cryosphere (snow cover, glaciers, ice sheets, permafrost and seasonally frozen ground, freshwater ice, and sea ice) and the climate system, as well as the role of the cryosphere as a climatic indicator for monitoring. Significant questions concern the contribution of glacier melt to sea level rise, the effects of changes in snow and ice cover on water resources, and the impacts of climate change on polar sea ice and on frozen ground. The text of the CliC plan is available at http://www.npolar.no/acsys/CLIC/clic_may.pdf.

4.2.2 Arctic Information

Arctic and Antarctic Regions is available for Windows, DOS, and Internet use from NISC. Comprehensive polar coverage on this CD offers over 800,000 records compiled by the major polar regions research organizations in the U.S., Canada, and the U.K.

A Polar web site, a collaborative project of the Polar Libraries Colloquy and others, provides a guide to Internet resources. The address is http://arktinen.urova.fi/polarweb/.

NOAA has created the Arctic Theme Page (www.arctic.noaa.gov), which contains overview material on Arctic science issues aimed at the non-technical reader. Links are provided to sources of technical information, pictures, and organizations active in Arctic science.

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Appendix A: Glossary of Acronyms

ABNP	Alaskan Basic Neuroscience Program
ACAP	Arctic Council Action Plan to Eliminate Pollution in the Arctic
ACIA	Arctic Climate Impact Assessment
ACMAP	Atmospheric Chemistry Modeling and Analysis Program
ACSYS	Arctic Climate System Study
ADCC	ARCSS Data Coordination Center
ADEOS	Advanced Earth Observation System
ADRO	Applications Development Research Opportunity
AEDD	Arctic Environmental Data Directory
AEPS	Arctic Environmental Protection Strategy
AFB	Air Force Base
AFSC	Alaska Fisheries Science Center
AGES	Age, Gene/Environment Susceptibility study
AHDRN	Arctic Health Disparities Research Dissemination Network
AICC	Arctic Icebreaker Coordination Committee
AIP	Arctic Investigations Program
AMAP	Arctic Monitoring and Assessment Program
AMEC	Arctic Military Environmental Cooperation
AMMTAP	Alaska Marine Mammal Tissue Archival Project
AMSR	Advanced microwave radiometer sensor
ANTR	Alaska Native Tumor Registry
AO	Arctic Oscillation
ARC	Arctic Research Commission
ARCSS	Arctic System Science
ARCUS	Arctic Research Consortium of the United States
ARM	Atmospheric Radiation Measurement program (DOE)
ARPA	Arctic Research and Policy Act
ASOF	Arctic/Sub-Arctic Ocean fluxes
ASF	Alaska SAR Facility
ATSDR	Agency for Toxic Substances and Disease Registry
AUV	Autonomous underwater vehicles
AVHRR	Advanced very-high-resolution radiometer
AWS	Automatic weather station
BASC	Barrow Arctic Science Consortium
BLM	Bureau of Land Management
BRD	Biological Resources Division (USGS)
CAFF	Conservation of Arctic Flora and Fauna
CAREER	Faculty Early Career Development program (NSF)
CDC	Centers for Disease Control and Prevention
CFC	Chloroflourocarbon
CIRES	Cooperative Institute for Research in Environmental Sciences
CISET	Committee on International Science Engineering and Technology
CLIC	Climate and Cryosphere program
CLIVAR	Climate Variability and Predictability program
CMDL	Climate Monitoring and Diagnostic Laboratory (NOAA)
COGA	Collaborative Study of the Genetics of Alcoholism
CRREL	Cold Regions Research and Engineering Laboratory
CRSTIAC	Cold Regions Science and Technology Information Analysis Center
CT	Computerized tomography
DA	Department of Agriculture
DAAC	Distributed Active Archive Center
DHHS	Department of Health and Human Services
DHS	Department of Homeland Security
DMSP	Defense Meteorological Satellite Program
DOC	Department of Commerce
DOD	Department of Defense
DOE	Department of Energy
DOI	Department of the Interior
DOS	Department of State
DOT	Department of Transportation
EDF	Environmental Diplomacy Funds
EO	Environmental Observatory
EOS	Earth Observing System
EOSDIS	Earth Observation System Data and Information System
EPA	Environmental Protection Agency
EPPR	Emergency Prevention, Preparedness and Response
ERS	European Remote-sensing Satellite

EWG	Environmental Working Group
FAA	Federal Aviation Administration
FERF	Frost Effects Research Facility
FOCI	Fisheries–Oceanography Cooperative Investigations
FSU	Former Soviet Union
FUDS	Formerly used defense sites
FWS	Fish and Wildlife Service
FY	Fiscal year
GCM	General circulation model
GC-Net	Greenland Climate Network
GEF	Global Environment Facility
GIS	Geographic information system
GISS	Goddard Institute for Space Studies
GLAS	Geoscience laser altimeter system
GLIMS	Global Land Ice Measurements from Space
GOCADAN	Genetics of Coronary Artery Disease in Alaska Natives study
GODAR	Global Oceanographic Data Archaeology and Rescue Project
GPS	Global positioning system
HAARP	High Frequency Active Auroral Research Program
HARC	Human Dimensions of the Arctic System (NSF)
HBV	Hepatitis B virus
HCH	Hexachlorocyclohexane
HCV	Hepatitis C virus
HDGC	Human Dimensions of Global Change program
HF	High frequency
HIRS	High-resolution infrared radiation sounder
HIV	Human immunodeficiency virus
HRSA	Health Resources Services Administration
HVS	Heavy vehicle simulator
IARPC	Interagency Arctic Research Policy Committee
IASC	International Arctic Science Committee
IASSA	International Arctic Social Sciences Association
ICS	International Circumpolar Surveillance
IOC	Intergovernmental Oceanographic Commission
IPA	Intergovernmental Personnel Act
IPCC	Intergovernmental Panel on Climate Change
IPMC	Interagency Program Management Committee
IUCH	International Union for Circumpolar Health
IWG	Interagency Working Group
JCCEM	Joint Coordinating Committee for Environmental Management
LANL	Los Alamos National Laboratory
LTER	Long-Term Ecological Research
MAB	Man and the Biosphere
MMS	Minerals Management Service
MOA	Memorandum of agreement
MODIS	Moderate Resolution Imaging Spectroradiometer
MRI	Magnetic resonance imaging
NAGPRA	Native American Graves Protection Act
NASA	National Aeronautics and Space Administration
NATO	North Atlantic Treaty Organization
NAVICE	Naval Ice Center
NCCOS	National Centers for Coastal Ocean Science
NCDC	National Climate Data Center
NCEH	National Center for Environmental Health
NCI	National Cancer Institute
NCID	National Center for Infectious Diseases
NDSC	Network for Detection of Stratospheric Change
NEI	National Eye Institute
NEP	Needle exchange program
NESDD	NOAA's Environmental Services Data Directory
NESDIS	National Environmental Satellite Data and Information Service
NEWNET	Neighborhood Environmental Watch Network
NGDC	National Geophysical Data Center
NGO	Non-governmental organization
NIA	National Institute on Aging
NIAAA	National Institute on Alcohol Abuse and Alcoholism
NIC	National Ice Center
NIDA	National Institute on Drug Abuse
NIH	National Institutes of Health
NIOSH	National Institute for Occupational Safety and Health
NISC	National Information Services Corporation
NISE	Near Real Time Ice and Snow in EASE grid
NIST	National Institute of Standards and Technology

NLM	National Library of Medicine
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NODC	National Oceanographic Data Center
NPR–A	National Petroleum Reserve–Alaska
NPS	National Park Service
NSF	National Science Foundation
NSIDC	National Snow and Ice Data Center
NSR	Northern Sea Route
NTS	Nevada Test Site
NTSB	National Transportation Safety Board
NURP	National Undersea Research Program (NOAA)
NWR	National Wildlife Refuge
NWS	National Weather Service (NOAA)
OAS	Office of Aircraft Services
OLS	Operational linescan system
OMAO	Office of Marine and Aviation Operations (NOAA)
OMB	Office of Management and Budget
ONR	Office of Naval Research
OPP	Office of Polar Programs (NSF)
OSRI	Oil Spill Recovery Institute
PAME	Protection of the Arctic Marine Environment
PARCA	Program for Arctic Regional Climate Assessment
PCB	Polychlorinated biphenyls
PDO	Pacific Decadal Oscillation
PMEL	Pacific Marine Environmental Laboratory (NOAA)
POLES	Polar Exchange at the Sea Surface
POP	Persistent organic pollutants
PROBES	Processes and Resources of the Bering Sea Shelf
RAIPON	Russian Indigenous Peoples of the North
RAPS	Resource Apprenticeship Program (DOI)
REU	Research Experience for Undergraduates program
RGI	Regional Geographic Initiative (EPA)
RGPS	Radarsat Geophysical Processor System
ROV	Remotely operated vehicle
SAR	Synthetic aperture radar
SBI	Western Arctic Shelf Basin Interaction program (NSF)
SDWG	Sustainable Development Working Group
SEARCH	Study of Environmental Arctic Change
SEER	Surveillance, Epidemiology, and End Results program (NCI)
SGER	Small Grants for Exploratory Research (NSF)
SHEBA	Surface Heat Budget of the Arctic Ocean program
SI	Smithsonian Institution
SIDS	Sudden infant death syndrome
SMMR	Scanning multichannel microwave radiometer
SPAWAR	Space and Naval Warfare Systems Command
SSC	Science steering committee
SSM/I	Special sensor microwave/imager
SUSV	Small unit support vehicle
TEA	Teachers Experiencing the Arctic program (NSF)
THC	Thermohaline circulation
TIAC	Technical Information Analysis Center
UAA	University of Alaska Anchorage
UAF	University of Alaska Fairbanks
UNEP	United Nations Environmental Program
UNOLS	University National Oceanographic Laboratory System
USACE	United States Army Corps of Engineers
USCG	United States Coast Guard
USDA	United States Department of Agriculture
USFS	United States Forest Service
USGCRP	United States Global Change Research Program
USGS	United States Geological Survey
USIABP	United States Interagency Arctic Buoy Program
UV	Ultraviolet
VPR	VECO Polar Resources
WC&P	West Coast and Polar Center (NOAA)
WCRP	World Climate Research Program
WDC	World Data Center
WHO	World Health Organization

Appendix B: Ninth Biennial Report of the Interagency Arctic Research Policy Committee to the Congress

February 1, 2000, to January 31, 2002

Prepared by the National Science Foundation for the Interagency Arctic Research Policy Committee.

Background

Section 108(b) of Public Law 98-373, as amended by Public Law 101-609, the Arctic Research and Policy Act, directs the Interagency Arctic Research Policy Committee (IARPC) to submit to Congress, through the President, a biennial report containing a statement of the activities and accomplishments of the IARPC. The IARPC was authorized by the Act and was established by Executive Order 12501, dated January 28, 1985.

Section 108(b)(2) of Public Law 98-373, as amended by Public Law 101-609 directs the IARPC to submit to Congress, through the President, as part of its biennial report, a statement "detailing with particularity the recommendations of the Arctic Research Commission with respect to Federal interagency activities in Arctic research and the disposition and responses to those recommendations." In response to this requirement, the IARPC has examined all recommendations of the Arctic Research Commission since January 2000.

Activities and Accomplishments

During the period February 1, 2000, to January 31, 2002, the IARPC has:

- Prepared and published the sixth biennial revision to the United States Arctic Research Plan, as required by Section 108(a)(4) of the Act.
- Published and distributed four issues of the journal *Arctic Research of the United States.* These issues reviewed all Federal agency Arctic research accomplishments for FY 98 and 99 and included summaries of IARPC meetings and activities. The Fall/Winter 2001 issue contained the full text of the sixth biennial revision of the U.S. Arctic Research Plan.
- Consulted with the Arctic Research Commission on policy and program matters described in Section 108(a)(3), was represented at meetings of the Commission, and responded to Commission reports and recommendations (Appendix A).
- Continued the processes of interagency cooperation required under Section 108(a)(6), (7), (8) and (9).
- Provided input to an integrated budget analysis for Arctic research, which estimated $241.9 million in Federal support for FY 00 and $240.4 million in FY 01.
- Arranged for public participation in development of the sixth biennial revision to the U.S. Arctic Research Plan as required in Section 108(a)(10).
- Supported continued U.S. participation in the non-governmental International Arctic Science Committee, via the National Research Council.
- Participated in the continuing National Security Council/U.S. Department of State implementation of U.S. policy for the Arctic. U.S. policy for the Arctic now includes an expanded focus on science and environmental protection and on the valued input of Arctic residents in research and environmental management issues.
- Participated in policy formulation for the Arctic Council. The Council incorporates a set of principles and objectives for the protection of the Arctic environment and for promoting sustainable development. IARPC supports the contributions being made to projects under the Council's Arctic Monitoring and Assessment Program by a number of Federal agencies.

- Approved coordinated Federal agency research initiatives on 1) the Study of Arctic Environmental Change (SEARCH), 2) Bering Sea Integrated Assessment, and 3) Arctic Health. These initiatives are designed to augment individual agency mission-related programs and expertise and to promote the resolution of key unanswered questions in Arctic research and environmental protection. The initiatives are intended to help guide internal agency research planning and priority setting. It is expected that funding for the initiatives will be included in agency budget submissions as the objectives and potential value are of high relevance to the mission and responsibilities of IARPC agencies.
- Convened formal meetings of the Committee and its working groups, staff committees, and task forces to accomplish the above.

Appendix C: Arctic Research Budgets of Federal Agencies

		Budget (dollars in thousands)		
Dept/Bureau	*Program name*	*FY 02 actual*	*FY 03 estimated*	*FY 04 estimated*
DOD	Arctic Engineering	2,750	1,246	1,150
DOD	Permafrost/Frozen Ground	430	500	400
DOD	Snow and Ice Hydrology	1,485	1,877	1,900
DOD	High Latitudes Program	3,030	3,050	2,959
DOD	Lower Atmosphere	100	269	100
DOD	High-Freq Active Auroral Program	10,700	7,600	10,000
DOD	Medical and Human Engineering	898	700	600
	DOD TOTAL	19,393	15,242	17,109
DOI/MMS	Technology Assessment/Research	2,892	3,100	3,000
DOI/MMS	Environmental Studies	4,248	4,176	4,000
DOI/USGS	Energy and Minerals	3,500	3,500	2,000
DOI/USGS	Natural Hazards	3,500	7,500	7,500
DOI/USGS	Global Change	1,000	1,000	1,000
DOI/USGS	Marine and Coastal Geology	250	250	250
DOI/USGS	Geomagnetism	250	250	250
DOI/USGS	Ice and Climate	250	250	250
DOI/USGS	Hydrology	1,270	1,280	1,370
DOI/USGS	Mapping	750	1,540	1,540
DOI/USGS/BRD	Marine Mammals	1,660	1,560	1,660
DOI/USGS/BRD	Migratory Birds	2,390	2,250	2,350
DOI/USGS/BRD	Fisheries Research	360	360	360
DOI/USGS/BRD	Cooperative Research	330	330	330
DOI/USGS/BRD	Terrestrial Ecology	1,130	1,060	1,110
DOI/USGS/BRD	Park Research	1,140	1,070	1,070
DOI/BLM	Natural Ecology	1,698	1,294	1,043
DOI/BLM	Minerals Research (Non-O & G)	2,247	2,063	1,830
DOI/BLM	Minerals Research (O & G, NPR–A)	1,159	1,809	1,393
DOI/BLM	Cultural Resources	205	208	179
DOI/BLM	Pipeline Monitoring	564	130	0
DOI/BLM	Fire Control	223	382	339
DOI/BLM	Mining Administration	350	0	0
DOI/NPS	Cultural Resources	1,400	1,296	1,351
DOI/NPS	Natural Ecology	2,486	2,810	1,950
DOI/NPS	Inventory and Monitoring	0	3,500	5,000
DOI/BIA	Cultural Resources	600	600	600
DOI/BIA	Subsistence Studies	1,250	1,250	1,250

Dept/Bureau	Program name	Budget (dollars in thousands) FY 02 actual	FY 03 estimated	FY 04 estimated
DOI/FWS	Migratory Birds	3,884	3,800	3,800
DOI/FWS	Fisheries	4,068	4,300	4,300
DOI/FWS	Marine Mammals	1,768	2,255	2,231
DOI/FWS	Conservation of Flora and Fauna (CAFF)	200	200	200
DOI/FWS	U.S.–Russia Environmental Agreement	150	350	350
	DOI TOTAL	47,172	55,723	53,856
NSF/OPP	Arctic Natural Science	11,472	12,200	14,152
NSF/OPP	Arctic System Science Program	19,093	20,699	24,011
NSF/OPP	Arctic Social Sciences Program	1,975	2,758	3,199
NSF/OPP	Arctic Research and Education	250	300	300
NSF/OPP	Arctic Research Support	797	823	848
NSF/OPP	Arctic Data/Info/Coordination	248	270	300
NSF/OPP	Arctic Research Commission	1,017	1,080	1,190
NSF/OPP	Arctic Logistics/Instrumentation	27,580	29,166	31,400
NSF/OPP	Sub-total OPP	62,431	67,296	75,400
NSF	Other NSF Science Programs	23,557	24,786	26,302
	NSF TOTAL	85,988	93,082	101,702
NASA	Polar Ice Interactions	4,000	4,500	5,000
NASA	Ecology	535	700	700
NASA	Solid Earth Science	5,000	1,500	2,000
NASA	Arctic Ozone	6,500	7,000	6,500
NASA	Atmospheric Chemistry	0	1,500	1,500
NASA	Clouds and Radiation	750	750	1,200
NASA	Sub-orbital Science	2,500	2,500	2,000
NASA	Iono/Thermo/Mesospheric SR&T	1,500	1,500	1,500
NASA	Magnetospheric SR&T	200	200	200
NASA	Geospace Sciences	2,100	2,100	2,100
NASA	FAST Auroral Snapshot	1,300	1,300	1,300
NASA	Solar Terrestrial Theory	400	400	400
NASA	Arctic Data Systems	12,600	11,000	12,000
NASA	Sounding Rocket Program	1,100	1,100	1,100
	NASA TOTAL	38,485	36,050	37,500
DOC/NOAA	Atmos Trace Constituents	800	300	400
DOC/NOAA	Fisheries Assessment/Management	18,900	18,900	18,900
DOC/NOAA	Marine Mammal Assessment	12,675	6,675	6,675
DOC/NOAA	Ocean Assessment	15	10	10
DOC/NOAA	Stratospheric Ozone	250	200	250
DOC/NOAA	Data Management	357	331	331
DOC/NOAA	Remote Sensing	388	273	345
DOC/NOAA	Aircraft/Vessels	2,053	550	950
DOC/NOAA	Weather Research	0	25	25
DOC/NOAA	Western Arctic/Bering Sea Ecosystem	7,507	2,050	2,100
DOC/NOAA	Barrow Observatory	1,350	650	850
DOC/NOAA	Ocean Exploration	808	250	300
DOC/NOAA	Tsunami Warning/Environ. Observations	250	250	250
DOC/NOAA	Arctic Research Initiative	1,650	2,000	1,650
DOC/NOAA	Ocean Observations/Arctic Fluxes	360	360	360

Dept/Bureau	Program name	Budget (dollars in thousands) FY 02 actual	FY 03 estimated	FY 04 estimated
DOC/NOAA	Arctic Climate Research (SEARCH)	0	2,000	2,000
DOC/NOAA	CIFAR	0	350	0
	DOC/NOAA TOTAL	47,363	35,174	35,396
DOE/SC	Nat Inst Global Env Change	106	200	200
DOE/SC	Atmos Radiation/Planning	3,200	3,200	3,200
DOE/FE	Alaska Fossil Fuels	9,800	8,300	250
DOE/EE	Wind Activities in Alaska	1,900	750	750
DOE/EM	Neighborhood Environmental Watch	50	50	50
DOE/EM	JCCEM/Arctic Transport Studies	750	3,750	0
	DOE TOTAL	15,806	16,250	4,450
DHHS	National Institutes of Health	21,292	32,776	33,775
DHHS	Health Resources Services Administration	500	0	0
DHHS	Centers for Disease Control/Prevent.	4,400	4,400	4,400
	DHHS TOTAL	26,192	37,176	38,175
SMITHSONIAN	Anthropology	400	400	400
SMITHSONIAN	Arctic Biology	50	50	50
	SMITHSONIAN TOTAL	450	450	450
DHS/USCG	Arctic Science/Logistics Support	10,375	5,841	8,186
DHS/USCG	Extramural Science Support	30	30	30
	DHS TOTAL	10,405	5,871	8,216
EPA	Research and Development	200	377	340
EPA	Regional Activities	100	100	100
EPA	International Activities	100	100	100
	EPA TOTAL	400	577	540
USDA/FS	Forest Service–Global Change	729	653	653
USDA/NRCS	Natural Resources Cons Svc–Soil Survey	560	360	260
USDA/ARS	Agricultural Res Service–Global Change	2,000	2,000	2,000
	USDA TOTAL	3,289	3,013	2,913
	GRAND TOTALS	294,994	298,608	300,307

Appendix D: Federal Arctic Research Program Descriptions

Department of Defense

- Arctic Engineering: The study and development of technologies for construction and maintenance of facilities and equipment in Arctic environments.
- Permafrost/Frozen Ground: The study of the formation, structure, characteristics, and dynamics of permafrost and frozen ground.
- Snow and Ice Hydrology: The study of the snowpack and river, lake, and sea ice, their formation, structure, and dynamics.
- Oceanography: The study of Arctic Ocean features and processes including sea ice dynamics.
- Lower Atmosphere: The study of Arctic weather with an emphasis on heat budget.
- Upper Atmosphere: The study of physical processes in the thermosphere, ionosphere, and magnetosphere. Studies also include applied research to investigate, predict, and assess the impacts from the thermosphere, ionosphere, and magnetosphere to communication, navigation, surveillance, and satellite systems.
- High-Frequency Active Auroral Research Program (HAARP): The use of radiowave energy to study basic physical response and composition of the ionosphere and upper atmosphere.
- Medical and Human Engineering: The study of human response to cold climates and methods to mitigate those effects.

Department of the Interior

Minerals Management Service

- Technology Assessment and Research Program: Research to support Minerals Management Service offshore operations. Studies address operational needs for permitting of drilling and production operations, safety and pollution inspections, enforcement action, accident investigations, and well control training requirements.
- Environmental Studies Program: Research to provide information needed for prediction, assessment, and management of impacts from offshore natural gas and oil and mineral development activities on human, marine, and coastal environments of Alaska.

U.S. Geological Survey

- Energy and Minerals: Research to assess the distribution, quantity, and quality of energy and mineral resources with an increasing emphasis on characterizing the environmental impact of resource occurrence and use. This information assists the Nation in managing its land, formulating environmental policies, and ensuring stable and safe supplies of resources.
- Natural Hazards: Research to forecast and delineate hazards from earthquakes, volcanoes, landslides, and related phenomena. Losses from future natural hazard events can be significantly reduced through studies of past and potential events applied to disaster mitigation and response planning.
- Global Change: Research to investigate the impact that potential global change, such as global warming, would have on our planet. This is part of the U.S. Global Change research program, which provides the scientific basis for developing policy relating to natural and human-induced changes in the global earth system.
- Marine and Coastal: Research to address issues of national, regional, and local concern that involve marine and coastal geology. These issues involve natural hazards, natural resources, and environmental quality and restoration; they span the full continuum from coastal wetlands and seashores to the deep ocean.
- Geomagnetism: Research to measure, map, and model the earth's magnetic field within various time scales and to publish and disseminate this information for use in navigation and orientation by Federal, state, local, and international groups. Eleven magnetic observatories are operated, and repeat magnetic field surveys are performed to determine how and how fast the earth's magnetic field is changing.
- Ice and Climate: Research to understand the

causes, characteristics, and effects of changes in glacier conditions over annual to decadal time scales, as well as of changes in snow conditions in mountainous areas over monthly to seasonal time scales.
- Hydrology: Research to monitor and assess the sensitivity of surface water and wetland hydrology to variations and changes in climate.
- Mapping: Program to develop geologic and environmental maps of Arctic Alaska.

U.S. Geological Survey–Biological Resources Division
- Marine Mammals: Research on marine mammals to provide information needed for USGS to fulfill its stewardship responsibilities under the Marine Mammal Protection Act.
- Migratory Birds: Research on migratory birds to provide basic biological information needed for responsible implementation of the Migratory Bird Treaty Act.
- Fisheries: Research related to land management responsibilities on National Wildlife Refuges and National Parks or focusing on treaty issues involving the U.S. and Canada.
- Cooperative Research: Research addressing issues relating to short-term or site-specific resource management issues.
- Terrestrial Ecology: Research related to land management, emphasizing potential effects of resource development on National Wildlife Refuges.
- Park Research: Research related to land management, emphasizing issues specific to National Parks.

Bureau of Land Management
- Natural Ecology: Inventorying and monitoring the quantity and status of waters, soils, vegetation, fish and wildlife populations, and habitats in Arctic Alaska. This is a major effort to support lands and resources management in this unique area.
- Cultural Resources: Studies of man's prehistoric activities in the Arctic. Recent findings in northern Alaska have helped in understanding man's migration into North America.
- Pipeline Monitoring: Program to ascertain that permittees are in compliance with the agreement and grant right-of-way for the Trans-Alaska Pipeline in Arctic Alaska. There is constant monitoring of pipeline integrity and the status of the natural resources in and adjacent to the right-of-way.
- Fire Control: Studies of fuels, ignition, burning, fire spreading, and methods of control of wildfires in the Arctic. A network of remote automatic weather stations has been established. The primary purpose of this network is to help understand the influence of weather on wildfires.
- Mining Administration: Monitoring of placer mining on public lands in Arctic Alaska. The goal is to assure compliance with the approved plan of operations and minimize the impact of mining on the riparian wetland resource.

National Park Service
- Cultural Resources: Research and investigation of cultural resources as they pertain to historic places in National Parks. The Shared Beringian Heritage Program promotes international cooperation in multidisciplinary studies of Beringia.
- Natural Ecology: Research to monitor and understand natural resources in National Parks.

Bureau of Indian Affairs
- Cultural: Research and investigation of learned and shared behaviors as they pertain to historic places and cemetery sites applied for under the provisions of the Alaska Native Claims Settlement Act (P.L. 92-203).
- Subsistence: Research on the customary and traditional uses of fish, game, and plant resources.

National Science Foundation

- Arctic Natural Sciences: Research in atmospheric, space, ocean, biological, earth sciences, and glaciology that is primarily investigator-initiated; this is basic research that is concerned with processes and phenomena in the entire Arctic region, including Alaska, Canada, Greenland, Svalbard, Russia, the Arctic Ocean and adjacent seas, and the upper atmosphere and near space.
- Arctic System Science (ARCSS): An interdisciplinary program that examines the interactions within and between the climatic, geologic, biologic, and socioeconomic subsystems of the Arctic. ARCSS is a regional component within the U.S. Global Change Research Program.
- Arctic Social Science: A multidisciplinary and interdisciplinary program focused on issues

of human–environment interactions, rapid social change, and community viability.

- Arctic Science Support: Support for Intergovernmental Personnel Act (IPA) personnel assigned to the Arctic Sciences Section of the Office of Polar Programs (OPP), and scientific meeting, panel, and publication support.
- Arctic Data and Information, and Advisory and Coordination: Support for a program of Arctic data and information research and advisory services, including support for the Interagency Arctic Research Policy Committee, and conferences, workshops, and studies to further develop and implement Arctic research planning and policy.
- Arctic Research Commission: Support for the Commission staff and members. Funding for the Arctic Research Commission is included in the NSF budget for administrative convenience.
- Other Sciences: Research supported in divisions and programs outside the OPP in atmospheric, ocean, biological, earth sciences, and glaciology that is primarily investigator-initiated basic research.
- Engineering: Engineering research that is related to the Arctic.
- Education: Education research that is related to the Arctic.

National Aeronautics and Space Administration

- Cryosphere: This program is focused on the Arctic ice cover and its interactions with the oceans and atmosphere. The long-range goals are to significantly improve our ability to represent high-latitude processes in models of global climate and climate change and to understand the current and likely impact of changes in ice mass on sea level.
- Ecology: This program is focused on the function of high-latitude terrestrial ecosystems and their interactions with the atmosphere and hydrosphere, with particular emphasis on carbon cycling and land–atmosphere interactions.
- Solid Earth and Natural Hazards Science: This program is focused on improving our understanding of the earth's gravity field, oscillations in the length of day and tilting of the axis of rotation, geodesy to determine the rate of past-glacial rebound of the lithosphere for ice mass and structural studies, the earth's magnetic field to determine crustal structure, and topography and topographic change of the Arctic and Antarctic regions. The program also contributes to other polar studies by providing a frame of reference with which to monitor changes such as the volume of the ice sheets.
- Arctic Ozone Studies: This program is supporting a number of tasks related to chemical and dynamical processes in the Arctic stratosphere, with the aim of measuring and understanding changes in Arctic stratospheric ozone in an atmosphere with increasing abundances of greenhouse gases.
- Arctic Data Systems: NASA provides support for two Distributed Active Archive Systems (DAACs) for high-latitude data: one at the National Snow and Ice Data Center (NSIDC) in Boulder, Colorado, and one at the Alaska SAR Facility (ASF) in Fairbanks, Alaska. The ASF is responsible for acquiring, processing, archiving, and distributing synthetic aperture radar (SAR) data from several non-U.S. spacecraft, and the NSIDC handles most other satellite data over the high latitudes. In addition, NASA supports the development of several high-latitude "Pathfinder" data sets, comprising higher-level information derived from various satellite data.
- Clouds and Radiation: NASA supports comprehensive studies of the impact of Arctic clouds and aerosols on the Arctic radiation balance and its impact on the global radiative balance. Studies supported include modeling and analysis of satellite cloud and aerosol data obtained over the polar regions. In addition, NASA supports missions to the Arctic (e.g. FIRE-ACE) that include ground, ship, and airborne sensors coordinated with satellite observations to study the processes that contribute to the evolution of cloud and aerosol distributions.
- Geospace Physics: NASA provides support for a vigorous program of experimental and theoretical studies of geospace phenomena originating in or affecting Arctic regions, including the mesosphere, thermosphere, ionosphere, and magnetosphere. It includes these programs listed in the NASA budget table: Sun-Earth Connection Theory Program, Fast Auroral SnapshoT Explorer spacecraft, Geospace Low Cost Access to Space (suborbital) program, and the Geospace Sciences Supporting Research and Technology program.

Department of Commerce

National Oceanic and Atmospheric Administration

- Atmospheric Trace Constituents: Continuous and discrete measurements of atmospheric trace constituents (for example, greenhouse gases) that are important to understanding global change.
- Marine Fisheries Assessment: Assessment by the National Marine Fisheries Service (NMFS) of U.S. living marine resources in Arctic waters.
- Marine Fisheries Research: NOAA's Pacific Marine Environmental Laboratory (PMEL) and Alaska Fisheries Science Center (AFSC) conduct the Fisheries Oceanography Coordinated Investigations (FOCI) program in the Bering Sea and North Pacific. FOCI is concerned with understanding and predicting the impacts of interannual variability and decade-scale climate change on commercially valuable fish species.
- Marine Mammal Assessment: Long-term research by NMFS's National Marine Mammal Laboratory on the population biology and ecology of Arctic marine mammals. NMFS also participates in the Marine Mammal Health and Stranding Response Program, which oversees the Arctic Marine Mammal Tissue Archival Program (AMMTAP) in collaboration with the Department of the Interior (FWS, BRD, and MMS) and the National Institute of Standards and Technology (NIST). The AMMTAP collects, analyzes, and archives tissues for contaminants and health indices to provide a database on contaminants and health in marine mammal populations in the Arctic.
- Coastal Hazards: Activities directed towards developing a better understanding of the effects of tsunami propagation and run-up.
- Ocean Assessment: A wide range of programs and activities directed toward NOAA's environmental stewardship responsibilities, including environmental monitoring and assessment, technology transfer, and education and outreach. Ocean assessment includes the National Status and Trends Program, the Coastal Ocean Program, and other pertinent activities of the recently formed National Centers for Coastal Ocean Science (NCCOS), National Ocean Service.
- Stratospheric Ozone: A program that is developing an understanding of the dynamics and chemistry of Arctic ozone depletion, as part of activities directed to understanding the global depletion of stratospheric ozone.
- Satellites/Data Management: Research addressing NOAA's responsibilities for collecting, archiving, processing, and disseminating environmental data and providing specialized data analyses and interpretations.
- Remote Sensing: A substantial program (jointly with NASA, NSF, and DOE) for developing, testing, and using ground-based remote sensors for Arctic meteorological research. The emphasis is on prototypes for future operational systems that can operate in the Arctic with minimal attention. The scientific issues include boundary layer turbulence and structure, cloud macro- and micro-physical properties, and cloud-radiative coupling relevant to Arctic climate.
- Aircraft/Vessels: Platform support from the Office of Marine and Aviation Operations (OMAO) to conduct the research and observations associated with NOAA's Arctic research program.
- Climate and Global Change: Studies that are assessing Arctic processes as forcing functions of climate and global change and as "barometers" of global change. NOAA's Arctic Research Office chairs the Interagency Working Group on the Study of Environmental Arctic Change (SEARCH).
- Arctic Ice: The National Ice Center, jointly operated by NOAA, the U.S. Navy, and the U.S. Coast Guard, provides analyses and forecasts of ice conditions in all seas of the polar regions, the Great Lakes, and Chesapeake Bay. The National Snow and Ice Data Center (NSIDC), affiliated with NOAA's National Geophysical Data Center (NGDC), archives many new and rescued ice data sets.
- Arctic Weather: Research primarily addresses four concerns: 1) Forecasting snow in mountainous terrain for real-time use and for climate-related information; 2) Remote sensing for detecting clouds and for developing cloud phase techniques; 3) Improving the numerical modeling of weather over both the short and long term in complex terrain such as Alaska; and 4) Locating and understanding the dynamics of the Arctic Front.
- Boreal Forest Fires and the Arctic: Modeling, research, and observations to understand the influence of Northern Hemisphere boreal forest fires on atmospheric chemistry in the Arc-

tic, especially focusing on the production of surface-level ozone and other pollutants and the atmospheric and climate effects of the input of soot.

- Arctic Research Initiative: The Arctic Research Office was formed in FY 00 to administer the Arctic Research Initiative and to build a NOAA program focused on Arctic science issues of national importance. For this purpose, the "Arctic" is defined loosely as the northern hemisphere land area underlain by permanent or discontinuous permafrost, and ocean areas subject to permanent or annual sea ice cover. Consideration of watersheds and airsheds that flow to the Arctic can extend the geographic boundaries significantly, as can consideration of impacts of Arctic processes on hemispheric weather and climate. In FY 03, newly appropriated funds are available to initiate a NOAA contribution to the interagency Study of Environmental Arctic Change (SEARCH). Under the overall guidance of the NOAA Strategic Plan, the ARO has formulated more specific goals that relate to its specific mission. These goals are:
  - Characterize poorly known high-latitude marine habitats, and understand and model factors controlling the populations of key marine species in the Arctic and sub-Arctic;
  - Understand ecosystem impacts of critical contaminants and human uses in the Arctic; and
  - Understand causes and impacts of atmospheric, oceanic, and climate variability and change in the Arctic.

  Several projects are planned over the next few years to address these goals and contribute to the SEARCH Science Plan. These projects are: a) Retrospective Analysis of Ocean Climate and Populations of Key Living Marine Resources; b) A collaborative, international program of Arctic exploration; c) Bering Sea Ecosystem Study; d) Atmospheric and Cryospheric Change in the Arctic; e) Arctic/Sub-Arctic Ocean Fluxes; f) Arctic System Reanalysis; g) Arctic Climate Impact Assessment; h) Environmental Sources, Fate, and Impact of Mercury and Persistent Organic Pollutants in the Arctic; I) Assessment of Environmental and Economic Impacts of Oil and Gas in the Arctic; j) Development of an updated AMAP Strategic Plan.

Department of Energy

- Climate-Related Atmospheric Radiation Research: Continued operation of an Atmospheric Radiation Measurement (ARM) research ("testbed") site on the North Slope of Alaska to improve mathematical simulations of cloud and radiative transfer processes in general circulation models (GCMs).
- Neighborhood Environmental Watch Network (NEWNET): Continued operation of an Alaskan network (Fairbanks, Kotzebue, Nome, Point Hope, and Seward) of public-accessible environmental gamma-radioactivity monitoring stations and data storage/processing systems, based on concepts developed by the DOE for the Community Monitoring Program at the Nevada Test Site (NTS) Nuclear Testing Facility.
- Joint Coordinating Committee for Environmental Management (JCCEM) Contaminant Transport Studies: Continuing assessment of the hydrogeologic framework and radioactivity contamination status of the West Siberian Basin from past and ongoing releases of commercial and defense-related nuclear and hazardous waste disposal operations at the former Soviet Union's Mayak, Tomsk, and Krasnoyarsk sites. (This program was terminated in FY 03.)
- Ecosystem Changes in Alaska: DOE's National Institute for Global Environmental Change (NIGEC) supports two projects (one continuing and one to begin in FY 03) that document recent changes in selected ecosystems in Alaska. The research is aimed at determining whether recent climatic changes in Alaska are affecting, or are likely to affect in the future, Alaskan forests and the goods and services they provide to society.
- Alaska Fossil Fuels: The DOE's Office of Natural Gas and Petroleum Technology continues to be involved in several projects related to the occurrence of methane hydrate deposits in the North Slope of Alaska.
- Wind Activities in Alaska: To better understand the role that wind energy can play, the DOE's Wind Energy Program continues to be engaged in collaborative efforts with Alaskan organizations at the state and local levels to explore ways in which wind can make a greater contribution in the production of electric power. Efforts are particularly focused on smaller rural communities, where the cost of

diesel-generated electricity is very high. Current Alaskan locations include Kotzebue, Wales, Nome, Nightmute, Nunapitchuk, Selawik, and Unalakleet.

Department of Health and Human Services

National Institutes of Health

- Basic and applied research that relates primarily in the areas of rheumatic diseases, cancer, drug and alcohol abuse, and coronary heart disease that affect Arctic residents.

Centers for Disease Control and Prevention

- A research program designed to evaluate infectious disease prevention and control strategies in the Arctic and sub-Arctic, with a special focus on diseases of high incidence and concern among the indigenous peoples of the circumpolar region.
- An occupational injury research program focusing on the Nation's geographic area with the highest risk of occupational-related injury.
- Research on human exposure to environmental persistent organic pollutants in the Arctic.

Agency for Toxic Substances and Disease Registry

- A research program to identify and reduce risks from exposure to environmental contaminants while maintaining the benefits of the subsistence lifestyle.

Smithsonian Institution

- Anthropology: Research and interpretation of Arctic cultures and natural history; training of Arctic residents and Natives in museum studies, collections care, conservation, and cultural heritage programs; studies of the origin and history of northern cultures and their interactions with their environment and with European cultures are central features of this research.
- Arctic Biology: Basic research on biological and evolutionary studies in botany, zoology, and other natural history fields. Interactions of Arctic flora and fauna with human cultures are emphasized.

Department of Homeland Security

U.S. Coast Guard

- Arctic Science/Logistics Support: The costs of providing and maintaining polar icebreakers for use in the Arctic.
- Test and Evaluation: The cost of tests designed to evaluate polar icebreakers in the performance of Arctic missions. (Previously, unreimbursed Arctic science mission costs were included in this category.)
- Extramural Science Support: Funding provided to other agencies for Arctic science studies, research, or vessel availability studies.

Environmental Protection Agency

- Research and Development: Intramural and extramural basic and applied research founded on the risk assessment and risk management paradigm. EPA research interests in the Arctic include water quality, watershed cumulative effects, air quality, land use, bioremediation and the combined impact of contaminants, climate change, and resource use on freshwater and marine ecosystems. Research efforts address issues of long-range transport and transformation of contaminants to the Arctic and the status and trends of contaminants such as persistent organic pollutants and heavy metals within the Arctic environment.
- Regional Activities: Activities of EPA's Region 10 (Pacific Northwest and Alaska office) are conducted in partnership with tribes, the state, and local communities to resolve key issues in rural sanitation, clean drinking water, clean-up of formerly used defense sites, regulation of local industry, and other issues key to protecting human health and the unique Arctic and sub-Arctic environments.

Department of Agriculture

Forest Service

- Research directed toward improving the understanding, use, and management of Alaska's natural resources, especially the northern boreal forest. Research centers on the dynamics of mixed stands and the cumulative effects of management activities on hydrology, soils, vegetation, wildlife, carbon reserves, insects, and fire in boreal ecosystems.
- Important portions of the boreal ecosystems research are conducted at the Bonanza Creek Long-Term Ecological Research Site near Fairbanks, Alaska.

Natural Resources Conservation Service

- Research in support of the National Cooperative Soil Survey program addressing permafrost, soil cryogenic processes, soil reduction and oxidation properties, temperature, water status and gas flux in wetlands, reindeer and caribou grazing needs, and vegetation trends.
- Establishment of a network of climatic stations in both the Arctic and Antarctic as well in other areas with soils affected by permafrost, allowing for studies of changes in the active layer and providing data for many other users. They are linked to sites established by NSF-funded projects, all of the sites have complete soil characterization data, and all of the data collected are provided to NSIDC.
- Research on vegetation, landform, carbon sequestration, and other greenhouse gas relationships in support of the Global Change Research Program.
- Research in support of the snow survey program. Snowfall measurement techniques are being studied to support the snow survey, which continues to be used to predict snowmelt, water availability, river breakup timing, and wildlife movements.
- Research conducted jointly with scientists from Russia and other countries to look at active layer dynamics and soil genesis, classification, and formation.
- Establishment of climatic stations, with both below- and above-ground sensors, in much of Alaska, with comparable sites in the permafrost regions of China as well as in Antarctica.

Agricultural Research Service

- Research on plant sciences emphasizing germplasm preservation to protect native and Russian plant species with emphasis on medicinal value and utility for erosion control.
- Research in animal sciences to investigate Alaska fisheries byproduct use (especially for feed stocks), integrated pest management for grasshopper control in Alaska's central basin, and the biosystematics of Holarctic ruminant parasites to assess pathogen distribution in food resources of northern communities.

Department of State

- Coordination of U.S. involvement in the Arctic Council and its working groups, including the Arctic Monitoring and Assessment Program; Conservation of Arctic Flora and Fauna, which the U.S. vice-chairs; Emergency Prevention, Preparedness, and Response; Protection of the Arctic Marine Environment, which the U.S. chairs; Sustainable Development; and the Arctic Council Action Plan to Eliminate Pollution of the Arctic.
- Chairmanship of regular meetings of the interagency Arctic Policy Group and overall responsibility for the coordination and formulation of U.S. policy in the Arctic.

Appendix E: Arctic Research and Policy Act, As Amended

PUBLIC LAW 98-373 - July 31,1984; amended as
PUBLIC LAW 101-609 - November 16, 1990

An Act

To provide for a comprehensive national policy dealing with national research needs and objectives in the Arctic, for a National Critical Materials Council, for development of a continuing and comprehensive national materials policy, for programs necessary to carry out that policy, including Federal programs of advanced materials research and technology, and for innovation in basic materials industries, and for other purposes.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled:

TITLE 1-ARCTIC RESEARCH AND POLICY

SHORT TITLE

SEC. 101. This title may be cited as the "Arctic Research and Policy Act of 1984, as amended".

FINDINGS AND PURPOSES

SEC. 102.(a) The Congress finds and declares that—

(1) the Arctic, onshore and offshore, contains vital energy resources that can reduce the Nation's dependence on foreign oil and improve the national balance of payments;

(2) as the Nation's only common border with the Soviet Union, the Arctic is critical to national defense;

(3) the renewable resources of the Arctic, specifically fish and other seafood, represent one of the Nation's greatest commercial assets;

(4) Arctic conditions directly affect global weather patterns and must be understood in order to promote better agricultural management throughout the United States;

(5) industrial pollution not originating in the Arctic region collects in the polar air mass, has the potential to disrupt global weather patterns, and must be controlled through international cooperation and consultation;

(6) the Arctic is a natural laboratory for research into human health and adaptation, physical and psychological, to climates of extreme cold and isolation and may provide information crucial for future defense needs;

(7) atmospheric conditions peculiar to the Arctic make the Arctic a unique testing ground for research into high latitude communications, which is likely to be crucial for future defense needs;

(8) Arctic marine technology is critical to cost-effective recovery, and transportation of energy resources and to the national defense;

(9) the United States has important security, economic, and environmental interests in developing and maintaining a fleet of icebreaking vessels capable of operating effectively in the heavy ice regions of the Arctic;

(10) most Arctic-rim countries, particularly the Soviet Union, possess Arctic technologies far more advanced than those currently available in the United States;

(11) Federal Arctic research is fragmented and uncoordinated at the present time, leading to the neglect of certain areas of research and to unnecessary duplication of effort in other areas of research;

(12) improved logistical coordination and support for Arctic research and better dissemination of research data and information is necessary to increase the efficiency and utility of national Arctic research efforts;

(13) a comprehensive national policy and program plan to organize and fund currently neglected scientific research with respect to the Arctic is necessary to fulfill national objectives in Arctic research;

(14) the Federal Government, in cooperation with State and local governments, should focus its efforts on the collection and characterization of basic data related to biological, materials, geophysical, social, and behavioral phenomena in the Arctic;

(15) research into the long-range health, environmental, and social effects of development in the Arctic is necessary to mitigate the adverse consequences of that development to the land and its residents;

(16) Arctic research expands knowledge of the Arctic, which can enhance the lives of Arctic residents, increase opportunities for international cooperation among Arctic-rim countries, and facilitate the formulation of national policy for the Arctic; and

(17) the Alaskan Arctic provides an essential habitat for marine mammals, migratory waterfowl, and other forms of wildlife which are important to the Nation and which are essential to Arctic residents.

(b) The purposes of this title are—

(1) to establish national policy, priorities, and goals and to provide a Federal program plan for basic and applied scientific research with respect to the Arctic, including natural resources and materials, physical, biological and health sciences, and social and behavioral sciences;

(2) to establish an Arctic Research Commission to promote Arctic research and to recommend Arctic research policy,

(3) to designate the National Science Foundation as the lead agency responsible for implementing Arctic research policy, and

(4) to establish an Interagency Arctic Research Policy Committee to develop a national Arctic research policy and a five year plan to implement that policy.

ARCTIC RESEARCH COMMISSION

SEC. 103. (a) The President shall establish an Arctic Research Commission (hereinafter referred to as the "Commission").

(b)(1) The Commission shall be composed of seven members appointed by the President, with the Director of the National Science Foundation serving as a nonvoting, ex officio member. The members appointed by the President shall include—

(A) four members appointed from among individuals from academic or other research institutions with expertise in areas of research relating to the Arctic, including the physical, biological, health, environmental, social and behavioral sciences;

(B) one member appointed from among indigenous residents of the Arctic who are representative of the needs and interests of Arctic residents and who live in areas directly affected by Arctic resource development; and

(C) two members appointed from among individuals familiar with the Arctic and representative of the needs and interests of private industry undertaking resource development in the Arctic.

(2) The President shall designate one of the appointed members of the Commission to be chairperson of the Commission.

(c)(1) Except as provided in paragraph (2) of this subsection, the term of office of each member of the Commission appointed under subsection (b)(1) shall be four years.

(2) Of the members of the Commission originally appointed under subsection (b)(1)—

(A) one shall be appointed for a term of two years;

(B) two shall be appointed for a term of three years; and

(C) two shall be appointed for a term of four years.

(3) Any vacancy occurring in the membership of the Commission shall be filled, after notice of the vacancy is published in the Federal Register, in the manner provided by the preceding provisions of this section, for the remainder of the unexpired term.

(4) A member may serve after the expiration of the member's term of office until the President appoints a successor.

(5) A member may serve consecutive terms beyond the member's original appointment.

(d)(1) Members of the Commission may be allowed travel expenses, including per diem in lieu of subsistence, as authorized by section 5703 of title 5, United States Code. A member of the Commission not presently employed for compensation shall be compensated at a rate equal to the daily equivalent of the rate for GS-18 of the General Schedule under section 5332 of title 5, United States Code, for each day the member is engaged in the actual performance of his duties as a member of the Commission, not to exceed 90 days of service each year. Except for the purposes of chapter 81 of title 5 (relating to compensation for work injuries) and chapter 171 of title 28 (relating to tort claims), a member of the Commission shall not be considered an employee of the United States for any purpose.

(2) The Commission shall meet at the call of its Chairman or a majority of its members.

(3) Each Federal agency referred to in section 107(b) may designate a representative to participate as an observer with the Commission. These representatives shall report to and advise the Commission on the activities relating to Arctic research of their agencies.

(4) The Commission shall conduct at least one public meeting in the State of Alaska annually.

DUTIES OF THE COMMISSION

SEC. 104. (a) The Commission shall—

(1) develop and recommend an integrated national Arctic research policy;

(2) in cooperation with the Interagency Arctic Research Policy Committee established under section 107, assist in establishing a national Arctic research program plan to implement the Arctic research policy;

(3) facilitate cooperation between the Federal Government and State and local governments with respect to Arctic research;

(4) review Federal research programs in the Arctic and recommend improvements in coordination among programs;

(5) recommend methods to improve logistical planning and support for Arctic research as may be appropriate and in accordance with the findings and purposes of this title;

(6) recommend methods for improving efficient sharing and dissemination of data and information on the Arctic among interested public and private institutions;

(7) offer other recommendations and advice to the Interagency Committee established under section 107 as it may find appropriate;

(8) cooperate with the Governor of the State of Alaska and with agencies and organizations of that State which the Governor may designate with respect to the formulation of Arctic research policy;

(9) recommend to the Interagency Committee the means for developing international scientific cooperation in the Arctic; and

(10) not later than January 31,1991, and every 2 years thereafter, publish a statement of goals and objectives with respect to Arctic research to guide the Interagency Committee established under section 107 in the performance of its duties.

(b) Not later than January 31 of each year, the Commission shall submit to the President and to the Congress a report describing the activities and accomplishments of the Commission during the immediately preceding fiscal year.

COOPERATION WITH THE COMMISSION

SEC. 105. (a)(1) The Commission may acquire from the head of any Federal agency unclassified data, reports, and other nonproprietary information with respect to Arctic research in the possession of the agency which the Commission considers useful in the discharge of its duties.

(2) Each agency shall cooperate with the Commission and furnish all data, reports, and other information requested by the Commission to the extent permitted by law; except that no agency need furnish any information which it is permitted to withhold under section 522 of title 5, United States Code.

(b) With the consent of the appropriate agency head, the Commission may utilize the facilities and services of any Federal agency to the extent that the facilities and services are needed for the establishment and development of an Arctic research policy, upon reimbursement to be agreed upon by the Commission and the agency head and taking every feasible step to avoid duplication of effort.

(c) All Federal agencies shall consult with the Commission before undertaking major Federal actions relating to Arctic research.

ADMINISTRATION OF THE COMMISSION

SEC. 106. The Commission may—

(1) in accordance with the civil service laws and subchapter III of chapter 53 of title 5, United States Code, appoint and fix the compensation of an Executive Director and necessary additional staff personnel, but not to exceed a total of seven compensated personnel;

(2) procure temporary and intermittent services as authorized by section 3109 of title 5, United States Code;

(3) enter into contracts and procure supplies, services and personal property;

(4) enter into agreements with the General Services Administration for the procurement of necessary financial and administrative services, for which payment shall be made by reimbursement from funds of the Commission in amounts to be agreed upon by the Commission and the Administrator of the General Services Administration; and

(5) appoint, and accept without compensation the services of, scientists and engineering specialists to be advisors to the Commission. Each advisor may be allowed travel expenses, including per diem in lieu of subsistence, as authorized by section 5703 of title 5, United States Code. Except for the purposes of chapter 81 of title 5 (relating to compensation for work injuries) and chapter 171 of title 28 (relating to tort claims) of the United States Code, an advisor appointed under this paragraph shall not be considered an employee of the United States for any purpose.

LEAD AGENCY AND INTERAGENCY ARCTIC RESEARCH POLICY COMMITTEE

SEC. 107. (a) The National Science Foundation is designated as the lead agency responsible for implementing Arctic research policy, and the Director of the National Science Foundation shall insure that the requirements of section 108 are fulfilled.

(b)(1) The President shall establish an Interagency Arctic Research Policy Committee (hereinafter referred to as the "Interagency Committee").

(2) The Interagency Committee shall be composed of representatives of the following Federal agencies or offices:

(A) the National Science Foundation;

(B) the Department of Commerce;

(C) the Department of Defense;

(D) the Department of Energy;

(E) the Department of the Interior;

(F) the Department of State;

(G) the Department of Transportation;

(H) the Department of Health and Human Services;

(I) the National Aeronautics and Space Administration;

(J) the Environmental Protection Agency; and

(K) any other agency or office deemed appropriate.

(3) The representative of the National Science Foundation shall serve as the Chairperson of the Interagency Committee.

DUTIES OF THE INTERAGENCY COMMITTEE

SEC. 108. (a) The Interagency Committee shall—

(1) survey Arctic research conducted by Federal, State, and local agencies, universities, and other public and private institutions to help determine priorities for future Arctic research, including natural resources and materials, physical and biological sciences, and social and behavioral sciences;

(2) work with the Commission to develop and establish an integrated national Arctic research policy that will guide Federal agencies in developing and implementing their research programs in the Arctic;

(3) consult with the Commission on—

(A) the development of the national Arctic research policy and the 5-year plan implementing the policy;

(B) Arctic research programs of Federal agencies;

(C) recommendations of the Commission on future Arctic research; and

(D) guidelines for Federal agencies for awarding and administering Arctic research grants;

(4) develop a 5-year plan to implement the national policy, as provided in section 109;

(5) provide the necessary coordination, data, and assistance for the preparation of a single integrated, coherent, and multiagency budget request for Arctic research as provided for in section 110;

(6) facilitate cooperation between the Federal Government and State and local governments in Arctic research, and recommend the undertaking of neglected areas of research in accordance with the findings and purposes of this title;

(7) coordinate and promote cooperative Arctic scientific research programs with other nations, subject to the foreign policy guidance of the Secretary of State;

(8) cooperate with the Governor of the State of Alaska in fulfilling its responsibilities under this title;

(9) promote Federal interagency coordination of all Arctic research activities, including-

(A) logistical planning and coordination; and

(B) the sharing of data and information associated with Arctic research, subject to section 552 of title 5, United States Code; and

(10) provide public notice of its meetings and an opportunity for the public to participate in the development and implementation of national Arctic research policy.

(b) Not later than January 31, 1986, and biennially thereafter, the Interagency Committee shall submit to the Congress through the President, a brief, concise report containing-

(1) a statement of the activities and accomplishments of the Interagency Committee since its last report; and

(2) a statement detailing with particularity the recommendations of the Commission with respect to Federal interagency activities in Arctic research and the disposition and responses to those recommendations.

5-YEAR ARCTIC RESEARCH PLAN

SEC. 109. (a) The Interagency Committee, in consultation with the Commission, the Governor of the State of Alaska, the residents of the Arctic, the private sector, and public interest groups, shall prepare a comprehensive 5-year program plan (hereinafter referred to as the "Plan") for the overall Federal effort in Arctic research. The Plan shall be prepared and submitted to the President for transmittal to the Congress within one year after the enactment of this Act and shall be revised biennially thereafter.

(b) The Plan shall contain but need not be limited to the following elements:

(1) an assessment of national needs and problems regarding the Arctic and the research necessary to address those needs or problems;

(2) a statement of the goals and objectives of the Interagency Committee for national Arctic research;

(3) a detailed listing of all existing Federal programs relating to Arctic research, including the existing goals, funding levels for each of the 5 following fiscal years, and the funds currently being expended to conduct the programs;

(4) recommendations for necessary program changes and other proposals to meet the requirements of the policy and goals as set forth by the Commission and in the Plan as currently in effect; and

(5) a description of the actions taken by the Interagency Committee to coordinate the budget review process in order to ensure interagency coordination and cooperation in (A) carrying out Federal Arctic research programs, and (B) eliminating unnecessary duplication of effort among these programs.

COORDINATION AND REVIEW OF BUDGET REQUESTS

SEC. 110. (a) The Office of Science and Technology Policy shall—

(1) review all agency and department budget requests related to the Arctic transmitted pursuant to section 108(a)(5), in accordance with the national Arctic research policy and the 5-year program under section 108(a)(2) and section 109, respectively; and

(2) consult closely with the Interagency Committee and the Commission to guide the Office of Technology Policy's efforts.

(b)(1) The Office of Management and Budget shall consider all Federal agency requests for research related to the Arctic as one integrated, coherent, and multiagency request, which shall be reviewed by the Office of Management and Budget prior to submission of the President's annual budget request for its adherence to the Plan. The Commission shall, after submission of the President's annual budget request, review the request and report to Congress on adherence to the Plan.

(2) The Office of Management and Budget shall seek to facilitate planning for the design, procurement, maintenance, deployment and operations of icebreakers needed to provide a platform for Arctic research by allocating all funds necessary to support icebreaking operations, except for recurring incremental costs associated with specific projects, to the Coast Guard.

AUTHORIZATION OF APPROPRIATIONS; NEW SPENDING AUTHORITY

SEC. 111. (a) There are authorized to be appropriated such sums as may be necessary for carrying out this title.

(b) Any new spending authority (within the meaning of section 401 of the Congressional Budget Act of 1974) which is provided under this title shall be effective for any fiscal year only to such extent or in such amounts as may be provided in appropriation Acts.

DEFINITION

SEC. 112. As used in this title, the term "Arctic" means all United States and foreign territory north of the Arctic Circle and all United States territory north and west of the boundary formed by the Porcupine, Yukon, and Kuskokwim Rivers; all contiguous seas, including the Arctic Ocean and the Beaufort, Bering and Chukchi Seas; and the Aleutian chain.

Appendix F: Principles for the Conduct of Research in the Arctic

Introduction

All researchers working in the North have an ethical responsibility toward the people of the North, their cultures, and the environment. The following principles have been formulated to provide guidance for researchers in the physical, biological, behavioral, health, economic, political, and social sciences and in the humanities. These principles are to be observed when carrying out or sponsoring research in Arctic and northern regions or when applying the results of this research.

This statement addresses the need to promote mutual respect and communication between scientists and northern residents. Cooperation is needed at all stages of research planning and implementation in projects that directly affect northern people. Cooperation will contribute to a better understanding of the potential benefits of Arctic research for northern residents and will contribute to the development of northern science through traditional knowledge and experience.

These "Principles for the Conduct of Research in the Arctic" were prepared by the Interagency Social Science Task Force in response to a recommendation by the Polar Research Board of the National Academy of Sciences and at the direction of the Interagency Arctic Research Policy Committee. This statement is not intended to replace other existing Federal, State, or professional guidelines, but rather to emphasize their relevance for the whole scientific community. Examples of similar guidelines used by professional organizations and agencies in the United States and in other countries are listed in the publications.

Implementation

All scientific investigations in the Arctic should be assessed in terms of potential human impact and interest. Social science research, particularly studies of human subjects, requires special consideration, as do studies of resources of economic, cultural, and social value to Native people. In all instances, it is the responsibility of the principal investigator on each project to implement the following recommendations:

1. The researcher should inform appropriate community authorities of planned research on lands, waters, or territories used or occupied by them. Research directly involving northern people or communities should not proceed without their clear and informed consent. When informing the community and/or obtaining informed consent, the researcher should identify—
   a. all sponsors and sources of financial support;
   b. the person in charge and all investigators involved in the research, as well as any anticipated need for consultants, guides, or interpreters;
   c. the purposes, goals, and time frame of the research;
   d. data-gathering techniques (tape and video recordings, photographs, physiological measurements, and so on) and the uses to which they will be put; and
   e. foreseeable positive and negative implications and impacts of the research.
2. The duty of researchers to inform communities continues after approval has been obtained. Ongoing projects should be explained in terms understandable to the local community.
3. Researchers should consult with and, where applicable, include northern communities in project planning and implementation. Reasonable opportunities should be provided for the communities to express their interests and to participate in the research.
4. Research results should be explained in nontechnical terms and, where feasible, should be communicated by means of study materials that can be used by local teachers or displays that can be shown in local community centers or museums.
5. Copies of research reports, data descriptions, and other relevant materials should be provided to the local community. Special efforts must be made to communicate results that are responsive to local concerns.
6. Subject to the requirements for anonymity, publications should always refer to the informed consent of participants and give credit to those contributing to the research project.

7. The researcher must respect local cultural traditions, languages, and values. The researcher should, where practicable, incorporate the following elements in the research design:
   a. Use of local and traditional knowledge and experience.
   b. Use of the languages of the local people.
   c. Translation of research results, particularly those of local concern, into the languages of the people affected by the research.
8. When possible, research projects should anticipate and provide meaningful experience and training for young people.
9. In cases where individuals or groups provide information of a confidential nature, their anonymity must be guaranteed in both the original use of data and in its deposition for future use.
10. Research on humans should only be undertaken in a manner that respects their privacy and dignity:
    a. Research subjects must remain anonymous unless they have agreed to be identified. If anonymity cannot be guaranteed, the subjects must be informed of the possible consequences of becoming involved in the research.
    b. In cases where individuals or groups provide information of a confidential or personal nature, this confidentiality must be guaranteed in both the original use of data and in its deposition for future use.
    c. The rights of children must be respected. All research involving children must be fully justified in terms of goals and objectives and never undertaken without the consent of the children and their parents or legal guardians.
    d. Participation of subjects, including the use of photography in research, should always be based on informed consent.
    e. The use and disposition of human tissue samples should always be based on the informed consent of the subjects or next of kin.
11. The researcher is accountable for all project decisions that affect the community, including decisions made by subordinates.
12. All relevant Federal, State, and local regulations and policies pertaining to cultural, environmental, and health protection must be strictly observed.
13. Sacred sites, cultural materials, and cultural property cannot be disturbed or removed without community and/or individual consent and in accordance with Federal and State laws and regulations.

In implementing these principles, researchers may find additional guidance in the publications listed below. In addition, a number of Alaska Native and municipal organizations can be contacted for general information, obtaining informed consent, and matters relating to research proposals and coordination with Native and local interests. A separate list is available from NSF's Office of Polar Programs.

Publications

Arctic Social Science: An Agenda for Action. National Academy of Sciences, Washington, D.C., 1989.

Draft Principles for an Arctic Policy. Inuit Circumpolar Conference, Kotzebue, 1986.

Ethics. Social Sciences and Humanities Research Council of Canada, Ottawa, 1977.

Nordic Statement of Principles and Priorities in Arctic Research. Center for Arctic Cultural Research, Umea, Sweden, 1989.

Policy on Research Ethics. Alaska Department of Fish and Game, Juneau, 1984.

Principles of Professional Responsibility. Council of the American Anthropological Association, Washington, D.C., 1971, rev. 1989.

The Ethical Principles for the Conduct of Research in the North. The Canadian Universities for Northern Studies, Ottawa, 1982.

The National Arctic Health Science Policy. American Public Health Association, Washington, D.C., 1984.

Protocol for Centers for Disease Control/Indian Health Service Serum Bank. Prepared by Arctic Investigations Program (CDC) and Alaska Area Native Health Service, 1990. (Available through Alaska Area Native Health Service, 255 Gambell Street, Anchorage, AK 99501.)

Indian Health Manual. Indian Health Service, U.S. Public Health Service, Rockville, Maryland, 1987.

Human Experimentation. Code of Ethics of the World Medical Association (Declaration of Helsinki). Published in *British Medical Journal,* 2:177, 1964.

Protection of Human Subjects. Code of Federal Regulations 45 CFR 46, 1974, rev. 1983.

Appendix G: Acknowledgments

The following acknowledges the principal individuals responsible for this revision of the U. S. Arctic Research Plan.

The principal Federal agency contributors to this revision of the U.S. Arctic Research Plan were Charles E. Myers, Head, Interagency Arctic Staff, Office of Polar Programs, National Science Foundation; Sarah Brandel and Hale VanKoughnett, Department of State; CAPT Frank Garcia, Jr., Steven King, and David Cate, Department of Defense; Richard Cline, U.S. Forest Service; William Fitzhugh, Smithsonian Institution; James Devine, U.S. Geological Survey; John Calder and Tom Murray, National Oceanic and Atmospheric Administration; Merrill Heit, Department of Energy; Waleed Abdalati, National Aeronautics and Space Administration; Suzanne Marcy, Environmental Protection Agency; Jon Berkson and CDR George Dupree, U.S. Coast Guard; Philip S. Chen, Jr., National Institutes of Health, and Alan Parkinson, Centers for Disease Control and Prevention, Department of Health and Human Services; and John Haugh, Bureau of Land Management, Department of the Interior.

Section 2.2 was prepared in part by George L. Hunt, Jr., University of California, Irvine, and Suzanne Marcy, U.S. Environmental Protection Agency, and is based in part on the report of a workshop held in Laguna Beach, California, in September 2002 convened by George L. Hunt. Other workshop participants were Richard Beamish, Fisheries and Oceans Canada, Pacific Biological Station; Ken Drinkwater, Fisheries and Oceans Canada, Bedford Institute of Oceanography; Mikhail Vladimirovich Flint, P.P.Shirshov Institute of Oceanology, Russian Academy of Sciences; Jackie Grebmeier, Department of Ecology and Evolutionary Biology, University of Tennessee; Roger Harris, Plymouth Marine Laboratory, United Kingdom; George L. Hunt, Jr., Department of Ecology and Evolutionary Biology, University of California, Irvine; Nina Karnovsky, Department of Ecology and Evolutionary Biology, University of California, Irvine; Harald Loeng, Havforskningsinstituttet/ Institute of Marine Research, Norway; James Morison, Polar Science Center, Applied Physics Lab, University of Washington; Jeff Napp, Alaska Fisheries Science Center, National Oceanic and Atmospheric Administration; Brenda L. Norcross, Institute of Marine Science, University of Alaska Fairbanks; Geir Ottersen, Department of Biology, University of Norway; Clarence Pautzke, North Pacific Research Board; Naonobu Shiga, Marine Biodiversity Laboratory, Hokkaido University; Phyllis Stabeno, Pacific Marine Environmental Laboratory, National Oceanic and Atmospheric Administration; and Neil Swanberg, Office of Polar Programs, National Science Foundation.

Consistent with the provisions of the Arctic Research and Policy Act of 1984, as amended (15 U.S.C. 4108(a)), the President sent this eighth biennial revision (2004-2008) to the United States Arctic Research Plan to the Congress on May 20, 2004. The announcement is available at http://www.whitehouse.gov/news/releases/2004/05/20040520-17.html.

Report of Meeting

Interagency Arctic Research Policy Committee

Committee Members and Agency Representatives Present: Rita Colwell (Chair), Karl Erb, Charles E. Myers, Thomas Pyle, and Neil Swanberg, National Science Foundation; George Newton (ARC Chair) and Garrett Brass, Arctic Research Commission; Dennis Conlon, CAPT Frank Garcia, Jr., and Douglas Lamb, Department of Defense; Merrill Heit and Bernard Zak, Department of Energy; Peter Hartsock, Department of Health and Human Services; James Tate, Department of the Interior; James Devine, DOI, U.S. Geological Survey; John Haugh, DOI, Bureau of Land Management; Sarah K. Brandel, Margaret F. Hayes, and Hale Vankoughnett, Department of State; Jon Berkson and CDR Joseph Bodenstedt, Department of Transportation, U.S. Coast Guard; Suzanne Marcy (via phone), Joel Scheraga, and Lowell Smith, Environmental Protection Agency; Waleed Abdalati and Jack Kaye, National Aeronautics and Space Administration; Ronald Baird and John Calder, National Oceanic and Atmospheric Administration; William Fitzhugh, Smithsonian Institution; Richard Cline, Department of Agriculture; George Hunt, University of California–Irvine, Presenter.

17th Meeting: July 8, 2002

Dr. Rita Colwell, IARPC Chair and Director of the National Science Foundation, convened the meeting at the National Science Foundation in Arlington, Virginia.

Review of U.S. Arctic Policy/Arctic Council

Dr. Colwell called on Sarah Brandel, Department of State, to discuss Arctic Council activities during the past year. Ms. Brandel reminded the committee that the eight Arctic countries formed the Arctic Council in 1996. The Council now has five working groups:

- Arctic Monitoring and Assessment Program (AMAP);
- Conservation of Arctic Flora and Fauna (CAFF);
- Emergency Prevention, Preparedness, and Response (EPRP);
- Protection of the Arctic Marine Environment (PAME); and
- Sustainable Development Working Group (SDWG).

Finland is the chair of the Arctic Council for 2000–2002 and Iceland will chair the Council in 2002–2004. Ms. Brandel discussed U.S. leadership in council activities:

- NOAA/NSF are co-funding an Arctic Climate Impact Assessment (ACIA). This program will evaluate and synthesize knowledge on climate change, climate variability, and increased ultraviolet radiation and their consequences on the Arctic environment.
- NOAA chairs the PAME working group looking at land-based sources of pollutants in the Arctic.
- The Department of Interior, Fish and Wildlife Service contributed to the new publication *Flora and Fauna in the Arctic*.
- EPA was the lead author for the AMAP Phase II Heavy Metals chapter.
- The Centers for Disease Control (CDC) is working to build a circumpolar network of public health centers and laboratories. The NIH National Library of Medicine is developing a health database for the Arctic and expects to link it with similar sites in other member states of the Arctic Council.
- The State of Alaska has helped with several of these initiatives, including telemedicine and ecotourism.

Ms. Brandel thanked the agencies for their active roles that help the U.S. maintain leadership in the Arctic Council.

Margaret Hayes, Director of the Office of Oceans, State Department, provided some context for international issues. The U.S. continues to have problems gaining approval for vessels to visit the Russian Exclusive Economic Zone (EEZ) to conduct scientific research. This has hindered the development of other types of scientific partnerships. Russia has also submitted a claim that the Russian continental shelf extends beyond the 200-mile EEZ area. The U.S. has questioned the scientific basis for this claim.

Comments from the Arctic Research Commission

George Newton, Arctic Research Commission (ARC), provided an update on Commission accomplishments. Every two years the Commission publishes the *Report on Goals and Objectives for Arctic Research* and recommends major research policies, projects, and priorities to the President, Congress, and IARPC. A draft of the 2003 report will be provided to IARPC.

Major projects to be recommended include:

- The SEARCH program on Arctic climate change;
- A Comprehensive Study of the Bearing Sea Region, which goes beyond climate change to include the ecosystem, the fate of endangered species, the effect of various management regimes on fish stocks, and the economic and social effects of ecosystem changes on the region's inhabitants and other factors;
- A Coordinated and Comprehensive Study of Arctic Health, focusing on two areas: the

major causes of sickness and death, and health impacts of contaminants.
- Research on Permafrost and on Predicting the Changes in Permafrost Terrains. Roads, bridges, airfields, pipelines, and buildings are subject to the impacts of permafrost. As the climate changes, it will be essential to predict changes in permafrost terrains and develop techniques to cope with these changes.

Mr. Newton noted the Commission's concern about the decline in support for high-latitude research at the Office of Naval Research. The program has had a reduction in funding of over 90% in the last decade. The long-term requirement for a Navy presence in the Arctic is likely to expand, and with a reduction in research activities, there will be a reduced knowledge base for decision-making.

Bering Sea Science Research Priorities

Science Review. Dr. George Hunt, University of California–Irvine, discussed Research Priorities for the Bering Sea: Information for Understanding and Managing Resources in a Time of Global Change.

The Bering Sea area is an important region for research. The Bering Sea is one of the most productive high-latitude ocean systems.

Dr. Hunt shared data on changes in various fish populations, comparing the South and North Bering Sea. Changes in the sea include higher temperatures and declines in Steller's sea lion, fur seal, and bird populations. Other changes include a dramatic increase in the number of jellyfish.

Dr. Hunt suggested several priorities for Bering Sea Research:
- A program on biocomplexity in the Bering Sea that will study the linkages between physical drivers and the complex food web;
- A study of how climate variability affects the Bering Sea; and
- An investigation of the sources and fates of contaminants in the Bering Sea.

Action Item. Dr. Colwell requested that the group review a proposed action item to approve the following resolution:

> *RESOLVED, that the Interagency Arctic Research Policy Committee authorizes the staff to review and analyze the various existing Bering Sea plans, workshops, and programs and recommend to IARPC appropriate steps to achieve a coordinated interagency plan for Bering Sea Research; and to develop budget proposals for Bering Sea Research in response to the coordinated interagency plan.*

In discussion it was noted that there is a need for long-term measurement programs (10-, 15-, 20-, and 100-year measurements) and for process studies. The Bering Sea Working Group has proposed an integrated assessment for a sustainable Bering Sea, and international collaboration is required. Several successful collaborative efforts are in place with Japan and Russia.

The Committee approved the resolution, and Dr. Colwell directed the IARPC staff to develop a plan for Bering Sea research to be included in the next revision of the U.S. Arctic Research Plan.

Report from Study of Environmental Arctic Change (SEARCH) Working Group

John Calder provided an update on activities of the SEARCH working group since the last meeting:
- Preparation of the SEARCH FY 03 Interagency Implementation Plan;
- Establishment of an International Science Steering Group to further development of the Arctic/Sub-Arctic Ocean Fluxes Program; an Implementation Plan was published in April 2002;
- Sponsorship of a workshop on Atmospheric and Cryospheric Change in the Arctic; the report and recommendations were published in February 2002.
- Development of "Terms of Reference" for the SEARCH Interagency Working Group describing how it will function when it reaches operational status; and
- Addition of members to the SEARCH Science Steering Committee (SSC) to enable planning for the full scope of SEARCH.

Detailed science planning for ecological and social aspects of SEARCH is required in parallel with the existing physical science planning.

The Interagency Working Group will focus on developing an approach for identifying ongoing activities across the agencies that are relevant to SEARCH and for providing first-draft answers to SEARCH science questions. The first SEARCH science symposium could be held in FY 04.

Information Item: Strategic and Policy Implications of an Ice-Diminished Arctic

Lt. Commander Douglas Lamb of the National Ice Center shared findings from the Navy symposium on global- and tactical-scale sea-ice analysis and forecasting. Participants in the symposium included individuals from various branches of the Navy and other Arctic experts.

Lt. Commander Lamb stated that climate change appears to be seriously affecting the Arctic region, and if it results in an ice-diminished Arctic, Navy operations would be affected. The Navy greatly values the efforts of the research community and IARPC. The strategy and policy implications of an ice-diminished Arctic include increased economic activity, increased need for law enforcement, and increased security needs.

The main conclusions from the symposium were:

- A concept of operations for maritime forces in the Arctic will be required, including the types of platforms and weapons systems needed for Arctic operations.
- There is a lack of meteorological prediction capability required for safe naval operations in a rapidly changing polar environment.
- Forward logistics infrastructure is inadequate for extended operations.
- The polar communications and intelligence infrastructure appears to be inadequate.
- There will be an increased reliance on unmanned vehicles.
- Development and funding of Arctic research is required to measure, map, model, monitor, and predict the Arctic environment.
- Future naval capabilities should be evaluated to include technologies relevant to an ice-diminished Arctic.

In concluding, Lt. Commander Lamb stated that the operational implications of extended Arctic operations resulting from increased access to the region are not well known or understood and are not well appreciated outside the oceanographic community.

Mr. Newton added that the ARC has been successful in working with the Navy to declassify data. The National Ice Center has a wealth of information to further identify trends and climate change in the Arctic. Interagency cooperation is a prime focus. Mr. Newton thanked Dr. Colwell and IARPC for helping to raise the issue.

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