1. Introduction

1.1 National Needs, Goals, and Objectives

United States research in the Arctic and this biennial revision are governed by U.S. national policy on the Arctic (announced by the U.S. Department of State), the Declaration on Establishment of the Arctic Council (announced by the U.S. Department of State), research goals and objectives agreed upon by the Interagency Committee, and guidance provided by the Arctic Research Commission.

1.1.1 National Needs and Problems

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 post-Cold-War 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 should be coordinated with the efforts of state and local governments and the private sector. The research should be 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 needs. 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 Alaskan and the 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. Additionally the Department of the Interior reports that there are approximately 160 tcf of undiscovered natural gas in northern Alaska and offshore, which is approximately 30% of the Nation's undiscovered natural gas. Gas hydrate resources of Arctic Alaska have been estimated by the USGS to range from 0 to 119,000 tcf (at 95 and 5% probabilities), with a mean estimate of 32,894 tcf. 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 and peat resources. The U.S. Arctic has been estimated to contain about as much coal as the remainder of the U.S. However, U.S. Arctic coal production will be limited until the energy needs of Alaska grow substantially or the 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 60% of the U.S. zinc output. 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.

Dramatic and unexplained fluctuations have occurred in the catch of groundfish and shellfish and the stocks of marine mammals. There is considerable concern that the walleye pollock population will "crash" as others have in the past. Managing for sustainable yields requires further research. A number of other important fish and non-fish species are declining in North Pacific and Bering Sea coastal systems as well. For example, Pacific salmon runs have been at all-time lows in several major western Alaska watersheds over the past few years. Sea otters in the western Aleutians have declined dramatically. There are concerns that walruses may be experiencing population changes because of shifts in ice distribution. Populations of terrestrial and marine birds exhibiting significant declines include loons; sea ducks such as the threatened Steller's and spectacled eiders, and at-risk species such as black scoter, long-tailed duck, and common eider; seabirds such as red-legged kittiwakes and common murres; and several shorebirds including bristle-thighed curlews and buff-breasted sandpipers. Importantly, for most of these species there is little known about their life history, population dynamics, and habitat requirements, thus complicating the identification of factors that may be limiting their recovery to former levels of abundance. Additionally, Alaska Natives living in many coastal villages near the North Pacific and Bering Sea depend on these species for subsistence. Changes in their distribution and abundance would be devastating to the villages.

The impact on the coastal economy of Alaska and other northwestern U.S. states is magnified by substantial capitalization in vessels, port facilities, and processing plants and related income to a broad sector of the economy. A sustainable, predictable fishery stock is fundamental to the viability of this sector of the U.S. economy. Research on Arctic marine ecosystems is essential for understanding and managing their resources.

1.1.4 Global Change

High latitudes may experience the earliest onset of global warming if a "greenhouse effect" occurs on Earth. Global climate models suggest that the amount of warming may be significantly greater in northern high-latitude regions than in lower latitudes, but the models do not agree on the amount of warming to be expected at high latitudes.

Furthermore, there is growing evidence that the polar regions play a key role in the physical processes responsible for global climate fluctuations and in some circumstances may be a prime agent of such fluctuations. For example, North Atlantic deep water formation may be affected by a delicate balancing in the amount of fresh water that is exported from the Arctic Basin and that flows from the East Greenland Current into the region of deep vertical convection in the North Atlantic. Heat flux through the variable ice cover of the Arctic Ocean may have a profound effect on the surface heat budget and the global climate.

Arctic biological processes can also affect global processes and result in positive feedback on CO_2 increase and warming. It remains unclear whether Arctic ecosystems are functioning as sources or sinks for excess CO_2. For example, a shift in vegetation from tundra to trees could have significant effects on regional climate.

High-latitude warming may disturb the equilibrium of Arctic ice masses and hence global sea levels. Such events are preserved in the geologic record, and polar regions are a natural repository of information about past climatic fluctuations.

The Arctic ozone layer has exhibited significant changes—concentrations are decreasing. These are expected to deepen over the next decade, as atmospheric chlorine and bromine reach high levels because of previous releases. Their causes and implications will continue to be a subject of research. Additional data may shed light on the causes and effects of both catastrophic and evolutionary global change. Arctic research provides a critical component of virtually every science element in the U.S. Global Change Research Program.

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. The effects of environmental change, including climate changes, can have enormous 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 social and economic 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, have been 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.

Recent studies have found that concentrations of carbon dioxide and methane in Arctic haze layers are elevated with respect to background levels. Concentrations of these two gases are correlated, suggesting a common anthropogenic source (fossil fuel combustion) and subsequent transport into the Arctic. Soot carbon has been traced for thousands of kilometers across the Arctic, where it remains suspended in a dry, stable atmosphere. Ozone depletion in the polar vortex has enormous health implications to the people of the entire Northern Hemisphere.

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, which bring bright, dynamic auroral displays and intense ionospheric currents. These induced currents can cause massive network failures in electric power distribution systems and permanent damage to multi-million-dollar equipment in power generation plants.

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 a natural laboratory, 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 in the Arctic and determine their significance;
- 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 are expected to 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 2000–2002 period. The total interagency Arctic expenditure for FY 00 was $242 million; for FY 01 it is $240 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 02. Program descriptions may be assumed to reflect the general direction of agency programs.

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

Agency	*FY 00 Actual*	*FY 01 Actual*	*FY 02 Proposed*
DOD	23.3	20.4	8.6
DOI	43.9	43.9	43.0
NSF	67.5	74.2	76.6
NASA	46.6	34.2	38.5
NOAA	29.7	30.7	32.8
DOE	4.7	4.2	4.0
DHHS	13.8	15.9	16.0
SI	0.5	0.5	0.5
DOT	6.3	10.9	7.9
EPA	0.7	0.7	0.4
DA	4.8	4.9	4.9
DOS	0.0	0.0	0.0
Total	241.9	240.4	233.3

1.3 Interagency Coordination

The Arctic Research and Policy Act (Appendix E) requires cooperation among agencies of the U.S. Government having 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 in implementing recommendations has been made, 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 14, Spring/Summer 2000), 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.

Many interagency agreements and planning and coordinating activities already exist. Coordination with global change programs is an integral part of Arctic program development and implementation. Improved communication at all levels through existing newsletters and journals is encouraged.

1.4 International Cooperation

On October 13, 2000, in Barrow, Alaska, the U.S. Department of State completed its two-year chairmanship of the Arctic Council and handed the gavel to Finland for the 2000–2002 period. 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 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 post-Cold-War 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 in a post-Cold-War world. 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 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, at the Barrow Ministerial meeting, stated that they were interested in taking a more active role in the Council's work. The U.S. welcomed the offer by the United Kingdom to host a preparatory meeting of the Senior Arctic Officials in London prior to the Ministerial meeting in Barrow.

1.4.1 Environmental Protection

The U.S. expanded its international cooperation during the U.S. Chairmanship beyond the scope of the Arctic Environmental Protection Strategy (AEPS).

The United States is fully engaged in the Arctic Council Action Plan to Eliminate Pollution in the Arctic (ACAP). 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 U.S. also supports implementation of other projects to eliminate dioxins and obsolete pesticides from the Arctic.

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 a substantial portion 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 environmen-

tal protection. In 1991 in Rovaniemi, Finland, they reached agreement on 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 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 organics, 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.

Arctic Council Ministers approved the recommendation that the Senior Arctic Officials, under the leadership of the Finnish Chair, review the allocation of environmental work among the four working groups (AMAP, CAFF, PAME, EPPR) to remedy gaps and duplication, if any.

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 Barrow Ministerial meeting in October 2000, Ministers endorsed and adopted the Arctic Council's Sustainable Development Framework Document, which forms a basis for continuing cooperation on sustainable development in the Arctic. The Framework Document, consistent with the Terms of Reference and Iqaluit Ministerial Declaration, identifies sustainable development projects, cooperative activities, and priorities for the Council's consideration.

In 1998, Ministers approved several sustainable development project proposals. In Barrow, Ministers welcomed the work accomplished during the 1998–2000 period. The U.S., with leadership from the Institute for Circumpolar Health Studies at the University of Alaska Anchorage, completed its report on Arctic telemedicine. Alaska's Department of Community and Economic Development has a network of private, nongovernmental, and Arctic Council member states in support of its Arctic ecological and cultural tourism project. Ministers at Barrow approved a project of the Arctic Investigations Program of the U.S. Centers for Disease Control and Prevention (CDC) to establish an integrated infectious disease–International Circumpolar Surveillance (ICS) system through a network of hospital and public health laboratory authorities in the Arctic.

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 U.S. 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 is 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 an important tool 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. 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 and Other Nations

Via the Department of State's Environmental Diplomacy Funds (EDF), the U.S. is supporting international projects that assess pollutants in Russia for the benefit of the entire Arctic region. In FY 00, EDF contributed to an Arctic-Council-led project on Persistent Toxic Substances, Food Security, and Indigenous Peoples of the Russian Far North. The project will establish an air quality monitoring station in the Russian Far East to gather high-quality, comprehensive data on pollutants in the Russian Arctic. This project will also assess local pollution sources that affect the traditional foods of Natives in Russia. In FY 01, EDF will help support the Swedish-led Evaluation of Dioxins and Furans in the Russian Federation. 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 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 for contaminating 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 represent the objectives of Federal agencies, focusing on the period covered by this revision (2002–2006). They are presented in eight major categories, and where common activities exist they are presented as collective activities. Individual agency mission accomplishments were discussed in the Spring/Summer 2000 issue of *Arctic Research of the United States* and will be updated in 2002. 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.