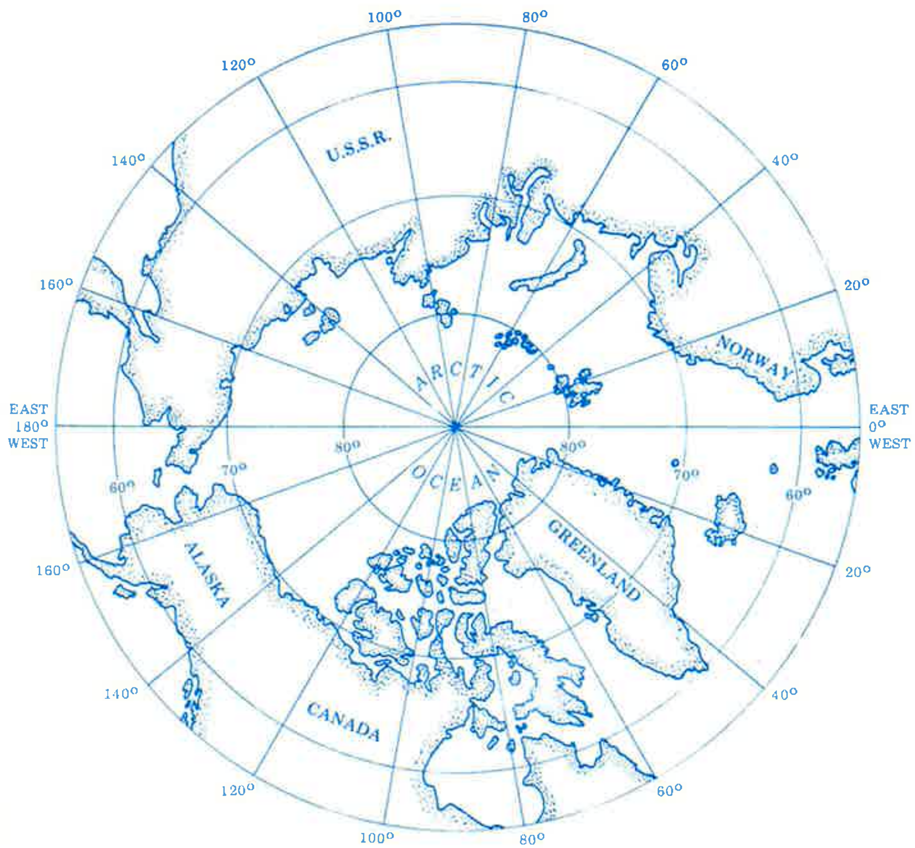
United States Arctic Science Policy



Alaska Council of
Science and Technology
January 1983

United States Arctic Science Policy

by

David M. Hickok
Gunter Weller
T. Neil Davis
Vera Alexander
Robert Elsner

Alaska Council of
Science and Technology

January 1983

Originally published by

Alaska Division, American Association
for the Advancement of Science

February 1981

CONTENTS

UNITED STATES ARCTIC SCIENCE POLICY

INTRODUCTION

During the past 30 years the importance of northern and arctic science has been largely ignored and neglected at a time when this nation has stepped up its use and occupancy of the North in response to growing national resource needs. The critical need now, of course, is to alleviate the nation's energy problems. This imperative, however important, should not and need not be an excuse to run roughshod over proper procedures and good science. In the long run, a well-thought-out and integrated arctic science policy would guarantee the best management and use of the Arctic's diverse resources—natural, strategic, and human.[1] During the past three decades government basically has paid "lip service" to this concept with token and procedural programs in arctic science. Governmental coordination, priority determinations, and sporadic pronouncements concerning arctic science have, in effect, been a farce in every sense. The nation simply cannot afford any longer to be complacent in its approaches to the acquisition of arctic knowledge.

Clearly, the time for a renaissance in arctic science is now. We need a strong and cohesive U.S. arctic science policy to guide national program effort in resource development, international relations, defense, environmental protection, and human health. A coherent U.S. science policy would contribute to the solution of the following national and regional problems which now adversely affect the well-being of the nation.

1. Delays in energy resource development
2. The unhealthy state of the U.S. economy
3. The low status of the United States among nations active in the Arctic
4. Lack of economic infrastructure to more fully utilize North Pacific fisheries resources

5. Lack of appropriate facilities and logistic capabilities to support both science and industrial development in the arctic region
6. Insufficient education and training of enough arctic scientists and technologists to fulfill national needs in the region
7. Conflicts between indigenous peoples and governmental and resource development interests in the Arctic
8. Conflicts between environmental and development interests in the Arctic
9. Critical health, trauma, and morbidity conditions among arctic occupants

In this paper we first review past U.S. efforts to establish arctic science policies designed to promote fulfillment of national needs. Second, we discuss within an arctic context the relationships of science to natural resource development, environmental protection, national defense, understanding climatic change, enhancement of human life and occupancy, and the Arctic as a scientific research laboratory. Finally, we offer the case for legislative action as the essential policy foundation for the development of coherent and comprehensive programs to achieve national objectives in the arctic region.

HISTORICAL PERSPECTIVE

Throughout history, U.S. government policies concerning the Arctic have been reactive to special interests and events. The conduct of U.S. arctic affairs during the past 20 years (1960-1980) is most germane to the need for a forum on arctic affairs today, but earlier history serves to set the stage for more recent events.

Prior to and during the nineteenth century, the federal government provided little policy direction pertinent to activities in the North. Exploitation of resources worldwide was the rule. In this context U.S. interests shared or led the rush to reap the riches of the Arctic—

furs, fisheries, whales, gold, and other minerals.[2] The Arctic was explored in order to more efficiently exploit its economic resources. Scientific inquiry into arctic environments, indigenous peoples, and high-latitude phenomena was incidental. Often during these times, scientific and exploration activities of U.S. organizations, citizens, and government employees received little direct official support and sometimes engendered actual opposition.[3] Westward expansion, or "manifest destiny," was the driving force, and the goals were the economic imperatives of the times. Nevertheless, by the turn of the century, scientific knowledge of the arctic region had greatly increased,[4] and a number of humanistic and progressive economic policies toward indigenous peoples had been adopted.[5]

By the 1920's, there was a further increase in the breadth of arctic scientific inquiry, setting the stage for several major policy-shaping events. Based largely on Ernest Leffingwell's identification of major oil structures on Alaska's Arctic coast, President Warren G. Harding established Naval Petroleum Reserve No. 4 (NPR-4) by executive order in 1923.[6] Eastward, between the Greenland and Barents seas in the Svalbard Archipelago, the United States agreed to the concept of international sharing of offshore resources.[7] Finally, the experiences and writings of one man, Vilhjalmur Stefansson, created an intellectual appreciation for the arctic technologies of indigenous peoples and explained them in the context of Western science. Most importantly, he convinced people throughout the world that the Arctic was not as forbidding as most believed.[8]

As the clouds of World War II gathered, the United States had taken only sporadic and partial actions to develop policies dealing with resource exploration in the North and the equitable relations with arctic Native peoples. Little thought was given to defense strategy in the Arctic and sub-Arctic, to the sociopolitical and cultural values of Native people, to transportation and communication in and over the arctic lands and waters and, of course, to pertinent environmental protection as we know it today.

During the post-World War II era of the late 1940's and the decade of the 1950's,[9] diverse agencies did develop piecemeal policies on many of these subjects, but they lacked cohesion. During this period three sets of events gave impetus to U.S. arctic science activity. These were (1) the exploration of NPR-4 from 1946 to 1953, the concurrent establishment of the Naval Arctic Research Laboratory (NARL) at Pt. Barrow, Alaska, plus the development of the Air Force Research and Development Command's Project 572, Distant Early Warning (DEW) line; (2) the 1957 International Geophysical Year (IGY) program; and (3) commitment of the U.S. Indian Health Service to eliminate or reduce the incidence of tuberculosis and environmentally associated disease in the populations of Alaska Natives.[10]

Exploration of NPR-4 focused on geological investigation of the Alaskan Arctic and laid the foundation of knowledge necessary for the later (1968) discovery of oil at Prudhoe Bay.[11] Activities in the biological fields at NARL developed understandings of the tundra vegetation, physiology of arctic animals, and the life history of northern fishes. Meanwhile, the doctors and biologists of the Indian Health Service and the Arctic Health Research Center of the Public Health Service conducted investigations and research on a broad array of endemic disease, environmental health, and genetic problems, thereby effectively reducing disease and mortality among indigenous peoples.[12] In the physical sciences, high-latitude atmospheric phenomena became better understood,[13] forming the foundations for improved arctic communication and air transport. Oceanographers began systematic inquiry into arctic seas, and meteorologists pursued studies of the arctic climatic regime and its global effects.[14] All of these activities resulted in the development of a small cadre of skilled and dedicated arctic scientists and the foundation of knowledge necessary to understand and live and work in the arctic environment.

The decade of the 1960's was one of great change in the Arctic itself and in national events affecting U.S. interests in the North. Nationally, the 1960's brought an awareness of scientific deficiencies, particularly within the scientific community and the Congress of the United States. As a result, increased attention was given to environmental, ocean, and space sciences. Congress passed numerous laws to elevate the national posture and awareness in these areas of concern.[15] Several studies, reports, and actions within the executive branch, particularly emanating from the President's Science Advisory Council and the Office of Science and Technology, complemented the congressional sense of urgency about these topics of national importance.[16]

In Alaska the disastrous 1964 earthquake brought about an economic and societal recovery effort which greatly enhanced Alaska's well-being. Following that event, Alaska began to contribute to the national economy instead of, as before, being almost completely dependent upon federal largess. The economic development brought about by postearthquake recovery and oil industry exploration (based on earlier NPR-4 investigations) culminated in the 1968 discovery of the nation's largest oil field on the arctic coast at Prudhoe Bay.[17] These events placed new demands on arctic science and technology. The few existing scientists with experience in arctic environments—permafrost construction, the dynamics of coastal ice forces, fisheries and wildlife, soils and vegetation—were in great demand by both industry and government. They participated and directed a new thrust in arctic science and technology applied to natural resource recovery, improved arctic communities, and transportation and communication development. Suddenly arctic science had new reason for being, even though many with foresight had seen the imperatives years earlier.

In the vanguard were Alaska's then-Senator E.L. "Bob" Bartlett and Joseph Fitzgerald, Chairman of the unique Federal Field Committee for Development Planning in Alaska.[18] Senator Bartlett served on the Appropriations Committee of the U.S. Senate. In that role he often compared U.S. funding of the antarctic research program with national allocations to arctic science. Bartlett reasoned that U.S. arctic interests, involving potential natural resource developments and the lives and conditions of the region's peoples, deserved at the very least the same national attention as those in Antarctica, albeit the national interests in the two polar regions were based on different rationales.[19]

Bartlett and Fitzgerald decided to do something about this disparity. Bartlett commissioned the Legislative Reference Service of the Library of Congress to prepare a report on the scope of U.S. arctic research,[20] and he requested that Fitzgerald implement a process to develop arctic policy within the federal executive branch. Chairman Fitzgerald prepared an initial broad statement of U.S. arctic policy and initiated discussions in 1965 with the heads of departments and agencies in Washington, D.C. Although this policy statement contained economic and societal elements, particularly involving indigenous people, it dealt strongly with the need for the conduct of coherent arctic scientific programs in all disciplines prerequisite to exploration for natural resources, their production and delivery, and environmental understanding of the arctic region generally.

The scientific content of the policy statement brought about a continued dialogue between the Federal Field Committee and the National Science Foundation. Ultimately, after diverse efforts, a U.S. policy statement was agreed to by all agencies concerned and forwarded to President Johnson in 1968. President Johnson did not act on the statement prior to leaving office, however.

Although the effort to secure a presidential pronouncement of U.S. arctic policy failed in 1968, the Interagency Arctic Research Coordinating Committee (IARCC) was established that year at the request of the Department of State in agreement with the Office of Science and Technology and the Federal Council for Science and Technology (FCST). Later, in 1972, it was

reconstituted as an interagency committee of the FCST, and the National Science Foundation was given a lead role. The primary purpose of the IARCC was to insure sound and rational development of arctic research through effective coordination of federal research programs and available logistic resources to support those programs and through the development of mutually beneficial cooperative research projects in the Arctic between the United States and other nations. Unfortunately, the record of IARCC from 1968 to its termination on June 30, 1978 turned out to be but a relatively ineffective shadow of the substance desired by Bartlett and Fitzgerald. The reason was simple—there was no overall policy guidance within which the committee could operate.[21]

At about this same time during 1968 and 1969, other events brought new focus to arctic science. The Congress was preparing new legislation, later to be entitled The National Environmental Policy Act (NEPA). Within the executive branch the National Oceanographic Program was being implemented through the provision of the Marine Resources and Engineering Development Act of 1966. In Alaska, economic recovery from the 1964 earthquake was taking form and substance despite a minor national recession in 1967. The big news came in the fall of 1968. The nation's largest oil field had been discovered on the arctic coast at Prudhoe Bay, Alaska.[22] Finally, too, after two years of study and analysis the Federal Field Committee's reports to the Congress on needs and means to resolve the aboriginal land claims of Alaska Natives was receiving greater attention.[23] Collectively, these events interacted and came into even sharper focus and interdependency as the problems presented by proposed construction of the trans-Alaska pipeline and tanker traffic from Alaska's ice-free Prince William Sound port of Valdez to the conterminous states became evident.

The problems of massive arctic marine, air, and terrestrial logistics, made even more apparent this nation's serious dearth of knowledgeable individuals experienced in arctic environments. Pipeline construction was a particular case in point. The pipeline plans originally conceived by industry engineers and presented to the U.S. Senate Committee on Interior and Insular Affairs in May 1969 called for a buried pipeline throughout its entire length except for 12 miles. The naivete of these plans was quickly pointed out by scientists from the U.S. Geological Survey, Cold Regions Research and Engineering Laboratory of the U.S. Army Corps of Engineers, and the University of Alaska, but they were largely ignored during the initial excitement. The December 1969 passage of NEPA added a new dimension. The pipeline project became the first major test of the new act. A broad public process and dialogue took place in the development of environmental impact assessments.[24] Significant scientific input was required regarding pipeline construction under arctic permafrost conditions and immediate and long-term effects of pipeline construction and operation on fish and wildlife resources, vegetation, erosion, and other natural surface values as well as the structural integrity of the pipeline itself. Many of these studies continue today.[25]

Governor Walter Hickel was pushing on the Alaska political front for increased development of arctic Alaska. He created the North Commission, which had explicit arctic mineral development and transportation objectives. Then, learning of the initiatives of Federal Field Committee Chairman Fitzgerald in arctic policy, Hickel brought these needs to the Republican convention of 1968, and for the first time U.S. arctic interests were incorporated in a major political platform. Later, in October 1969, Hickel, newly appointed Secretary of the Interior in the Nixon administration, convened the "Skyline Conference" (so called due to its convenance at Skyline in Shenandoah National Park). The major objective of the conference was to define the role that the federal government should take towards insuring a balance between exploitation of arctic resources and the protection of the land and the people of the North. But Secretary Hickel soon left the Nixon administration, and arctic interests were again stymied. One last surfacing came

about in the third report of the President to the Congress on marine resources and engineering development in *Marine Science Affairs—A Year of Broadened Participation, 1969*.[26] In this report parts of the earlier Federal Field Committee statements were combined with IARCC and National Council on Marine Resources and Engineering Development contributions to set forth a recommendation for a national arctic policy. Eleven years later this statement remains the clearest expression of U.S. arctic objectives.

Finally, in 1971, Under Secretary of State Irwin forwarded a renewed statement of U.S. arctic policy to the president for consideration, but efforts to give direction to U.S. arctic science failed again. All official government dialogue on the subject was effectively quelled by National Security Decision Memorandum 144 of the National Security Council on December 22, 1971.[27] This memorandum called for an Interagency Arctic Policy Group to be established and for "the development of a coordinated plan for scientific research in and on the Arctic . . ." There is no record that the policy group ever met, and although IARCC prepared its *Five-Year Coordinated Plan for Arctic Research*,[28] this report had many acknowledged deficiencies and could hardly be considered to meet the mandate of NSC Memorandum 144.

In 1972 there was yet another attempt to influence the course of arctic science direction by examining the potential environmental effects on the development of Alaska's North Slope. Under the aegis of the National Academy of Science, an *ad hoc* planning group under the leadership of Dr. Walter O. Roberts, then director of the National Center for Atmospheric Research, brought together and published recommendations in the fields of arctic science and technology.[29] Again, this effort did not produce any significant results.

Effectively, by 1972, after eight years of activity emanating from several governmental, political, economic, and scientific sources, efforts to develop coherent U.S. arctic policy were dead. But resource development and social change in Alaska, and indeed across the entire circumpolar Arctic, were increasing in both scope and speed. Government responded with many disparate, piecemeal program endeavors. The efforts given to an analysis of Alaska Native land claims between 1966 and 1971 gave added impetus to programs of research and investigations in the health sciences and housing, water supply, and waste treatment technologies relative to indigenous peoples and their communities.[30] A number of new laws also emerged, governing fish and wildlife resources, including rare and endangered species and marine mammals. These activated new investigations on arctic flora and fauna, particularly where conflicts with resource developments were perceived.[31]

Three major arctic science programs, each portending a semblance of scientific coordination, began in or near Alaska in 1970. The Alaska Sea Grant Program undertook a number of research efforts in arctic marine and coastal resources and environments. The Tundra Biome Program, sponsored by the National Science Foundation, was launched to render new understandings of tundra ecosystems through interdisciplinary study[32] as part of the U.S. participation in the International Biological Program. The Arctic Ice Dynamics Joint Experiments involved study of ice movements, forces, and effects in the Arctic Basin.[33] A fourth program, the Greenland Ice Sheet Project, collected paleoclimatic data from deep bore holes in the Greenland ice sheet. Despite their potential interrelationships, very little interprogram coordination took place in the Alaska-sited programs. Disturbed by this fact and concerned by the obviously unmet needs for coordinated new directions in arctic science, the Alaska Sea Grant Program and the National Science Foundation in 1974 sponsored a workshop to help develop a new "Arctic Offshore Program."[34] The program was to be a new major initiative of the NSF, and its formulation recognized the "lead agency" role in arctic science assigned to NSF by executive order.

As program and funding plans were being developed for this coordinated effort, the U.S. Department of Interior, Bureau of Land Management (BLM) entered into agreement with the National Oceanographic and Atmospheric Administration (NOAA) for the assessment of outer continental shelf (OCS) environs prerequisite to the BLM's leasing of the OCS for oil and gas. Major components of the resulting Outer Continental Shelf Environmental Assessment Program (OCSEAP) were studies in the Gulf of Alaska, Bering Sea, and the Beaufort and Chukchi basins. Appropriation levels were high enough so that a large program effort developed, utilizing much of the nation's northern and arctic scientific capability within universities and federal and state agencies. As OCSEAP progressed, criticism of the scientific direction of the program surfaced both within and outside government. The BLM and NOAA often disagreed on program directions, and research results were generally poorly synthesized with existing OCSEAP and other research programs' results. Often, too, as a particular research component neared completion and a satisfactory contribution to man's knowledge made, funds would be shifted to another investigation before the nearly completed work reached an acceptable scientific conclusion.

This kind of "crash" research program, at great public cost, epitomizes current governmental science efforts. They may appear to meet agency procedural and legal requirements, but they contribute little to environmental understandings of articulated objectives or increasing knowledge. Unfortunately, there are other examples in government of "science" for procedural or mission support purposes. Studies of the environment of the National Petroleum Reserve in Alaska (NPRA), mandated by the Naval Petroleum Reserves Production Act of 1976 (P.L. 94-258), were very costly and added little to existing environmental knowledge except in structural geology pertinent to oil and gas resources. In this case the gathering and republication of existing knowledge and the education of government personnel were the essential products of NPRA studies rather than any substantial new information regarding surface resources and environments of the arctic coastal plain, arctic foothills, and Brooks Range of Alaska.

With the passing of the 1970's the general inefficiencies of arctic science programs and the great wastes in money, manpower, and materials in relationship to the advancement of man's arctic knowledge became increasingly apparent. The history of U.S. arctic science over the past 20 to 30 years offers a montage of good, bad, and indifferent science performed at many scales but generally at high cost in relation to results.[35] Duplication of effort, replication of earlier work, poor knowledge synthesis, lack of direction to identify and fill gaps in knowledge, and "crash" research programs motivated by agency procedural requirements characterize these efforts. The result of lack of policy direction and program coordination is even more serious than wasted manpower and dollars because the ability of the United States to meet broader economic, societal, and national security purposes is also directly affected.

Importantly, this lack of foresight and concern about arctic matters in the United States is also clearly recognized by other nations. Dr. Tore Gjelsvik, director of the Norwegian Polar Institute in Oslo, wrote recently:

> In contrast to Antarctica, the international scientific cooperation in the Arctic is rather poorly developed and organized. On the national level, arctic science is differently developed. The Soviet-Russian organization and institutes charged with exploration and scientific studies are larger than the biggest in the west, and they carry out a large and systematic study of not only the Soviet arctic coasts and islands, but over the whole central arctic. The Soviet arctic technology is well developed, and the transportation system—consisting of powerful ice-

> breakers and aircraft—is superior to that of the west. The Arctic and Antarctic Institute of Leningrad is the central polar organization, but in addition, many specialized agencies or institutes have been established. More than 20,000 scientists must be involved in arctic studies on the Soviet side.
>
> In the biggest arctic nations in the west, their polar research, although increasing in size and quality, is rather poorly coordinated. Neither USA nor Canada has established a central organization for arctic science. This also makes international cooperation and coordination difficult. Arctic science in the west has grown considerably since the discovery of oil and gas in the American Arctic but is still lagging behind the Soviet one. If the gap is not bridged, or at least diminished, there is a danger of unwanted consequences of future political and legal arrangements within the central Arctic.[36]

Dr. Gjelsvik concluded by urging the Western governments to increase funds for arctic science and to coordinate their efforts on an international level. We heartily concur.

THE RELATIONSHIP OF U.S. SCIENCE POLICY TO NATIONAL NEEDS AND OBJECTIVES IN THE ARCTIC

Arctic Issues and Their Importance

The arctic science community is besieged by a wide range of demands to provide information and solve problems, both real and perceived, for a host of national interest programs. In today's world the economics of northern resource development occupy the center stage of arctic events. In part this reflects the discovery of immense oil and natural gas deposits in the region and technological advances that make their development feasible, but it also emphasizes man's seemingly insatiable appetite for energy, the depletion or uncertainty of customary sources of supply, and the sharp upsurge in international price levels for petroleum. The most apparent problems involve natural resource exploration, extraction, and transportation and the resolution of legal challenges on a number of environmental-developmental conflict fronts, including those with traditional resource use by indigenous people. Others, such as cold weather medicine for both military and civilian use, advanced work in space, atmospheric and submarine communications, climatic change, and the development of new ship and aircraft technology, serve to illustrate the broad reliance on science and technology to deliver the answers that can help satisfy national needs in the Arctic.

In view of these trends, it seems as if arctic resource development should be proceeding much more rapidly than it is, particularly in the energy-starved and inflation-beleagured United States. Although many barriers to arctic development for the United States have fallen, several problems and constraints remain. On the one hand, world economics are more favorable, aboriginal claims are settled in Alaska, a framework for the political resolution of Alaska land status has been achieved, and regulatory reform is under way. On the other hand, the scientific and industrial communities in many cases lack the site-specific information base to apply existing workable technologies. In other cases there is lack of basic knowledge prerequisite to the design of new and acceptable developmental approaches. Additional constraints and issues spring from an increased awareness and concern over the impact large-scale developments may have on sensitive arctic natural systems and upon indigenous peoples and the resources and environments they depend upon.

So far, energy resource exploitation has been directly connected with developed and developing fields in areas where territorial sovereignty is generally recognized by all governments concerned. Thus, little political dispute of a jurisdictional nature has resulted. Some political and legal uncertainty nevertheless exists as to the offshore extent of coastal state jurisdiction over the arctic seabed and superjacent waters, an area believed to contain immense hydrocarbon reserves. Agreement is lacking on the delimitation of continental shelf boundaries between several adjacent nations and on the scope of coastal state rights to regulate shipping and other activities beyond territorial waters. For example, in the Svalbard area the situation is made more difficult by a lack of agreement over access to the mineral resources of the continental shelf, and just north of St. Lawrence Island between the USSR and the United States a triangular no-man's land exists under the present law of the sea.

This lack of jurisdictional resolution has strategic as well as political and economic implications inasmuch as the vital energy resources have added to the strategic relevance of the Arctic. The possibility of arctic tanker traffic, the advent of the nuclear-powered submarine, and the massive buildup of the Soviet fleet along the Barents Sea have enhanced the importance of the Arctic Ocean as a transit area. The situation is particularly sensitive with regard to the entrance to the Barents Sea, where the Soviets might view offshore petroleum development as a restriction to the free passage of their northern fleet. The extension in 1977 of 200-mile economic zones to all arctic coastal waters also opens new possibilities for disagreement, especially should the coastal states expand their substantive jurisdiction within their claimed zones.

To be able to exploit arctic resources, legally, economically, and in an environmentally acceptable fashion; to conduct military operations in the area; and to represent its interests in the Arctic intelligently and from an informed basis, the United States must have a substantial and well-coordinated scientific research program in the Arctic. Such a program does not presently exist, neither does a coherent policy on arctic research nor any priority sense of purpose. Consequently, the United States has only very limited arctic scientific and technological expertise and capability. Only a strong, stable, long-term science effort can supply the answers needed now and to train a generation of future arctic scientists.

Natural Resources

Worldwide demand for energy, food fiber, and other materials grows continuously in response to increasing numbers of consumptive markets. Particularly acute demand exists for such resources as oil and gas, strategic and critical minerals, and fisheries. The use and management of other resources, such as marine mammals, terrestrial wildlife, birds, and water, are also affected by the extraction and exploitation of the resources of primary interest.

OIL AND GAS

In every sense the U.S. requirement for oil is the most acute national need to be partially met from arctic regions. U.S. need for this resource is so pervasive that it is beyond comprehension that the nation has not already marshaled its wealth and know-how—scientific and otherwise—to assure rapid delivery of petroleum. The Central Intelligence Agency recently reported that total oil supplies available to the Western industrial countries (over the next few years) are unlikely to increase significantly and may well fall.[37] Further, according to the General Accounting Office, the United States has experienced a net decline in domestic petroleum output since 1970, and it is estimated that domestic production will fall from 10.1 million barrels per day in 1978 to 8.0 in 1990, remain level through about 1995, then increase to about 8.5 million barrels per day by 2000, "*depending largely on how the Alaska dilemma is resolved.*"[38] (Emphasis added by authors.)

Just what is the Alaska dilemma; or, more precisely, what is the arctic dilemma? We know that it is in arctic Alaska and Canada and their offshore waters that the greatest potential for significant increase in U.S. and North American oil production exists. Development of arctic petroleum resources will undoubtedly occur, partly because these resources appear to be huge and partly because of uncertainties in the customary Middle East

supplies and sharp increase in price levels. What, then, is holding us back? Some additional background will facilitate understanding.

During the last decade major oil and gas deposits have been discovered along the northern fringes of Alaska, Canada, and the Soviet Union. Exploitation of several of these land areas is under way (including Alaska's Prudhoe Bay, the largest oil field in North America), but the development of new offshore areas will require huge new investments and further advances in technology. The Prudhoe Bay field presently produces close to 1.5 million barrels of oil per day, or nearly 20 percent of total U.S. production. Importantly, the U.S. Geological Survey estimates that, added to already proven reserves, Alaska's recoverable totals are from 22 to 59 billion barrels of oil and 61 to 164 trillion cubic feet of gas. Offshore areas appear more promising for both oil and gas than do land areas, and offshore development in the Beaufort Sea has begun. In addition, planning for petroleum development by both industry and government is well under way for basins within the Chukchi and Bering seas. Canadian oil and gas reserves are concentrated in two main basins—the Mackenzie Delta/Beaufort Sea near Alaska and the Sverdrup Basin within its high-arctic island geography. More than half of the reserves in both areas is believed to lie offshore. (Development of these basins already portends territorial and environmental conflict with U.S. interests from proposed transportation systems using ice-breaking tankers. Elsewhere in the Arctic, near Greenland and Svalbard, exploration that also has potential effects on U.S. interests is proceeding.)

The dilemma is created by the fact that we do not currently have the knowledge and technical capability, regardless of industrial capital expenditure or escalated lease sale schedules, to solve many necessary exploration, production, and delivery problems immediately. Sustained commitments from both government and industry would have to be made in scientific investigation and training if the information necessary for design of arctic oil production and delivery systems and related environmental protection are to be forthcoming. This must be achieved before serious decline of U.S. domestic oil and gas production a decade hence.

The Alaska Natural Gas Transportation System is an excellent onshore case in point. Despite years of planning, scientific and technological research has just begun to attempt to answer several questions pertinent to the burying of a cold gas pipeline in certain permafrost soils, in soils subject to differential frost heave, and under particular conditions of groundwater movement. Obviously, this lack of knowledge has a tremendous effect on design, costs, and security factors necessary to complete planning and construction of this project.

Offshore, exploration and future production facility design in all basins north of the Aleutians is severely hampered by lack of data on ice characteristics and dynamics, information on currents and sediment transport, knowledge of the occurrence of subsea permafrost, and data on superstructure icing and storm occurrence. Operating offshore drill rigs in the ice-covered waters of the Arctic in a safe and environmentally acceptable fashion is difficult and costly. The numerous natural hazards in the Arctic, particularly sea ice, make a cautious approach, in which technologies and environmental procedures are continually being tested and improved, mandatory. Petroleum companies operating on arctic continental shelves have found accurate forecasting of sea ice behavior to be indispensable. The normal hazards of offshore drilling are magnified many times by the wide variations in weather and ice conditions. Pipelines from drilling platforms to shore are subject to rupture by the scouring action of massive pressure ridges and ice islands, and enormous forces can build up on the drilling platforms as the moving ice piles up against it. Without such information the construction of offshore, year-round production facilities is impossible.[39]

Another problem related to offshore operations in all basins under current statute is that many voids currently

exist in baseline biological data needed for impact assessment to fisheries and to marine mammals and bird life, several species of which are classified as rare or endangered. Without these data, particularly beyond nearshore environs, offshore production operations may be legally unacceptable. Equally important, production operations would create major economic and political conflicts with national and international fisheries interests.

Presumably, production of nearshore and offshore petroleum resources would follow the present exploration phase. This would bring a flurry of new activities and problems, particularly those related to transport. Both pipelines and shipping, including ice-breaking oil and LNG tankers, would be used to transport the oil and gas to markets. Sea ice conditions present serious hazards to shipping. Forecasting of ice occurrence and movement are prerequisite to expanded shipping in the Arctic.

The ideal situation is for needed technological and environmental research to precede development. In reality, development not only often drives the pace of research, it races ahead of it. Recognizing this mismatch and concerned with the requirements of frontier area leasing schedules, the Alaska Oil and Gas Association, an industry consortium of major companies active in Alaska petroleum development, drew up in 1974 a list of research priorities, which has been refined in succeeding years. The association's perception of critical data gaps for the next decade is that they increase in number and severity from the nearshore ice to the offshore pack ice zone. They include such conditions or occurrences as ice movement during freezeup, winter ice movement, summer pack ice invasions, presence and movement of multiyear floes and ridges, grounded ridges and icebergs, and ice gouging of the ocean floor. Permafrost under the sea, waves, storm surges, and superstructure icing are additional hazards. The association's recommendations received wide distribution within the federal government, but due to fiscal constraints only limited program response has resulted.

Similarly, a 1973 U.S. Maritime Administration timetable for development of arctic shipping technology, developed in concert with U.S. shipbuilders, has fallen at least five years behind schedule. Arctic shipping is feasible, as has been demonstrated by the Soviet Union along its heavily used Northern Sea Route and by one of its ice breakers reaching the North Pole as well as by the voyage of the supertanker *Manhattan* through the Northwest Passage. What is needed is a real-time forecasting system that matches Soviet practices.

Equally important is protection of the arctic environment and subsistence life-styles of the indigenous people. Abundant biological resources, including fish, birds, seals, walrus, whales, and polar bears, are potentially threatened by petroleum development and related activities. In turn, their decline could mean the demise of an entire human culture. The adequacy of information to fully consider the broad effects of petroleum development off the Alaskan arctic coast has already been successfully challenged in U.S. courts on procedural grounds. It is important to realize that most of these data needs are also essential to facility design and operation. Without a committed and planned research program by both industry and government and a strong policy direction, these scientific and technological gaps could not be filled, even if all other economic, political, regulatory, and societal barriers were overcome.

COAL AND STRATEGIC AND CRITICAL MINERALS

The arctic circumpolar region holds tremendous stores of useful minerals, ranging from gemstones to fertilizers. Mining development in the Arctic, however, is more costly than in other regions and is often feasible only when transportation, energy, and manpower requirements of extraction can be economically mèt. As the United States is increasingly denied access to world mineral resources elsewhere and as transportation and energy availability in the Arctic improve with increased petroleum development, the prospects of mineral extraction in the region will also improve.

Although Alaska contains vast coal reserves and numerous occurrences of strategic and critical metals,[40] only a few currently appear to be economically competitive in the world market. They are:

1. A group of mineral prospects for zinc, lead, and silver near the headwaters of the Wulik River north of Noatak known as Lik, Southeast of Lik, Red Dog, and South Red Dog
2. A group of copper prospects in association with silver, lead, zinc, and antimony in the Ambler-Bornite area northeast of the village of Kobuk on the Kobuk River (There is another nearby prospect known as Picnic Creek near the headwaters of the Kobuk River, but this does not appear economically viable at present.)
3. Deposits of coking-quality coal along the Kukpowruk River, east of Cape Beaufort and south of Pt. Lay village
4. The Beluga coal fields north of Cook Inlet
5. The currently operational Nenana coal fields
6. The molybdenum prospect known as Quartz Hill at the head of Boca de Quadra Arm in southeastern Alaska
7. A major nickel prospect located at Brady Glacier in the Glacier Bay National Monument[41]

Even given rising economic potential and the lessening of political, land tenure, and regulatory barriers to development, the lack of environmental knowledge and impact predictability, particularly in areas of continuous and discontinuous permafrost and high groundwater content, complicate development. Nearly all of these prospects would require water diversion for development, and the likely impacts of these diversions, with their associated sediment and chemical waste problems, should be evaluated now. Coordinated geological-geophysical studies are needed on the geologic history of Alaska. This history is only beginning to emerge and should be expected to provide a firm background of thinking about the state's mineral resources in the future. Geological mapping should be conducted, particularly in areas of suspected mineralization or in areas which will aid in basic understanding of the geological development of the Alaska region. To date, detailed mapping of only 7% of the state has been completed.

Other arctic nations are presently more active in mineral exploration in their northern lands than is the United States. The Soviet Union extracts far greater quantities of arctic mineral resources than any other country. Deposits of national importance include nickel, copper, platinum, apatite, tin, diamonds, gold, and coking coal. Although mining within permafrost regions is extremely costly, the government of the USSR is willing to develop these areas to gain greater mineral self-sufficiency and to achieve sociopolitical objectives. Mineral production in other arctic areas includes iron ore in northern Sweden, coal on Svalbard, lead-zinc in Greenland, and lead, zinc, asbestos, copper, and other minerals in northern Canada. The overall mineral potential of the Arctic is very great.

If the development of metallic and coal prospects of Alaska is in the national interest for energy, defense, and production purposes, and presumably it is, then policies furthering scientific and technological investigation are prerequisite to progress. To delay these undertakings greatly affects production design and adds unnecessary cost to the capitalization of these developments.

FISHERIES

Arctic seas contain some of the world's oldest and richest commercial fishing grounds. In contrast with the rich upwelling regions associated with important fisheries in other parts of the world's oceans, where fish populations can be related more or less directly to the influx of nutrients and plankton production, in northern high-latitude waters the mechanism for sustaining high yields appears to be local high plankton production associated with oceanic frontal structures and a short food chain. An example of this is a series of fronts on the southeast Bering Sea shelf near the shelf break. Here, the highly productive fishery is associated with locally enhanced primary production and a short pelagic food chain. Additionally, local mixing at the Aleutian passes produces local maxima in planktonic growth. On shallower regions of the shelf, much of the phytoplankton production is not grazed in the water column but drifts to the bottom, where it sustains a different food chain involving shellfish and some marine mammals, especially walrus. The retreating ice edge has a major influence over shallow shelf regions in spring. As it melts, a strong zone of water column stability and frontal structure results, creating a burst of plant growth (algae) under the ice. In turn, this plant life supports an abundant food chain.

Of the arctic catch areas, the Bering Sea and the Aleutians are most important with a five-year average (1971-75) of more than 2 million metric tons. Next are the Barents Sea (1.6 million mt), Norwegian Sea (1.1 million mt), Iceland (1.1 million mt), Svalbard (0.4 million mt), and Greenland (0.2 million mt). The percentage of total arctic catch taken by various nations is: Iceland, 93%; Norway, 64%; Federal Republic of Germany, 35%; United Kingdom, 26%; Japan, 16%; USSR, 15%. In the Bering Sea and the Aleutians (the area of greatest immediate interest and concern to the United States) Japan and the Soviet Union catch most of the fish. The U.S. catch, expressed as a percentage of the total five-year catch, is negligible.

A new era of fisheries management began in October 1975, when Iceland extended its exclusive coastal fishing zone to 200 miles. Every other arctic nation has since done the same. All arctic fishing grounds are now under some form of national management. Each nation has sole authority within its fishing zone to determine how much fish may be taken and by whom. For the United States to effectively control and regulate fish catches in the huge areas of the Bering Sea and along the Aleutians, it must have proper scientific information. Since the United States presently has a minimal presence of fish-catching vessels in the area, other means of obtaining the needed information are necessary. Long-term research and monitoring of the fish resources must be part of such efforts.

International consumer demand for marine fish and shellfish from North Pacific (including Bering Sea) waters is increasing. The rate of increase, however, is not equal among the various fishery products available. Two types of fishery products, in terms of the historic U.S. harvest interest, are of concern. First, there are the traditionally sought after species, such as salmon, crab, halibut, herring, and shrimp; and second, there are those species which have been under- or unutilized by the U.S. domestic fleet, such as Pacific Ocean perch, Alaska pollock, sablefish, Pacific cod, and many other rockfish and flatfish species (collectively called groundfish).

American consumer demand for traditionally sought species is comparatively stable. These species have been fished by U.S. fishermen for long periods of time and are generally harvested at maximum sustainable yield levels. If demand for species in this group increased, supply would still be governed by biological limitations. Domestic demand is increasing for under- and unutilized species, but, so far, the U.S. harvest is much less than the quantity of resources available. As of late 1979, U.S. fishermen were expected to take 45,000 metric tons of the 374,750 metric tons considered the optimum yield of these species of the Gulf of Alaska.[42] The remainder of the resources would be allocated to foreign vessels or not be harvested. When additional markets are found for domestically caught groundfish and economic constraints are lifted, these species could be harvested at much higher levels if research needs, some of which are listed below, were met.

1. Research to support better management of the traditionally sought fish species through increased understanding of population dynamics, life history, and migration habitat utilization.

2. Economic research for the underutilized groundfishery, which could help solve labor, marketing, fishery capitilization, and other related problems. These economic constraints to full domestic entry into the fishery must be overcome if U.S. fishermen are to fully participate. Economic constraints are, perhaps, much more important than the multitude of other groundfish research needs, such as in the areas of life history, migration, stock size, and general utilization.
3. Research from the fishery and marine ecosystem viewpoints on the physical and biological conflicts inherent in the advent of Bering Sea oil and gas production and transportation. While these research needs are most important in the large overview sense of national economic and political concerns, timely and practical resolution of many ocean use conflicts are bound to arise in the next two decades, particularly between oil and gas development and biotic resources. Resolution would require a comprehensive and holistic knowledge of North Pacific and Bering Sea marine systems—both physical and biological.

The Arctic also contains millions of marine mammals, including walrus, whales, and 10 species of seal. Commercial exploitation of marine mammals in the past has put considerable pressure on the arctic ecosystem. Within 30 years of discovery, the sea cow of the western Bering Sea was annihilated; and the North Atlantic walrus and the Pacific fur seal and gray and bowhead whale populations nearly suffered the same fate. Through international cooperation, the situation has been arrested and in some instances reversed: the fur seal population has returned to a size capable of supporting a viable industry, and the gray whale population has returned to near its original size; the walrus population has greatly increased and bowhead populations are stable.

To protect all arctic mammals from suffering unacceptable reductions and possible extinction, a great deal more must be known about the ecosystem in which they function, their food habits, and their natural fluctuations in population as well as those induced by man. This is not an esoteric exercise in arctic science, but one on which depends, among other things, the pace and extent of future petroleum developments in the Arctic. A reminder of the importance of such investigations is the fact that neglect of research on bowhead whales has led to court action resulting in delays in offshore oil and gas development and embarrassing legal complications for the United States, both domestically (Native subsistence whaling) and internationally (IWC bowhead hunting quotas).

Environmental Protection

Despite urgent energy concerns, people throughout the world share a global responsibility to uphold environmental quality and improve it wherever possible. Tradeoffs may be necessary between meeting national priority needs which may cause environmental degradation on the one hand and the maintenance of relatively undisturbed natural ecosystems on the other. The best way to intelligently evaluate these tradeoffs is to possess sufficient knowledge to make informed judgments. Physical and biological change in the environment induced by natural forces (e.g., earthquakes, volcanism, storms, electromagnetic disturbances, and rapid fluctuations in specific animal populations) will go on without the intervention of human reasoning. Man-induced environmental change, however, offers the opportunity to apply logic. This is the shared responsibility of humankind; to shirk it is to violate the global ethic of environmental concern. It simply must be done, not merely given lip service and procedural attention. We have this obligation to today's world community and to future generations as well.

Much concern has been expressed about the need to protect the sensitive ecosystems, both terrestrial and

marine, in the Arctic. Nowhere have the conflicting goals of development and environmental interests clashed more directly than in Alaska, which has been labelled the "nation's storehouse of energy" while at the same time is called the "nation's last wilderness." Conflicts like this most often surface as polarization occurs over such issues as the trans-Alaska oil pipeline and offshore oil leasing in the Beaufort Sea. Yet many people who have been involved in these matters over the years believe that a unique opportunity exists for protecting the arctic environment while simultaneously extracting minerals and petroleum.

Arctic biological systems can be thought of as tough since they have adapted themselves to a climate at the cold margin of tolerance for life, but because they are on this margin, they are highly sensitive to disturbances. When such disturbances take place, the links in the food chain are broken and rapidly replaced by new ones. This results in the "boom-and-bust" biological community that is often described as fragile. The description is valid for small areas and relatively short time frames, but over a wide area and longer time frame, i.e., given several decades to recover from a disruptive event, these ecosystems probably have quite strong survival powers—unless the disturbance is widespread and severe.

The northern part of Alaska is a semiaquatic environment with a large proportion of the surface covered by standing waters. These waters are poorly buffered and subject to impact by pollutants. We must be especially concerned about the extremely serious problems which other northern countries are having with the impact of acid rain on their fresh waters. Even more disturbing is the recent finding that high levels of sulphur dioxide are found throughout the Arctic in the winter. The source is apparently the industrial regions of northern Europe. When this material accumulates in the snow and enters the spring runoff, deleterious effects can be expected before long.

The potential for oil pollution in arctic seas is also of great concern. Spills of crude oil, for example, could constitute a large disturbance. Oil takes 20 to 50 times longer to degrade at 5°C than 25°C and could remain toxic even longer if spilled under sea ice. Major oil spills in arctic waters could have a devastating effect on populations of waterfowl, sea and shore birds, marine mammals, and polar bears. Many of these species regularly concentrate in large numbers in open leads in the pack ice or in lagoons and nearshore locations where they would be highly vulnerable to oil that was either spilled at or carried by currents to these areas. It is clear that there is a basic lack of knowledge of potential pollution sources, pollutant pathways, and various effects of petroleum on biota, including cumulative effects along the food chain in ice-covered waters. Little is known about the likely transport paths and rates of pollution by ice. No adequate cleanup technology exists. Other effects of petroleum development such as noise, displacement of biota, and destruction of habitat are also important. U.S. courts have made it clear that lack of consideration of these factors may be perceived as inadequacies in environmental analysis. This has led to delays and restrictions in offshore petroleum development, which may continue until legally adequate environmental information, as mandated by the Marine Mammal Protection Act, the National Environmental Policy Act, and other legislation, is available.

The foregoing discussion has emphasized problems in the physical and biological natural environment, but there is another set of disciplines with which we must be concerned. These seek understanding of the societal and cultural impacts of environmental change (both physical and biological) on indigenous peoples as well as newcomers to the North. These impacts may be economic, structural in societal terms, and biological in nature as they affect human physiological conditions. Just as there are interactive relationships between physical and biological change in the natural environment, there is also a complex web of interaction in the sphere of human activity and well-being.

Climate Change

If environmental protection in the context of industrial development transcends national boundaries, climatic change due to man's interference does so even more. The Arctic and Antarctic are sensitive indicators as well as regulators of worldwide climatic change, each having long-term temperature fluctuations considerably greater than those of the hemisphere as a whole. The large masses of ice also respond dramatically to any temperature change. Throughout geological history the poles have mostly been either frozen or unfrozen, with only brief transitional periods between. Consequently, the polar regions are not only indicators of change but also seem to function as climatic controls that can cause abrupt (in geological time) reversals of climatic conditions.

Past climatic cycles can be deduced from a variety of phenomena, including pollen records, variations in sea level, deposits of ancient windblown dust, and from cores drilled in present ice sheets. By analyzing such data it is possible to conclude that parts of the Northern Hemisphere, now hot and dry, were at one time cool and humid; that areas now desert were once covered with ice; and that the Arctic—from which continental glaciers have periodically penetrated the heart of North America, Europe, and western Siberia—formerly supported stands of temperate and subtropical vegetation. Paleoclimatic data indicate that there have been at least three major glacial epochs in the history of the world. The most recent of these, the Pleistocene, extends back over the past million years or so, a period characterized by numerous ice ages with advances and retreats of continental ice sheets in the Northern Hemisphere.

Analysis of current trends has led some scientists to speculate that a new "mini ice age" may be in the offing. Others, noting particularly man's ever-increasing energy use and the resulting additions of carbon dioxide to the atmosphere, foresee a gradual warming trend as a result of what is called the "greenhouse effect" of atmospheric modification. That change of some kind will occur is not debated. Periods of benign climate such as that of the past 8,000 to 10,000 years are unusual, having prevailed only 8% of the time during the last 700,000 years.

No matter which group of scientists proves to be correct, the rather precarious balance of world agriculture and human habitation obviously will be upset. The world's glaciers are particularly responsive to climatic change. They cover an area equal to about 10% of the Earth's surface, down from 26% during the last glacial advance. Should temperatures rise and eventually melt the ice they now contain, the water released would raise the level of the world's oceans by about 76 meters. A sustained decline in temperature on the other hand, even of only a few degrees, could trigger yet another glacial advance.

It is apparent that research must be conducted to predict these eventual climatic changes, if possible. Such research should monitor the output of pollutants, their eventual fate, and effects on the atmosphere and the ice in the Arctic. The first step in determining the latter is to monitor the extent of sea ice, snow, glaciers, and ice sheets in the Arctic and sub-Arctic and the corresponding changes in sea level and atmospheric and oceanic circulation. Such an effort would require a sophisticated system of satellite, aircraft, and surface measurements and the cooperation of at least all nations in the Northern Hemisphere, if not the world. Although such cooperation is feasible and has some precedents in such programs as the World Weather Watch in tropical regions, it is far from becoming a reality in the Arctic. U.S. policy in the Arctic must be directed toward achieving cooperation in this vital area of concern which is common to all nations on Earth.

Defense

The stategic importance of the Arctic derives in part from its central position between the North American and Eurasian continents and the fact that it contains important economic resources and military bases. The northernmost

tip of Canada, for example, is closer to Murmansk on a great circle route (2,500 km) than it is to Ottawa (4,000 km). Furthermore, a future global war may be fought with missiles or spacecraft passing through the polar ionosphere, which has important properties that are highly variable and mainly governed by wide varations in the solar-terrestrial relationship. Numerous radar sites have been built along both the North American and USSR sides of the Arctic Ocean to provide early warning against aircraft and missile attack. The arctic seas are of particular interest to the Soviet Union as they provide the shortest marine routes linking the extremes of the USSR and afford the Soviet northern naval fleet and its large oceangoing fishing fleet year-round access to the North Atlantic from home ports on the Kola Peninsula.

Various jurisdictional problems in the Arctic also have strategic as well as political and economic implications. There is disagreement, for example, about the extent of coastal state jurisdiction over the arctic seas and on Norway's claim to exclusive control of the resources of Svalbard's continental shelf. Controversy also marks the effort to establish a Norwegian-Soviet continental shelf boundary in the Barents Sea, and the continental shelf boundary between Canada and Alaska has not yet been agreed upon. The possibility of arctic tanker traffic, the advent of the nuclear-powered submarine, and the massive buildup of the USSR fleet along the Barents Sea have enhanced the importance of the Arctic Ocean as transit areas, particularly to the USSR and to such an extent that some observers have begun to refer to the Arctic Ocean as a "Soviet lake." The Soviet Union's scientific effort in the Arctic Ocean and along margins exceeds the combined efforts of all the other littoral countries.

Recognition of the special problems that auroral-related phenomena of the arctic region create for military communications dawned during the Lend-Lease Program of World War II. Aircraft being transferred from the United States to the Soviet Union encountered severe communication difficulties over Alaska and its environs. It soon became evident that standard long-distance communication techniques and vehicle tracking could not be used in polar regions. Additionally, the technological advances of more recent times that have allowed both military and civilian usage of the stratosphere, upper atmosphere, and the near-Earth reaches of space beyond have generated other problems specific to operations in the polar regions. Of particular concern for military purposes are the difficulties that aurora-related phenomena create for missile tracking, the potential for confusion between natural auroral phenomena and nuclear explosions, and the potential impacts that electric fields and high-altitude winds associated with natural auroral phenomena can have upon the dispersion of materials released by explosions in the polar and high-latitude atmospheres.

These potential effects relate to the fact that polar regions are where the interaction between the Earth's magnetosphere, the ionosphere, and the neutral atmosphere is most intense, owing to the dipolar configuration of the Earth's magnetic field. At times, intense fluxes of charged particles stream into the high-latitude ionosphere to create visible auroras and severe changes in the ionosphere. Strong electric fields and intense currents accompany the precipitation of particles into the polar atmosphere.

The National Academy of Sciences recently emphasized the importance of studying these interrelated phenomena, stating, "The important closed chain of cause and effect relationships involving magnetic field-aligned currents, electric fields, the ionosphere and magnetosphere plasmas, and atmospheric winds must be understood quantitatively and self-consistently.[43]

To facilitate research, these phenomena are best observed from satellites above them, the Earth's surface below them, and from ballons and rockets travelling within the regions where they occur. The Arctic has been the principal locale for such studies over the past three decades. This work has been pursued with the support of both military and civilian agencies. Support was strong during

the early post-Sputnik era but has declined dangerously in recent years.

Many defense concerns involving science and technology in the Arctic are classified. Nevertheless, there is common knowledge of much of this research and development despite the government's secrecy. In many cases such classification is doubtlessly spurious—imposing limitations on the acquisition of knowledge—nonstrategic, yet critical—for arctic activities and furtherance of scientific understanding. Such limitations decrease the potential value of research undertakings directly involved with military weapons systems and the detection of similar activities of other states. Much of it could, without any security risk, come out of the "military closet." For example, research in the transmission of sound in arctic waters conducted for submarine deployment purpose has potential application to the avoidance of conflict between offshore oil and gas development and the conservation and management of marine mammals, particularly endangered whales. The deployment of submarine detection electronics in the Bering Strait (a practice that is common knowledge to the Alaskan civilian community) also has possible application to oil and gas development and the acquisition of marine mammal knowledge. On other scientific fronts, knowledge about the subsurface structure of sea ice as measured from submarines has extremely valuable application to surface oil and LNG tanker and ice-breaker design and operation, development of shipping routes and spill cleanup technology, and positioning of offshore arctic facilities.

Aside from those areas requiring comprehension of polar atmospheric phenomena, physical oceanographic parameters of arctic water temperature and density variability, ice structure and dynamics, current movement, and sediment transport for both military and civilan purposes, there are at least two other areas of defense research, investigation, and training needed to alleviate U.S. military deficiencies in the Arctic. These are:

1. Knowledge of local ice, current, wind, and weather conditions essential to the deployment

of forces in coastal environments from the Aleutians to the high-arctic islands, Greenland, and Svalbard. Apart from a very few scientists and resource experts, local Natives, and a few units of the Alaska National Guard, Eskimo Scouts, we suspect that there is virtually no knowledge within the military sphere to conduct arctic amphibious or coastal troop activities.

2. Cold regions medicine, especially for military but also for other purposes, is woefully inadequate. The needs for preventative medicine techniques as well as treatment procedures for frostbite, hypothermia, mental disorientation, and trauma from cold and darkness are acute and are not receiving needed attention. Also, the treatment of physical impairments to the human body under cold conditions is an area of deficiency in medicine and surgery. Though it can be argued in this era of global military systems that this knowledge is of no real military significance, the trend toward geographically limited conflicts could prove disastrous to U.S. interest if the allocation of arctic resources escalated from an issue to combat. Examples of similar situations erupting into warfare are common. It may be debatable as to whether or not intimate local knowledge of arctic conditions and military medical procedures under situations of cold and darkness will ever be needed. That they could be, added to the other imperatives for the more routine development of arctic resources and the human occupancy of arctic environments, should create even more incentive to develop and act upon a set of U.S. arctic science priorities.

Human Life and Occupancy

If the Arctic is to be occupied and its resources utilized by the peoples of the North and by the world community, it is essential that an understanding of impacts upon and between individuals and groups, often possessing different value systems, be reached. Man is part of the arctic "ecosystem" and environment, which is sparsely settled by descendants of peoples who probably left central Asia thousands of years ago in pursuit of animals that followed retreating ice sheets northward. Highly inventive and adaptable, these people have developed needed technologies and adopted beneficial methods or tools from other cultures. This adaptive process will doubtless go on as long as man resides in the North. Historically, the Lapp's forebearers penetrated Scandinavia and the Kola Peninsula, and many diverse groups peopled the vast lands eastward of the Chukotskiy Peninsula. Ancestors of the Indians crossed the Bering Strait or went along the Aleutian Islands chain to North America. Eskimos were later arrivals. Ranging from Siberia to Greenland, Eskimos are close enough in language to understand one another. Today, their union is also political, and their cultural and environmental concerns have been brought into focus in two Inuit Circumpolar Conferences, at Barrow, Alaska in 1977 and at Nuuk, Greenland in 1980. All Eskimo groups except those of the Soviet Union were represented.

These diverse peoples met the Arctic's harsh environment and limited food and other resources with a common response in the use of snowshoes, clothes of reindeer or caribou skins, and similar homes, hunting techniques, and social organizations. The ingenious design of the Eskimo kayak and the toggle harpoon are examples of early technological innovation for arctic conditions. Since the time of Western contact, the Eskimo has continued to adopt new technologies which enhance his livelihood, while still maintaining distinct cultural and societal values and physiological needs.

Now the indigenous peoples of the Arctic, from Greenland across Canada to Alaska, are involved with national economics and politics through their participation in northern resource developments and land management. Nevertheless, all of these circumpolar peoples maintain cultural, societal, and, indeed, often imperative nutritional ties to the environment and its renewable biotic resources. Whenever new resource developments threaten their cultural and societal values, whether they are directly benefiting in an economic sense or not, they have thus far defended their priority values. In the past, however, whether in Noril'sk, Nome, Kiruna, or Yellowknife, industry that has brought new life to polar areas has largely bypassed indigenous arctic peoples in favor of immigrant labor. In North America this is no longer the case except in highly technical or management jobs, due in large part to Native economic and political involvement. Even here, greater participation is increasing rapidly through educational and training opportunities. While technological change has been adopted by northern peoples in many ways, e.g., in communications, home appliances, and hunting and fishing equipment, other items are either unacceptable or too costly. We see this today in the introduction of temperate-latitude housing, woefully inefficient in the North, and the imposition of unworkable and costly water and sewer systems.

The proper application of technology is, of course, important to the human condition in the Arctic. Well-insulated and -ventilated housing is basic to health, as are safe water supplies and sanitary disposal systems. There are, moreover, several health-specific problems associated with populations in northern latitudes. For example, Alaska has the nation's highest death rate due to alcoholism, accidents, and violence. Its citizens are uniquely exposed to hazards of cold injury and hypothermia, both at work and at play. Rapid sociocultural change is having major impacts not only on behavior, but also in such fields as nutrition, physical fitness, and the incidence of degenerative disorders of Western Civilization. An important

exemplary area is that of dental health, with massive tooth decay linked to dietary change in children in Native communities.

Alaska also has unique problems and solutions in the delivery of health care to areas of low population density. Alaska industrial development is likely to involve very large projects in extremely difficult climates. The field of arctic industrial medicine is important to the economy of the state as well as the welfare of its citizens. Health problems and accident patterns of workers on the trans-Alaska pipeline construction project should have been carefully documented for guidance in future undertakings. This opportunity was missed entirely, despite the likelihood that this information would benefit major projects to follow. Such projects invariably depend on imported labor in arrangements favoring minimum numbers of employees working at maximum productivity. In practice, this typically results in nonadapted personnel working 84 to 100 hours per week in remarkable cold, in extended periods of darkness or daylight, wearing cumbersome clothing under hazardous conditions, and operating heavy equipment designed for temperate climates. Off-duty hours entail stresses related to family separation, sleep cycle disturbance, and confinement.

Because the number of arctic residents has been insufficient to command national priorities, the health effects of arctic environmental factors have been little studied. For example, there have been no studies of seasonal variations in the incidence of ulcer, depression, and other disorders, which appear to be real on anecodotal grounds. The importance of these problems is illustrated by an event involving the inappropriate opening of a single small valve on the trans-Alaska pipeline resulting in a fire which destroyed a pump station, reducing pipeline capacity by 20% for more than a year.

Research is proceeding in Alaska and throughout the circumpolar Arctic on such subjects as the behavioral aspects of death, cold injury and hypothermia, nutrition, health impacts of air pollution, intoxication behavior, temperature regulation, significant disease patterns, and health delivery mechanisms. Such research, however, is often done by single individuals and, in view of the prospects of increasing arctic populations, is woefully inadequate to meet needs in the immediate future. Areas of important research include the following priorties:

1. Alcoholism and behavioral disorders; implications for individual clients, their children, families, and communities
2. Cold injury and hypothermia, clinical management, domestic, recreational, and industrial risk situations and groups
3. Basic studies of environmental influences on human well-being, including thermal stress, extreme annual variation in light and darkness, and influence of longer wave electromagnetic radiation at high altitudes
4. Personal behavior and biologic health, including nutrition and physical fitness; implications for dental disease, cardiovascular, and malignant disease
5. Arctic industrial medicine; patterns of illness and accidents, biologic effects of long work hours in stressful environments; community impact on alcoholism, venereal disease, and mental health
6. Chemical hazards in Alaska; chronic exposure to arsenic in well water, carbon monoxide in polluted air, mercury in river water, and other chemical hazards[44]

These research needs, like others discussed here, are currently conducted without the benefit of any formal coordination and structure, although informal contact within the governmental, academic, and private medical health science community has been fairly impressive. Nevertheless, a more directed focus will be necessary if the health requirements of growing northern populations are

to be protected and the productive capacities of man living and working under arctic conditions are to be enhanced.

In summary, the Arctic can be a "friendly" and healthy environment, but specific needs must be met, leading to an understanding of the best means of living and occupying the North, of cultural and societal values that differ from Western society, and of physiological and mental adaptation. Through such knowledge, we may bring to the Arctic new dimensions of economic prosperity to be enjoyed by peoples of good physical health and mental attitude.

The Arctic as a Scientific Research Laboratory

NATIONAL IMPORTANCE

A number of crucial issues of direct practical consequence to the nation have been identified above. Within a wider framework, more fundamental scientific problems are also of national importance, since numerous major benefits to mankind have been derived as a result of breakthroughs in the fundamental sciences. As has already become obvious in the preceding sections, the Arctic is a gigantic "natural laboratory" of surprising diversity which offers exciting research possibilities in almost every branch of science.

In examining this large-scale natural laboratory, starting in outer space above the Arctic, a number of fascinating features becomes apparent. The field lines of the magnetic field surrounding the Earth converge in the polar regimes. This means that charged particles from the sun enter the Earth's atmosphere in these regions, producing conspicuous effects such as the aurora, magnetic storms and substorms, and ionospheric disturbances which may black out radio communication.

Lower in the atmosphere, the high-velocity westerly jet stream is affected by processes of energy exchange at the Earth's surface in the Arctic—by sea ice distribution and ocean and land temperatures—and in turn affects the weather and climate of the entire hemisphere or even the whole Earth. Major centers where the weather of the Northern Hemisphere is being manufactured are the low pressure areas in the Gulf of Alaska and near Iceland. Drought in the Midwest and freezing temperatures on the East Coast have their origin in the activities of these subpolar centers.

Nowhere else is ice and snow in all its forms—sea ice, glaciers, permafrost, river and lake ice—as widespread and diverse as in the Arctic. Alaska is an ideal laboratory for studying these ice forms, from individual ice crystals under a microscope to the millions of square kilometers of sea ice as seen by a satellite. The solution of practical problems associated with avalanches, building roads and houses on permafrost, extracting petroleum from ice-covered waters, surging glaciers, icebergs threatening shipping lanes, and numerous others depend on fundamental research that can be conducted in the Alaska setting.

Unlike the Southern Hemisphere, a major ocean covers a large area around the pole in the Northern Hemisphere. This ocean is largely ice covered and exhibits a wide range of dynamic behavior of its ice and water masses. Scientific stations have drifted on the ice of the Arctic Ocean to explore its water structure, marine biota, and ocean floor. It has now become the scene of exploration of petroleum, and some of its marginal seas, such as the Bering, continue to be the sources of 10% of the world's fish catches.

Alaska is also part of the Pacific "Rim of Fire," where tectonic activity has created a unique and dangerous environment. Within its boundary, Alaska encloses a long island arc associated with a deep ocean trench, 40 active volcanoes, and heavy earthquake activity. Since from 5 to 7% of the world's potentially most devastating earthquakes occur in Alaska, this is an ideal location for the study of the earth's structure and its often violent surface movements.

The Arctic has a rich fauna and flora which has adapted itself to the harsh conditions of low temperatures and light levels for most of the year. It is the breeding

ground of millions of migrating birds and migrating whales and other animals, some of them rare or endangered species. It also has large numbers of year-round residents, particularly the huge herds of walrus and seals in the ocean and caribou on land. Polar bears and Arctic foxes range widely into the most remote and inhospitable regions of the central Arctic Ocean.

Finally, man has occupied the Arctic for thousands of years and has adapted himself in a unique way to the environment. His customs and technology are of great interest to scientists, as are his problems in adapting to ever-changing outside Western influences. Archaeologists, ethnologists, anthropologists, and other social scientists find Alaska—the bridge for major migrations from Asia to North America—a fascinating area for their studies.

These brief examples illustrate the uniqueness and diversity in structure, dynamics, and behavior of the arctic region as an important part of the whole Earth. Other nations are expending great efforts in the study of the Arctic because they understand that the keys to many of our planet's present and future problems may lie in this region. If the United States is to participate in this process in any meaningful way, it must begin to involve itself in arctic research now.

SCIENTIFIC TRAINING

The intensive study of the arctic environment obviously requires a cadre of trained and experienced scientists and resource specialists. Over the span of the last few decades the demands for polar science from one year to another and the fluctuating funding levels for arctic research have prevented the creation of a body of researchers of sufficient dedication and size to adequately respond to arctic problems. Thus, whenever a problem arises, scientific teams must be created virtually from scratch, and solutions to the problems are unnecessarily delayed. Moreover, when work on a specific task is completed, the teams are allowed to disintegrate. This is not an efficient procedure. It wastes valuable training and experience and squashes professional enthusiasm.

A good example of such an occurrence was the Arctic Ice Dynamics Joint Experiment (AIDJEX), which took place in the Arctic from approximately 1970 to 1978. The experiment arose from the need to study basic and applied aspects of ice dynamics in the Arctic Ocean. AIDJEX was particularly important for developing adequate forecasting of ice conditions, which could be used in the annual Prudhoe Bay barge supply and for future tanker traffic in the Arctic. Also, AIDJEX perhaps was a response to the perceived need to close the arctic research gap with the Russians. The AIDJEX experiment was highly successful. With the sophisticated instrumentation and computer technology available to the U.S. and Canadian researchers, it made a giant stride in catching up with the Russians. However, when it was completed, funding stopped, and the scientific team was allowed to disintegrate—losing almost entirely for the United States its accumulated collective experience. A few years later, new teams had to be assembled to examine similar problems associated with the offshore industrial development of the Arctic. That the originally assembled talent could not be utilized for subsequent tasks emphasizes the absence of foresight, planning, coordination, and long-range interest by the federal government in arctic science.

A number of highly topical and important problems, both pure and applied, are not adequately addressed at present because there are no scientists available to do so, even if funds were available. When an agency in the federal government suddenly discovers the urgent need to obtain data to solve one of these problems, the inevitable and all too familiar crash program results. An example of the federal government's lack of foresight in recognizing the need for long-term research are the outer continental shelf studies of the U.S. Department of the Interior, which examine the possible effects of petroleum exploitation offshore Alaska. Lack of long-term research on bowhead whales has already led to litigation, delays, and loss of revenues and threatens additional delays and possibly severe reductions in offshore oil and gas development in the Arctic and embarrassing legal complications for the United States, both domestically and internationally (International Whaling Commission bowhead hunting quotas).

Similarly, most of the research conducted on Alaska fish resources in the Bering Sea has been done by foreign countries. The consequence is that we do not know as much as we should about the fish resources we allow other nations to exploit. In itself, the fact that one of the United States' most productive resource areas is almost entirely exploited by foreign countries shows a deplorable lack of interest by the United States in arctic and subarctic resources. There are numerous other examples of needed research which are of vital interest to the nation but which are not carried out because the United States does not encourage or support careers in arctic science.

LOGISTICS AND FACILITIES

Logistic and facilities support of arctic science must be directed by national priorities. This was the reason given by the U.S. Navy for closing its arctic research laboratory (NARL) at Pt. Barrow, Alaska. For the purposes of the Navy this seems justified, although it does not remove the need for other logistics and support facilities in the Arctic. The Navy had operated NARL since 1947. During this time the laboratory supported arctic science related to the Navy's mission as well as that of a host of civilian scientists supported by or representing other federal agencies, most prominently, the National Science Foundation, U.S. Geological Survey, and the Cold Regions Research and Engineering Laboratory (CRREL) of the U.S. Army Corps of Engineers. In the mid-1970's the Navy decided that its arctic mission no longer required the expensive ($10 million annually) maintenance of NARL. Recently, the Navy's office of naval research announced NARL's phasedown to caretaker status and its intention to seek closure of the laboratory in 1982 unless a new host agency was found prior to April 30, 1981.

Various study groups in both federal and state government and the University of Alaska have examined this situation with a view towards continuing the lab's operation under different aegis. As of this writing there is no federal agency willing to undertake future NARL management. Similarily the State of Alaska and the University of Alaska do not consider the high maintenance costs justifiable in relationship to their scientific research missions. There seems to be nearly universal agreement that the scope of arctic science has changed so dramatically in the past decade that alternate facilities and bases from the Bering Sea to the Mackenzie River delta and at Fairbanks and Anchorage, Alaska are generally more cost effective and suitable to the pursuit of scientific inquiry. A final determination of NARL's future is mandated by Sec. 1007 of the Alaska National Interest Lands Conservation Act (16 USC 3147). This section instructs the secretaries of the Departments of Interior, Defense, and Energy to initiate and carry out a study to determine the future of the laboratory within an overall context of "redirecting the United States Arctic research policy . . ." The secretaries will then make their recommendations about the future of the single laboratory devoted to U.S. arctic science.

The conduct of science in arctic seas is another story. The American oceanographic community has achieved its prestigious position largely through pioneering efforts and imaginative approaches in the temperate and tropical regions of the world's oceans. Its arctic capabilities and experience are sorely deficient. If national scientific priorities are to be reordered toward arctic interests, we must quickly develop a capability for the conduct of marine science in ice-covered seas.

Our national oceanographic fleet is notably deficient with respect to sea ice capability. U.S. Coast Guard icebreakers primarily are committed to other missions and are generally ill-suited to scientific pursuits. The need for research platforms, capable of operating in seasonal sea ice and in high latitude open oceans, is now widely appreciated within the national oceanography community. Basically, what is required is a long-term, broadly based commitment to arctic marine research in general, which would fully employ an array of new research facilities, including satellite imagery technology, long-range aircraft, submarines, drifting ice stations, and remote sensing. Most importantly, however, arctic scientific research requires economical, ice-strengthened, stable research ships, which to our national disgrace, we now lack.

FRAMEWORK FOR A U.S. ARCTIC SCIENCE COMMITMENT

A Sense of Urgency

U.S. arctic science policy must be more closely linked to national needs, primarily for extractive resources which exist in abundance in the Arctic. Most urgent is the U.S. need for oil and gas from arctic petroleum-bearing structures; second is the need for strategic and critical minerals; and third, food from fisheries. There can be no question that solutions to the "Alaska" or "arctic dilemma" of resource delivery may well be central to the economic survival of the United States in the next 20 to 50 years. The nation must face up to this reality. Already, a decade and a half have been lost due to the limitations placed on arctic science by the events surrounding National Security Council Memorandum 144 and by our increasing dependence as a nation on Middle East and other foreign energy imports. Needed now is a central and comprehensive national dedication to develop and increase the understanding of the Arctic—its people, its resources, its environmental hazards and frailties, and its ecosystem interactions. With these, a new productive future for North American society can be achieved—without it we will probably cease to be an important world society. It is that stark a reality and really that simple.

National attention on arctic problems is increasing. Many new disparate forums and programs are taking shape and substance, even while other programs decline. Certainly significant have been the recent strong resolutions of the Alaska Council on Science and Technology and the American Association for the Advancement of Science in support of strengthened and dedicated approaches to arctic science. Some major planning efforts are under way. The oil and gas industry, in partnership with the Department of Energy through the National Petroleum Council, is currently engaged in a comprehensive study designed to identify and overcome barriers to arctic oil and gas exploration, production, and delivery. In Alaska, hearings are under way before the Alaska Council on Science and Technology to identify gaps in federal programs in arctic science and technology and before the Alaska legislature to determine proper and priority roles for the State of Alaska in the conduct and support of northern science. These activities and their results will surely be communicated to the national level, but it is doubtful that they will have much effect without a national dialogue and subsequent federal commitment to develop a national arctic science policy.

Direction by Legislation

The arctic science community has been talking to itself for years. Dialogue between executive branch interagency committees and publications and reports of the National Academy of Sciences have described the problem but have resolved nothing. The only significant forum for the resolution of national needs is the Congress of the United States. Similarly, the only place to answer state needs is the Alaska legislature.

During the past 20 years or so both the Congress and the Alaska legislature have dealt with three problems specific to Alaska that are highly philosophical as well as political. These problems derive from three major forces in American history, which may now be reaching their climax in Alaska. First, the force of "westward expansion," or "manifest destiny"—the nation reaching the limits of its frontiers—came to an end with the passage of

the Alaska Statehood Act in 1958. Second, national efforts to deal with the rights of the aboriginal people of North America, begun nearly 200 years ago in decisions of Chief Justice Marshall, were consummated with the 1971 passage of the Alaska Native Claims Settlement Act. Third is the force leading to the identification of unique natural resources and environments, now culminating in the dedication of Alaska lands to the national park, national wildlife refuge, national forest, national wild and scenic rivers, and national wilderness preservation systems pursuant to the Alaska National Interest Lands Conservation Act of 1980. Thus, despite the still-existing irritants and impediments of bureaucratic process in the executive branch, the ways are open in Alaska to the fulfillment of those desires and ethics represented by these three forces of economic progress, social and economic justice for Native peoples, and the conservation and preservation of unique northern natural values.

One major problem requiring national commitment for solution remains. We do not have the knowledge necessary to achieve the results towards which these political forces drive toward. Surely the Congress and the Alaska legislature, recognizing the importance of these forces, albeit with some differing views, must now agree that a political recognition of the means for achievement through scientific research and technological innovation is essential. On the international front, too, knowledge is essential to the resolution of law-of-the-sea questions and jurisdictional limitations in the Arctic basin.

Those who support economic progress and the development of resources, the enhancement of human condition, and the comprehension of natural systems in the North must again turn to the Congress for the development of a national commitment to these ends. Such an agenda in the Congress could logically take one of two basic forms. In one approach, through the hearing process, Congress could examine problems and develop appropriate legislation. Another approach involves appropriate hearings in the Congress to focus on specifically introduced legislation designed to achieve a necessary commitment to arctic science. The Alaska Division of the American Association for the Advancement of Science intends to promote one or the other of these legislative approaches in the Congress. Further, both the executive and legislative branches of the State of Alaska are expected to strongly support congressional inquiry and development of solutions.

Recognizing that state and federal legislatures provide the nation's best opportunity to deliver, discuss, and resolve the imperatives presented here, we strongly urge (1) legislation in the Alaska State Legislature that identifies and financially supports priority science programs in Alaska for Alaska and (2) legislation in Congress that identifies national scientific research needs in the Arctic and encourages the pursuit of northern knowledge necessary for natural resource development, national defense, environmental protection, climate change, basic scientific research, and the health and well-being of arctic occupants as well as mechanisms for the timely delivery of such knowledge.

Considerations for Legislation

To adequately deal with the arctic science issue legislatively, the fragmented nature of the current situation should be recognized. We understand the derivation of this fragmentation from the mission assignments of agencies in a host of statutes and executive orders. However, if the Congress recognizes the national problems and challenges set forth in this paper, then it must also realize that for the past 20 years efforts within the executive branch to advance the cause of arctic science, as a prerequisite to natural resource development, improved defense systems, environmental protection, and the enhancement of human life in the Arctic, have all failed. The history of these efforts is clear. Our arctic national objectives simply will not be met by executive branch equivocation. Problems can be identified and solutions mandated only by Congress.

To solve the problems of meeting national energy, mineral, or defense needs from resources within the arctic region, the Congress should recognize that the industry sector possesses certain technological capacities beyond those of government. Equally important is for government, and the science community more generally, to develop understandings of natural processes and the environmental and societal impacts of industrial technology. One way to achieve a directed approach towards arctic resource and defense solutions is to legislatively establish appropriate partnerships between government and industry. Examples of how to achieve such partnerships exist in other spheres of interest (e.g., communication) and in other nations (e.g., Canada). We do not outline here the exact manner of such a partnership, but we strongly advocate that it be forged.

In other areas of arctic science concern, more directed coordination between the Alaska and federal governments is desired. Here again, specific problem-solving mechanisms are possible, and we urge that they be established, particularly in the fields of environmental comprehension and protection, medicine, and health.

Finally, the problem of establishing international accords in the arctic region also requires legislative mandate. The Departments of State and Defense have both exerted their influences within a secretive vacuum which has excluded contribution from the science community, the government of Alaska and the indigenous peoples of the region. In this arena, also, it appears to us to be quite desirable that Alaska's political and societal interests as well as the arctic scientific community's contribute their knowledge to those developing U.S. policy for the Arctic. From our collective knowledge, some meaningful contribution to the state of the nation should result.

The legislative consideration of these three subjects—government-industry partnerships in resource development; general state-federal partnership in science programming; and the involvement of Alaska scientific and societal interests within arctic international affairs—will do much to further our national purposes. Whatever approaches are advanced, they will be scrutinized by diverse interests, and properly so. The challenge for the nation in arctic science is to develop the best approaches possible in recognition of the national imperatives involved. We offer this paper in hope that it will stimulate this process.

SOURCE DOCUMENTS AND NOTES

1. For the purposes of this paper, the arctic region is generally defined as that area north of 60° north latitude, including those waters of the Bering Sea and other marginal seas of the Arctic Ocean that are subject to seasonal ice cover.

2. D.M. Hickok, A historic and current view of Alaskan arctic research and events, unpublished (Anchorage: Arctic Environmental Information and Data Center, University of Alaska, 1976), 29 pp.

3. H. Pollack and P.J. Anderson, United States policy for the Arctic, Arctic Bulletin. 1(1):2.

4. By the turn of the century many major expeditions had been sent to the Far North. Some of these parties were financed by private firms, such as the 1837 Dease and Simpson party sent by the Hudson's Bay Company. Journals of whaling ships, many of which overwintered in the Arctic, revealed much about the coast of arctic Alaska and its people. The U.S. government also became involved with arctic exploration. The International Polar Expedition to Point Barrow (1881-83) reported meteorological, archaeological, and other scientific observations. Lt. George Stoney explored the Kobuk River and Brooks Range in 1883 and 1885-86. Ensign W.L. Howard traversed the Noatak and Colville river drainages in 1885. Lt. S.B. McLenegan explored the Noatak in 1887. A U.S. Geological Survey party led by Frank C. Shrader reconnoitered the Brooks Range in 1889. Brief accounts of early expeditions to the Arctic can be found in Ernest Leffingwell's document on the Canning River region.

   E. Dek. Leffingwell, The Canning River region, northern Alaska. (Washington, DC: U.S. Government Printing Office, 1919), U.S. Geological Survey Professional Paper 109. 251 pp.; Hickok (see note 2).

5. Examples of federal legislation include: federal sponsorship of the reindeer industry, beginning in 1890; the Act of May 14, 1898, extending U.S. homestead laws to Alaska and providing for waterfront tracts for Native use; the Alaska Native Allotment Act of 1906, providing homestead tracts to Natives.

   Federal Field Committee for Development Planning in Alaska, Alaska Natives and the land (Washington, D.C.: U.S. Government Printing Office, 1968), 565 pp.

6. Exploration in the area of Naval Petroleum Reserve No. 4 began in 1904; however, with its designation as a reserve in 1923,

private industry efforts toward development were halted. A major exploration program from 1944 to 1953 assessed the petroleum potential of the area. Private industry exploration in the arctic coastal plain and foothills resumed in 1963.

U.S. Geological Survey, An environmental evaluation of potential petroleum development on the National Petroleum Reserve in Alaska (Washington, DC: U.S. Government Printing Office, 1979), 238 pp.; D.L. Morgridge and W.B. Smith, Geology and discovery of Prudhoe Bay field, eastern Arctic slope, Alaska. Memoir 16: Stratigraphic Oil and Gas Fields. American Association of Petroleum Geologists (1972). pp. 489-501.

7. The Spitsbergen (Svalbard) Archipelago Treaty (43 Stat 1892, Part 2 (1925); Treaty Series 686) was signed February 9, 1920 by representatives of the United States, Great Britain, Denmark, France, Italy, Japan, Norway, the Netherlands, and Sweden. Sovereignty of Norway over the archipelago was recognized, and all parties were given mutual liberty of access and entry to adjacent waters for fishing, hunting, maritime, industrial, mining, and commercial operations. Thus, today the continental shelf around Svalbard is available for U.S. fossil fuel exploration.

8. Stefansson made numerous trips in the Arctic. His success was in great part due to the readiness with which he learned from the Eskimos themselves, adopting survival skills enabling him to spend greater lengths of time in the Arctic than had previously been possible by using Western technology alone.

V. Stefansson. The friendly Arctic; the story of five years in polar regions (New York: The Macmillan Co., 1921), 812 pp. (Reprinted in 1969 by Greenwood Press, New York, NY.)

9. One example of policy conflict occurred after World War II with the advent of intercontinental weapons systems and the Distant Early Warning (DEW) line in northern Alaska and Canada. There was no effort to compensate Alaska Natives displaced by governmental action, and several impingements on indigenous peoples' property and civil rights occurred.

Federal Field Committee (see note 5); J.M. Nielson and North Slope Borough Planning Dept., Kaktovik, Alaska; an overview of relocations. Report for City of Kaktovik and North Slope Borough Commission on History and Culture (1977), 26 pp.; U.S. Eighty-sixth Congress, Ocean sciences and national security (Washington, DC: U.S. Government Printing Office, 1960), Report of the Committee on Science and Astronautics, House Report No. 2078, 180 pp.

10. The U.S. Public Health Service was given responsibility for the health care of Alaska Natives in 1955, at which time a major tuberculosis control program was designed and implemented. The tuberculosis incidence rate in 1952 was 1,854 cases per 100,000; by 1970 this had dropped to 154 per 100,000.

M.W. Johnson, Health services reports (Washington, DC: U.S. Government Printing Office, 1973), 88(3): 247-254.

11. The U.S. Geological Survey began studies of the petroleum potential of northern Alaska in 1944. From 1945 to 1953 the survey and the navy together explored NPR-4 and adjacent areas. George Gryc was responsible for much of the geological investigations in the Sagavanirktok and Canning-Shaviovik River areas, leading to the eventual discovery of the Prudhoe Bay oil field. The Prudhoe Bay discovery well, ARCO-Humble No. 1, was completed in June 1968.

J.C. Reed, Exploration of Naval Petroleum Reserve No. 4 and adjacent areas, northern Alaska, 1944-53; Part 1. History of the exploration (Washington, DC: U.S. Government Printing Office, 1958), U.S. Geological Survey Professional Paper 301. 192 pp.; F.K. Rickwood, The Prudhoe Bay field (Proceedings of the Geological Seminar on the North Slope of Alaska, American Association of Petroleum Geologists, Pacific Section, Palo Alto, California, 1970); Morgridge and Smith (see note 6).

12. NARL was established in 1947 by the Office of Naval Research. Several contractors operated the facility and the University of Alaska served in this function since 1954. The laboratory provided logistical support for transient scientists working on a broad range of both applied and basic research programs. The Arctic Health Research Center, located in Anchorage, was first funded in 1948. Its activities included grants adminstration for special health needs and provision of technical assistance to the Alaska State Health Dept. as well as research. Studies covered animal-borne diseases, biochemistry and nutrition, entomology, environmental sanitation, and physiology.

J.C. Reed. The story of the Naval Arctic Research Laboratory, 1969. Arctic. 22(3):177-183; T. Parran, et al., Alaska's health: a survey report (Pittsburgh, PA: University of Pittsburgh, Graduate School of Public Health, 1954), Report of the Alaska Health Survey Team.

13. The International Geophysical Year gave considerable impetus to these studies and the University of Alaska's Geophysical Institute achieved worldwide recognition for expertise in these fields.

14. Fletcher's Ice Island (T-3), a large stable ice floe in the Arctic basin, was occupied nearly continuously from 1952 to 1975 by scientists concerned with oceanography, marine geophysical and biology, climatology, and arctic air-sea interactions and effects on global climate. During that period it made three circumnavigations of the Arctic basin.

15. By the mid-1960's, two areas of Congressional concern were rapidly developing which would have great impact upon arctic science. These were environmental protection and rehabilitation and national ocean policy. A series of laws, which gave support and urgency to ecological investigation and research and to the reorganization of ocean programs in government, resulted.

16. Commission on Marine Science, Engineering and Resources, Our nation and the sea, a plan for national action (Washington, DC: U.S. Government Printing Office, 1969), Report of a Congressional Commission.

G.A. Doumani, Exploiting the resources of the seabed (Washington, DC: U.S. Government Printing Office, 1971), Report for the Committee on Foreign Affairs, U.S. House of Representatives. 152 pp.; President's Science Advisory Committee, Effective use of the sea. (Washington, DC: U.S. Government Printing Office, 1966), Report of the Panel on Oceanography. 144 pp.

17. The discovery of oil at Prudhoe Bay, Alaska identified oil and gas deposits with proven reserves estimated to be 9.6 billion barrels of oil and 26.5 trillion cubic feet of gas. Construction for the field's development required new technologies in well drilling and facilites construction to deal with permafrost and climatic conditions.

U.S. Geological Survey (see note 6).

18. The Federal Field Committee for Development Planning in Alaska was created to help guide federal efforts during postearthquake recovery from the devastating 1964 earthquake. It was a unique body, composed of the heads of federal agencies in Alaska and chaired by presidential appointee Joseph Fitzgerald, who reported directly to the cabinet of the president. Although the committee involved itself in some program matters, its essential forte was in securing federal policy considerations at high levels in government, both in the executive branch and in the Congress. The committee quickly identified several subjects which required resolution if there was to be long-term economic recovery and growth in Alaska. One of these was the need for the United States government to set forth a policy position on national interests in the entire circumpolar Arctic. Other major policy positions involved change in Alaska's communication and transportation systems, the resolution of aboriginal land claims, and improvements in Native housing, minority hire, and the health of indigenous peoples.

19. The antarctic science program is essentially a function of U.S. foreign policy as set forth between nations in the Antarctic Treaty.

20. G. Doumani, A report of federal arctic research (Washington, DC: U.S. Government Printing Office, 1967) a report for the committee on appropriations, U.S. Senate, 90th Congress, Senate Document No. 71. 313 pp.

21. The text of the executive order dissolving the IARCC follows:

EXECUTIVE OFFICE OF THE PRESIDENT
FEDERAL COORDINATING COUNCIL FOR SCIENCE,
ENGINEERING, AND TECHNOLOGY
WASHINGTON, D.C. 20500

June 30, 1978

Dr. Edward P. Todd
Director, Division of Polar Programs
Directorate for Astronomic, Atmospheric,
Earth, and Ocean Sciences
National Science Foundation
1800 G Street, N.W.
Washington, D.C. 20550

Dr. Ed:

The purpose of this letter is to advise you of the formal dissolution of the Interagency Arctic Research Coordinating Committee (IARCC).

This step is being taken in accordance with the President's Reorganization Plan No. 1, effective October 18, 1977, as implemented by Executive Order 12039, effective February 26, 1978. The intent of this plan with regard to FCCSET is to strengthen its role by reconstituting the Council as a sub-Cabinet level working group, chaired by the President's Science and Technology Adviser. As such, it will focus its attention on significant, national, scientific, and technological issues cutting across government departments and agencies.

Over the past several months, my staff and I have reviewed the structure and function of FCCSET and assessed the continuing need for its various committees. As a result, we have formulated a plan whereby the functions and responsibilities of existing committees are either combined and assigned to a much smaller number of FCCSET committees, or reassigned to lead agencies. In the latter case, the lead agencies will coordinate research and development in the assigned area and periodically report to me on the status of those R&D activities. This concept is in accord with the President's desire to emphasize Cabinet and agency program management where possible.

In the case of IARCC, we believe that the need for inter-agency coordination is sufficiently understood, and the usefulness of the existing Committee sufficiently recognized, that its functions can now be carried out at the agency level. Accordingly, the Department of the Interior is coordinating polar research in Alaska and on the continental shelf, and NOAA is coordinating offshore and Gulf of Alaska research. We hope that you will take the lead in assessing the future need for additional coordination in the area of Arctic research and in establishing appropriate mechanisms for achieving that coordination.

I will greatly appreciate your apprising Committee members of this action and expressing to them the President's appreciation for their valuable work.

Yours sincerely,

Frank Press
Chairman

22. U.S. Geological Survey (see note 6).

23. Federal Field Committee for Development Planning in Alaska (see note 5).

24. The final result of a lengthy process of environmental examination and hearings was:

U.S. Dept. of the Interior, Special Interagency Task Force, Final environmental impact statement; proposed Trans-Alaska pipeline (Washington, DC: U.S. Government Printing Office, 1972), Report for the Federal Task Force on Alaskan Oil Development. 6 vols.

25. University of Alaska, Arctic Environmental Information and Data Center. Current research profile for Alaska (1979), 420 pp.

26. National Council on Marine Resources and Engineering Development, Marine sciences affairs—a year of broadened participation (Washington, DC: U.S. Government Printing Office, 1969), Report for the U.S. Congress, 251 pp.

27. Following is the full text of National Security Decision Memorandum 144.

December 22, 1971

TO: The Secretary of State
The Secretary of Defense
The Secretary of Interior
The Secretary of Commerce
The Secretary of Transportation
The Director, National Science Foundation
The Chairman, Council on Environmental Quality

SUBJECT: United States Arctic Policy and Arctic Policy Group

The President has reviewed the NSC Under Secretaries Committee's recommendations, conclusions and report regarding United States Arctic policy and organizational arrangements for its implementation, as forwarded by Under Secretary Irwin on August 9, 1971.

The President has decided that the United States will support the sound and rational development of the Arctic, guided by the principle of minimizing any adverse effects to the environment; will promote mutually beneficial international cooperation in the Arctic; and will at the same time provide for the protection of essential security interests in the Arctic, including preservation of the principle of freedom of the seas and superjacent airspace.

In furtherance of this policy, the President has:

— Directed that the NSC Under Secretaries Committee review and forward detailed action programs, including plans and specific projects (with budgetary implications as appropriate), for increasing mutually beneficial cooperation with Arctic and other countries in areas such as exploration, scientific research, resource development and the exchange of scientific and technical data; for improving the U.S. capability to inhabit and operate in the Arctic and the understanding of the Arctic environment; and for developing a framework for international cooperation with particular attention given the Northlands Compact approach. (These action programs should be forwarded for the President's consideration not later than March 1, 1972.)

— Directed that an Interagency Arctic Policy Group be established, chaired by the Department of State and including the Departments of Defense, Interior, Commerce and Transportation, the National Science Foundation, the Council on Environmental Quality and representatives of other agencies as appropriate. (The Department of State is responsible for providing the administrative support, including staff, necessary to enable the Arctic Policy Group to carry out its responsibilities.) The interagency Arctic Policy Group will be responsible for overseeing the implementation of U.S. Arctic policy and reviewing and coordinating U.S. activities and programs in the Arctic, with the exception of purely domestic Arctic-related matters internal to Alaska. In discharging these responsibilities, the Arctic Policy Group will report to and coordinate with the NSC Under Secretaries Committee. Any substantive policy issues requiring the President's decision will be referred to the NSC Senior Review Group for consideration.

— Approved the development of a coordinated plan for scientific research in and on the Arctic, including possible cooperative projects with Arctic and other countries, and the investigation of the feasibility of developing a comprehensive transportation system capable of meeting U.S. requirements in the Arctic, with appropriate recommendations to be made to the Arctic Policy Group.

There should be no public statements concerning U.S. Arctic policy and the other decisions set forth herein pending the President's review of the action programs requested above.

Henry A. Kissinger

cc: Secretary, Health Education and Welfare
Director of Central Intelligence
Administrator, Environmental Protection Agency
Chairman, Joint Chiefs of Staff
Director, Office of Management and Budget
President's Science Advisor

28. Two editions of this report, *Five-Year Plan for Arctic Research* were prepared by the Interagency Arctic Research Coordinating Committee, and published by the National Science Foundation. The first in February 1972 and a revised edition in November 1972.

29. National Research Council, Ad Hoc Planning Group for the Committee on Arctic Science and Technology, Summary report (1973), Vol. 1.

30. See the following:

C. Abrams, Housing the Alaska Native (Anchorage: Alaska State Housing Authority, 1967), 74 pp.; A.J. Fuelner, Summary of water supplies of Alaska communities (Anchorage: Resource Planning Team, Joint Federal-State Land Use Planning Commission, 1973). 6 vols.; A.J. Alter, Solid waste management in cold regions. (College: Alaska Water Laboratory, 1979), Alaska Dept. of Health and Welfare Scientific Research Data and Reports, Vol. 2, No. 2.

31. The Marine Mammal Protection Act of 1972 preempted any state authority over marine mammals and replaced it with a single federal program. The act created the Marine Mammal Commission, functioning as an advisory body to the Secretaries of Commerce and the Interior, charged the commission with conducting a continuing review and study of all stocks of marine mammals and of all U.S. activities relating to them.

Through the Endangered Species Preservation Act of 1966, the Endangered Species Conservation Act of 1969, and the Endangered

Species Act of 1973, the Secretary of the Interior was given responsibility for the conservation and protection of species "threatened with worldwide extinction." This included the development of a list of endangered species. The 1972 act authorized a more comprehensive program which incorporated the idea that populations could be recognized as seriously depleted before being eligible for endangered species status. Thus, the "threatened" category came into play.

See:

National Environmental Policy Act, 42 U.S.C. Sec. 4321-47 (1970); Marine Mammal Protection Act, 16 U.S.C. Sec. 1361-62, 1371-84, and 1401-97 (Supp. IV 1974) as amended by Fisheries Conservation and Management Act of 1976, Pub. L. No. 94-265, Sec. 404, 90 Stat. 331; Endangered Species Act of 1973, 16 U.S.C. Sec. 1531-43 (Supp. IV 1974) as amended by Pub. L. No. 94-359, 90 Stat. 913; Stat. 275; Endangered Species Preservation Act of 1966, Pub. L. No. 89-669, Sec. 1-3, 80 Stat. 926.

32. An impressive list of publications of the Tundra Biome Program includes:

J. Brown, ed., Ecological investigations of the tundra biome in the Prudhoe Bay region, Alaska (Fairbanks: Biological Papers of the University of Alaska, 1975), Special Report No. 2, 215 pp.; F.S. Chapin, III and K. Van Cleve, Nitrogen and phosphorus distribution in an Alaskan tussock tundra ecosystem: Natural patterns and implications for development (Environmental chemistry and cycling processes: Proceedings of symposium, Augusta, Georgia, 28 April-1 May 1976), U.S. Department of Energy, CONF-760429. pp. 738-753; J.E. Hobbie, ed. Limnology of tundra ponds, Barrow, Alaska (Stroudsburg, PA: Dowden, Hutchinson & Ross, Inc., 1980), 514 pp.; L.L. Tieszen, ed. Vegetation and production ecology of an Alaskan arctic tundra (New York, NY: Springer-Verlag, 1978), 686 pp.; J. Brown, et al., eds. An arctic ecosystem: the coastal tundra at Barrow, Alaska (Stroudsburg, PA: Dowden, Hutchinson & Ross, Inc., 1980), US/IBP Synthesis Series 12, 571 pp.

33. A series of reports on this project were published in the AIDJEX Bulletin; (40 issues 1970-1978) and a final synopsis volume, Sea ice processes and models.

34. See the Arctic Offshore Program (AOP) "A research program focused on the development of the natural resources of the arctic continental shelves," National Science Foundation, Office of Polar Programs, Washington, DC.

35. Exceptions were the Tundra Biome and Arctic Ice Dynamics Joint Experiment and more recently, although as yet uncompleted, the PROBES program (Processes and Resources of the Bering Sea Shelf).

36. Abstracts of a paper prepared for the Fifth International Conference on Port and Ocean Engineering under Arctic Conditions, (Spitsbergen Seminars), Trondheim, Norway, August 1979.

37. U.S. Central Intelligence Agency, "The world oil market in the years ahead," National Foreign Assessment Center, ER 79-10327U, Aug. 1979, p.2.

38. Comptroller General of the United States, *Oil and natural gas from Alaska, Canada and Mexico—only limited help for U.S.*, Report to Congress, U.S. General Accounting Office, EMD-80-72, Sept. 11, 1980, p.2.

39. See Environmental Assessment of the Alaska Continental Shelf, Interim Synthesis: Beaufort/Chukchi (National Oceanic and Atmospheric Administration, August 1978) for a discussion of sea ice and other hazards as seen by university, government, and oil industry scientists and engineers (pp. 335-355). Comptroller General of the United States (see note 37).

40. The U.S. government defines strategic and critical metals as those needed for defense for which there are no reliable substitutes and those upon which the United States has more than a 25% net import reliance. Although copper and lead are not listed as critical, their industrial importance is great; and copper especially is critical to the economic importance of several Alaskan deposits.

41. Alaska's foremost geologists believe that this nickel deposit may well be Alaska's most important prospect to allay strategic mineral shortages for the United States. Certainly, straightforward analysis of the value of the development of this prospect against the values of national monument preservation deserves attention.

42. North Pacific Fisheries Management Council, Fishery management plan for groundfish in the Gulf of Alaska (Anchorage, 1979).

43. Reports of the Study Committee and Advocacy Panels, Space Science Board, National Research Council, Space plasma physics: the study of solar system plasmas (Washington DC: National Academy of Sciences, 1978), Vol. I.

44. W.W. Myers, Health research in Alaska, a proposal by WAMI Medical Education Program, Universtiy of Alaska, Fairbanks, unpublished.