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ARCTIC LOGISTICS SUPPORT TECHNOLOGY



REPORT ON A SYMPOSIUM

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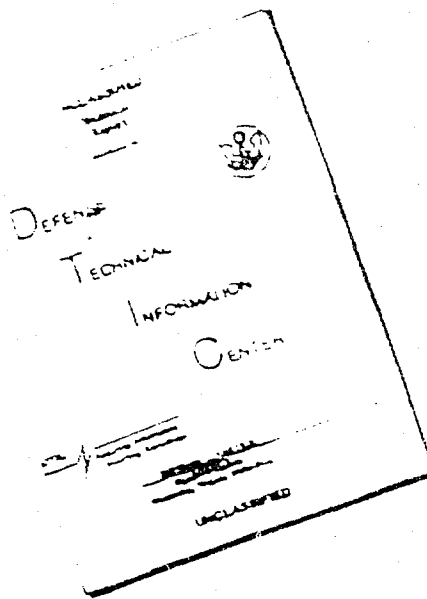
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Arctic Logistics Support Technology
Report on a Symposium

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document is a
Summary Report based on symposium held to identify, examine, and propose ways of providing support to ARPA's research efforts in the Arctic Basin. ARPA's interests in the Arctic were identified to focus on mobility, undersea operations, and information gathering. Important technologies were said to include such things as surface effect vehicles, under-ice acoustics, remote sensing, and cold region construction. It was emphasized that the ARPA arctic research program is an integral part of the total national arctic program.

The report was presented that described both the current state of the art for arctic logistics support technology and projected future development. They were divided into three main subject areas: (1) transportation, (2) life support, and (3) logistics support, i.e., meeting special needs of field investigators in performing their activities.

The proceedings will be published.

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Summary Report based on
symposium held in Hershey,
Pennsylvania on November 1-4, 1971

December 1971

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I. SHORT OVERVIEW

In November 1971, the Advanced Research Projects Agency sponsored a Symposium on Arctic Logistics Support Technology to identify, examine, and propose better ways of providing support to ARPA's research efforts in the Arctic Basin. ARPA's interests in the Arctic were identified to focus on mobility, undersea operations, and information gathering. Important technologies were said to include such things as surface effect vehicles, under-ice acoustics, remote sensing, and cold regions construction. It was emphasized that the ARPA arctic research program is an integral part of the total national arctic program.

New materials and improved designs have eliminated most of the old problems in operating large aircraft in the Arctic, but the same cannot be said of surface operations. The old ways were good enough for small-scale and exploratory operations, but not any longer. The nation is now poised on the brink of explosive development in the Arctic, and within a decade accelerating change will make 1971 seem like a primitive frontier.

The technology needed to make a quantum jump in support of arctic scientific operations is available now, but has not been applied adequately. Large-scale and high-priority scientific activities can be supported within the next five years only if a variety of components are pulled together into an integrated logistics support system. Advanced planning, multiple-year funding, and manning by experienced personnel are essential. The integrated arctic logistics support systems should include long-range aircraft like the C-130 for delivery of supplies to an advanced base, a compatible surface effect vehicle for movement on the sea ice, and a portable camp complex for housing workers on the sea ice. Means for utilizing data from remote sensing systems carried by aircraft and satellite are urgently needed to expand the scale of manned surface experiments. Airdroppable, unmanned remote data collection systems are needed to reduce dependence on manned camp activities and to speed up data collection. Manned and unmanned submersibles show considerable promise for underwater data collection. Refueling and resupplying camps and vehicles on the sea ice presents a major problem which requires immediate attention.

II. STATE OF THE ART

The specific objective of the Symposium was to identify, examine, and propose better ways of providing support to ARPA's research efforts in the Arctic Basin. A broader objective was to provide an

exchange of information and ideas on arctic technology between representatives of government, industry, and the scientific community for the purpose of stimulating fresh approaches to the problems of arctic research and operations support.

Papers were presented that described both the current state of the art for arctic logistics support technology and projected future development. Other papers were read by abstract only and were distributed to Symposium participants. Papers were divided into three main subject areas: (1) transportation, (2) life support, and (3) activity support; i. e., meeting special needs of field investigators in performance of their activities. Appendix 1 lists all speeches and papers presented at the Symposium as well as those read by abstract. Obviously, there were areas of logistics interest not covered at the Symposium, mostly because of limiting our specific objective to ARPA's needs in the Arctic Ocean but also to some extent because of lack of time. For example, submersible cargo vessels, airdroppable devices, and other subjects were not covered. However, we believe the subjects that were covered suffice as the basis for a forward-looking logistics support concept for research in the Arctic Ocean.

TRANSPORTATION

The vehicles required to provide an adequate integrated transportation system for support of research in the Arctic Basin either are available now or can be available in the next few years if presently planned developmental programs are pursued with sufficient funding support. The following discussion is by major types of vehicles.

STOL Aircraft

Aircraft such as the Lockheed Hercules (C-130), de Havilland Buffalo, de Havilland Twin Otter, Helio-Courier, and others have amply demonstrated the essential role of STOL aircraft in arctic transportation. The trend is toward higher speeds, increased flexibility for choice of landing sites, and improved all-weather capability.

The development of air-cushion landing gear is perhaps the item of greatest significance for improvement of the capability of STOL aircraft for use in the Arctic Ocean. Potentially, this development would permit landing and take-off from the Arctic Ocean ice during the summer months when melt conditions are apt to disrupt other STOL operations. The de Havilland Buffalo is being used as a testbed for this development. It is predicted that the air-cushion landing gear can

be developed for any high-wing aircraft regardless of size for operation on the softest surfaces; e. g., water, muskeg, and small obstacles. Further it should provide greater flexibility in the choice of landing sites in winter months.

Some polar logisticians question the need for increased speed in support operations. However, from the military point of view, speed is important in quick reaction tasks. Further, transportation economics show that higher speeds usually result in increased efficiency, although this is somewhat dependent on the amount of cargo and passenger requirements.

All too often, aircraft operations in the Arctic Ocean are disrupted by poor visibility. Ideally, for arctic operations, aircraft should have a reliable self-contained system that would permit landings at unprepared sites under near-zero ground visibility conditions. Relatively less expensive systems, such as the microwave system being developed for the intercity STOL ports in Canada, may suffice as an interim solution for installation at manned stations on the arctic pack ice.

Availability of STOL equipment for arctic operations at reasonable cost will depend largely on the development of acceptable STOL systems for transport in southern latitudes. The introduction of STOL into intercity markets will stimulate additional developments of direct benefit to the North. Improvements in the very large STOL aircraft, however, are likely to continue to depend heavily on military requirements and funding support.

An important role for STOL aircraft in an Arctic Ocean transportation system is delivery of cargo and personnel to research sites. Centrally located distribution points could be selected as delivery terminals for the larger STOL's. From these points, final delivery could be effected by helicopters, lighter STOL aircraft, or SEV's.

Another role for the STOL aircraft is to carry scientific packages and instruments for inflight observations and remote sensing and for landings to conduct investigations on the surface. Generally, however, inflight observations and remote sensing could be conducted more efficiently by conventional aircraft operating from land bases and observations requiring landings can better be accomplished by helicopter or SEV.

Helicopters

Helicopters do not require runways. They can be used to great advantage for distributing goods from hubs where low-cost, high-performance aircraft can deposit the tonnage required. Also, as just pointed out, they are extremely useful for local on-site transportation requirements, such as taking a scientist and his equipment to locations away from the main camp for a few hours' investigation work or perhaps to establish a remote unmanned station.

Among the very large helicopters, the flying crane provides flexibility for short-range heavy lifts of a variety of sizes and shapes. Military configurations such as the CH-47 and CH-53 that carry 10-ton payloads to a round-trip distance of about 100 miles at speeds near 180 knots also could be useful.

The currently used flying crane, S-64, has a payload of 10 tons at a range of 25 miles and 7 1/2 tons at 180 miles. Its purchase cost is \$2.2 million. A larger three-engine helicopter with a payload of 16 tons is under development. Farther in the future is a four-engine helicopter with a 50-ton payload capacity.

The larger helicopters can be ferried over distances of several hundred miles using auxiliary fuel tanks. Also, they can be refueled inflight if necessary.

The Jetranger, capable of lifting 1,600 pounds externally; the Huey (model 205A) with an external load capacity of 5,000 pounds; and the Huey Tug with an external lift capacity of 8,000 pounds are examples of current light and medium helicopters. All of these helicopters are air transportable by C-130 aircraft.

V/STOL aircraft are the most likely candidates to attain speeds comparable to conventional aircraft but retain the vertical takeoff and landing characteristics that make the helicopter so useful. The proprotor, in which rotors are tilted through a 90° angle, is a step toward this end. It is predicted that the proprotor will be flying in the next few years.

Even more significant developments, from the viewpoint of arctic operations, are those in avionics. A rotor blade radar antenna is said to provide a high-definition radar picture at a range of approximately 10 to 15 miles, the clarity of the presentation being so precise that it is possible to distinguish between a plowed field and a grass field at that distance. Avionics also have been developed for automatically bringing a helicopter to a hover over any type of surface -- land or water.

The system not only brings the aircraft to a hover in instrument conditions, but also egresses it to a safe speed and altitude upon completion of the hover. From the hover, it may be possible for the pilot to land in low visibility. This could be one of the most significant breakthroughs in V/STOL operations in the Arctic.

Surface Effect Vehicles

It is generally believed that the surface effect vehicle (SEV) offers the best prospect for attaining freedom of movement on (or just over) the surface of the Arctic Ocean. The development of SEV technology is receiving both government and commercial support and is being pursued in several countries. ARPA is spearheading the effort to develop a large arctic SEV. The present state of the art in SEV development can be likened to a Model T in automotive development or Spirit of St. Louis in aircraft development.

We believe that among its many potential arctic applications, the SEV will significantly enhance our capability to conduct research in the ocean. A concept for the 1980's would be the deployment of a complete research team in an arctic SEV with self-contained facilities for the group to live and work in while on the ice. However, it must be remembered that the SEV itself creates logistics requirements; e.g., refueling. Vehicles discussed at the Symposium ranged from 20- to 100-ton payloads. The approximate purchase cost of the 100-ton vehicle is estimated as \$6 million and its operating cost as \$600 per hour. The 20-ton payload SEV costs \$1 million.

Ships

Icebreakers

The first ship of the new class of icebreakers being provided by the U.S. Coast Guard as replacement for the Wind class will be completed in 1974. This new WAGB-10 class can navigate approximately 6 feet of ice in the continuous mode and 21 feet in the ramming mode. These figures are about double those for the Wind class. The larger physical size and total shaft horsepower available will allow the new class to be 25 percent more productive in transit and perhaps equally so in the ice. It will be possible to extend the usable on-scene days in a given area. It will not, of course, have an all-season capability. It should be noted that the WAGB-10 class has much improved laboratory and oceanographic research facilities over the older classes.

However, many authorities believe that the technology is available today for designing and building icebreaking ships having the capability to operate in and transit across the Arctic Ocean during all seasons. An example of an arctic icebreaker having such a capability suggested in a paper distributed at the Symposium has the following characteristics:

Length overall	604 feet
Beam	95 feet
Draft	35.6 feet
Displacement	32,281 tons (1)

The propulsion plant would be triple screw with 70,000 SHP per shaft, or 210,000 SHP total. At 2 knots it would break 10 feet of ice in the continuous mode; at 6 knots it would break 9 feet; etc.

It is unlikely that an icebreaker would be built especially to conduct research. It offers an attractive platform, however, for use on a shared basis, particularly in the marginal ice zones where ice floe stations are difficult to establish. In the marginal area, though, the newer high-performance icebreakers would not be necessary. It would be nice for the scientists to have exclusive use of a surplus icebreaker such as the Eastwind that could be commercially manned.

Where icebreakers are available and can reach desired locations in the pack ice, logistics support can generally be accomplished more economically by ship than by premium modes if large tonnages are involved.

Large Submersibles and Submarines

Submersible tankers, cargo vessels, and enders have all been proposed for the Arctic. No such vessels have been built, and we are not aware of any plans to construct such a vessel in the near future. We believe, however, that this area should receive more study. Potentially, submersibles for logistics support offer significant advantages in freedom of movement and all-season capability.

A nuclear submarine equipped for Arctic Ocean research would be extremely useful to scientists. In the long run, it might also be

¹ Voelker, R. P., "Ships to Transit the Arctic Ocean," ARCTEC, Inc., Columbia, Maryland

a most effective means for reducing logistics costs for oceanographic research. If the very important forecasting of large-scale motion of the pack ice should depend not only on knowledge of the wind pattern but also significantly on that of ocean currents, then availability of a manned research submarine could become mandatory. We venture to suggest that the Department of Defense could make an enormously valuable contribution to both logistics and research by converting a surplus nuclear submarine into an arctic oceanographic research vessel.

All-Terrain Vehicles

All-terrain vehicles play a useful role on land (a new vehicle described at the Symposium should be suitable for this purpose), but we do not believe they are needed for logistics support in the Arctic Ocean. The helicopter or SEV will be adequate for local transportation where leads must be crossed. For local personnel and light freight transportation in the immediate vicinity of a camp, snowmobiles and sleds should suffice.

The principal need for vehicles will occur at the main or hub campsite. Tracked vehicles for handling materials, heavy freight hauling for short distances, and runway preparation and maintenance are likely to be required. Current off-the-shelf vehicles are adequate for this purpose. At times, materials handling or construction vehicles may also be required at satellite stations. They could be delivered to the site by either helicopter or SEV.

LIFE SUPPORT

Selected topics were discussed for some of the more significant aspects of life support requirements for personnel conducting research from the arctic pack ice. Limited time precluded the inclusion of other important items such as food and nutrition, food preparation, clothing, etc. However, it is known that in these areas continuing effort is directed toward improvements, such as weight reduction packaging, etc.

Power and Heat

A review of new and prospective portable power and heat generators for field use justifies the belief that during the Seventies we shall be using the same kind of items as we are now using. A variety of

interesting, new, long-life isotope-based thermoelectric generators are spin-offs from space technology, but they will be too expensive for most applications, except highly specialized military ones and at unattended scientific stations where present power sources may restrain development of such stations to their full potential.

Given this situation, we recommend that if and when a new research and operations support logistics system is implemented, it should include an inventory of portable generators inflexibly limited with respect to manufacturer and model number. In addition, however, we suggest that the following program be pursued for future development and that emphasis be placed on reducing hardware costs and on reducing pollution to the environment:

- Develop small external combustion chemical engines for quick-reaction, low-cost arctic use
- Develop isotope-powered systems for long-term unattended arctic use
- Develop reliable integrated life support-power system hardware for arctic use.

Shelters

In general, adequate housing is available in any form desired, from austere to luxurious and from bare shelter to sophisticated pre-equipped, depending on what the customer is willing to pay. Again generally speaking, those forms that require the least manpower to set up a station on the ice are the most desirable and at times would be mandatory in the case of satellite stations.

Modular and lightweight concepts were rather thoroughly covered at the Symposium. Mention should be made, though, of the small pre-fabricated modular 8' x 8' x 8' hut used by the Naval Arctic Research Laboratory for the ARLIS stations. This hut has been popular with its users and is cheap enough to be expendable. Another structure that is expected to be of considerable value to ice satellite stations is the fold-truss shelter. This is an arrangement in which the trusses fold together for shipment like an old-fashioned clothes drying rack. It can be carried easily in a helicopter or light aircraft such as the Helio-Courier. Optional coverings are fabric or plywood. Both the NARL and the fold-truss huts are easily and economically heated.

Water Supply, Sewage, and Solid Waste Disposal

These areas require much attention. Conventional equipment is available, but conventional processes for water supply and waste disposal require almost continuous heat energy to be effective in the Arctic. Radical departures from temperate climate concepts are suggested. Such innovations would exploit cold resources and conserve energy. We believe the technical community should put more effort into solving the water supply, sewage disposal, and solid waste management problems of the Far North.

Medical Aspects of Arctic Research Stations

Problems related to providing for the health and physical well-being of personnel at remote stations were covered in the Symposium. Guidelines, as used in the antarctic program, were suggested for screening and selecting personnel. Major emphasis at arctic stations should be placed on preventive aspects of medicine. We believe that much remains to be done in the field of arctic medicine, both organizationally and technologically. An in-depth analysis of the problems should be made, and innovative concepts should be developed to meet the needs of arctic stations.

ACTIVITY SUPPORT

By "activity support" we mean those things that must be provided to meet the special needs of the scientist as distinguished from transportation, shelter, food, power, heat, etc.

Communications and Data Collection

Our ability to relay data via satellites and to communicate with outer space provides new techniques that have ready application in the Arctic. No longer are we confined by the propagation anomalies of HF radio and the restrictions of narrowband networks. Progress already made in digital data technology and wideband communications should enable us to process a variety of information, including voice, television, facsimile, and computer data. The hostility of the arctic environment, which constrains man from operating on a year-round basis, establishes a need for collecting scientific information unattended and on an automated basis. Remote sensing technology for space application is sufficiently advanced to permit immediate application to the Arctic and was thoroughly described at the Symposium in

an evening lecture by Dr. Ernst Stuhlinger of Marshall Space Flight Center. Conventional meteorological, oceanographic, and sea ice condition instruments must be redesigned to take full advantage of solid-state circuit techniques and reliabilities, low power drain, and compact packaging benefits. Versatile sensor platforms that may be readily implanted on the ice pack, on land, or above and below the water surface are needed. Long-life energy sources capable of at least six months of continuous operation in the arctic environment must also be developed at reasonable costs.

The chief goal is to provide a communication service that within practical limits provides the user with a quality of service he now enjoys in his home environment. In fact, it would be nice if, by pressing buttons in his laboratory, the user could command and collect all of the necessary field data required without setting foot outside his laboratory. We believe that the technology is available to accomplish this; however, the expense involved is currently beyond rationalization.

The demand for adequate communication services in the Arctic is inevitable as scientific, commercial, and defense interests expand. Proper data management -- the acquisition, routing, retrieval, and overall control of processing and communication -- will become a most important element when economic aspects of the network are evaluated. The development of a centralized polar data facility that can efficiently disseminate information and general communications is envisioned.

System concepts for data collection for near-term and long-range requirements of users is presently under study for ARPA and ONR by the Arctic Institute of North America and will subsequently be reported in detail.

Automatic On-The-Ice Instrument Stations

Two new types of stations are being developed for AIDJEX. They will record and transmit meteorological data, but they could handle a larger variety of sensor inputs. The LAMS (Localized Arctic Measuring System) is relatively short-lived (energy) and transmits on interrogation by an aircraft. The RAMS (Remote Arctic Measuring Station) has a 1,000-mile range and a 1-year life. Prototypes of both stations will be field tested during the 1971-72 winter. Cost considerations prevented the inclusion of wind direction reporting. Invention of a relatively cheap way of determining the azimuth of an automatic station (rotation of supporting ice floe) is highly desirable.

Remote Sensing by Airdroppable Devices

An airdroppable penetrometer has been developed which signals back deceleration data from which ice thickness can be calculated. In order to obtain average thickness over an area or along a line, a large number of penetrometers has to be dropped, which is costly (\$200 ea.) A new low-level flight system was presented (the E-phase remote sensor) which senses the electrical resistivity structure of surface layers some tens of feet below the surface. A preliminary test over sea ice indicated that the system may satisfy the requirement for airborne average ice thickness surveying.

The developed penetrometer system should be adapted to other purposes, where the ice-penetrating missile ends up suspending a signaling sensor in the water at a predetermined depth. By such means, digital data could be obtained at specific points more quickly and possibly more cheaply than with a quick-reaction manned station.

Nonpenetrating airdroppable packages are also needed. Work is being done on this by the U.S. Air Force for other applications and possibly could be adapted to use in the Arctic Ocean.

Navigation Systems

Navigation and precise positioning systems are required for arctic use. While not discussed in detail at the Symposium, the technology base for such systems is available. There is a need, however, for installation of far more navigational aids, both for ship and air navigation in the Arctic. Attainment of such systems is largely dependent on funding.

Scientific Instruments

Evaluation, selection, and modification of scientific instruments specifically for arctic use are presently based mostly on word-of-mouth information or on the individual experience of scientists. A handbook that documents criteria and other information for such evaluation, selection, and modification would be useful to the scientist. It would be particularly valuable to the new scientist planning his first work in the Arctic.

It was brought out in the Symposium that mechanical and electronic components of instruments can be disturbed by shock and vibration during transport and by low temperatures, high temperature

gradients, and moisture condensation while in storage and in use, resulting in physical damage, malfunction, and calibration drifting. Much of this grief can be avoided by thermal insulation, good packaging, careful handling in transit, and troubleshooting capability on location.

Unmanned Submersibles

The small unmanned submersible promises to become the most useful sensing instrument carrier for under-ice research and surveillance. One short-range system (1 square mile area) is already operational and can be rented for about \$2,000 per day. We here venture to state that further development for almost any desirable research or military purpose in the Arctic Ocean is strictly funding-limited. Increased financial support could make it possible to attain a very sophisticated capability in this area of technology.

Man in the Ocean

Man as a free-swimming diver is presently a small cog in the research machine. Resident time in the cold water will remain short until a lightweight, uncumbersome body-surface heat source is developed. Divers will occasionally be needed to recover expensive instruments snarled under the ice, but their main usefulness is in biological studies (which are unlikely to receive high priority in the envisaged research missions). Nevertheless, diver technology must not be neglected, because biological productivity of the arctic littoral seems much larger than had been thought, and we know close to nothing concerning the possible wider effects of prospective damage due to increased activity in the arctic seas.

III. MILITARY IMPLICATIONS

The Arctic is a unique region of over six million square miles. There is a deep central ice-covered ocean. Marginal ice exists over the broad continental shelf and within the extensive archipelago coast. Areas of tundra are impassable to surface vehicles in the summer thaw and are rigorously cold in the winter. These land areas are part of six nations (Canada, Denmark, Finland, Norway, the U. S. S. R., and the U. S. A.) of diverse political viewpoints. However, they all have strong interests in their sovereign rights to those lands, contiguous waters, and airspace.

Military advantage is achieved by utilizing systems, tactics, and strategy allowable by technical innovations. The Arctic, at the hub of the great circle paths between centers of political and industrial power, has inherent geopolitical values. Nevertheless, its strategic significance was of little concern until the advent, first, of the long-range bomber, then of the ballistic missile and the nuclear submarine. Each of these technical innovations, in turn, allowed new types of forces to deploy in areas where operations had not been possible.

It is unlikely that the Arctic would be a major theater of operations for conventional war because of the environmental limitations and relatively low immediate economic value. Yet today, geography makes it an important outpost for surveillance and in-depth defense of North America. Increasing economic values give added strategic significance for the future.

Presently, the North American Arctic is sparsely populated and contains relatively few military installations. Its natural resources have not been developed to any large extent. This situation is in the process of change. Developments in transportation, communications, and life support systems are advancing the exploitation of arctic resources. The North American Arctic will be an important source of oil, gas, and other minerals that will then need augmented local protection as well as continued in-depth defense of the North American continent. Conversely, many important military and industrial installations are presently located in the Soviet Arctic. The arctic population of the Soviet Union is about 4.5 million people. The Eurasian Arctic is already economically important to the Soviet Union and increasingly so. For example, by 1980 the Soviet Arctic will likely supply 40 percent of the U. S. S. R.'s oil requirements.

Since military R & D will be done simultaneously with civilian research directed toward resource development, we shall have a condition of overlap with respect to logistics, research methods, and instrumentation. Hence full logistic and research cooperation would benefit both parties (see Appendix 3).

IV. PROSPECTS

The Symposium demonstrated quite clearly that essentially all the basic technologies of arctic logistics necessary for scientific research activity, military or commercial, either already are available or are being so vigorously developed by industry and government that we can expect them to be available within a few years.

It is emphasized, however, that our arctic research, especially on the ocean, has in the past been logistically a modest operation, with the notable exception of the Canadian Polar Continental Shelf Project described in Appendix 2 as a useful model for an integrated program. This in no way deprecates the fine work accomplished by the Naval Arctic Research Laboratory with the modest means at its disposal over a continuing period of more than two decades. If future research is to be efficiently pursued on a larger scale, then logistics support costs will be much higher and justifiable only if research can be demonstrated to be necessary for the fulfillment of an important national objective. The priority of the objective rests on the economic value and military importance of the region, which in turn is related to an estimate of potential petroleum and gas reserves of the American Far North, stretching from Bering Strait through the Beaufort littoral and on through the Canadian Archipelago down to Davis Strait.

The North American oil production deficit is approaching 2 billion barrels annually. If the reserve estimate remains in the range of 10 to 20 billion barrels, to be recovered from land wells only, then pipelines are likely to remain the only means of transportation to ice-free ports, and Arctic Ocean research can be expected to retain its present modest status in the Seventies. If, however, the reserve estimate turns out to be anything above say 50 billion barrels, then we have a condition of high geopolitical significance, which, from the point of view of the scientific mission, has two aspects with respect to coverage.

1. We think only in terms of North American independence from petroleum sources beyond our control, for a period of not less than two or three decades. In this case, mission-oriented oceanographic research can be limited to a relatively narrow belt along the coast.
2. We think also in terms of expanded exports and of relieving Middle East pressure on Western Europe by developing shipping into the North Atlantic with the bonus of general commercial arctic shipping from the Far East to the American east coast and to Europe. This would call for extension of oceanographic research into the central regions of the Arctic Ocean.

So we see that the degree of development of Arctic Ocean applied research will depend entirely on the estimated size of the petroleum and gas reserves and on our willingness to exploit them, economically if they are relatively small and politically if they are sufficiently large. If condition 1 or 2 outlined above applies, then there exists an important

objective requiring a correspondingly important amplification of scientific and engineering research. Suggestions as to some of the elements associated with meeting the objective and the research subjects that need to be covered are contained in Appendix 3.

Given adequate logistics -- which must come close to providing access to any place on the ocean at any desired time, support of research activity on location, and accurate determination of location coordinates -- it will be a matter of scientific expertise to develop the research programs required to solve the multiplicity of problems. By and large, based on past experience, the scientists and engineers will know what to do and how to do it (PCSP and AIDJEX are good examples). They will, however, have to be guided by the problem-solving priorities to be determined in collaboration with the resource developers, the ship builders, and the ship operators. The resource developers may decide that their most pressing problems are offshore drilling and offshore terminal design; the ship builders will need information on maximum hull stresses; and the ship operators will call for routing information.

There is no assurance that all desirable technologies can be developed within acceptable cost. If it should be decided that a major resources development must be undertaken, there would surely need to be a centralized R & D planning and action group, hopefully based on an agreement between the U.S. and Canadian governments that an R & D effort of this size should not be truncated by the 141st meridian.

With respect to the results of the Hershey Symposium on Arctic Logistics Support Technology, we suggest that the high cost of good support systems dictates the creation of a single logistics pool to support all field work. It would not be useful for us to comment further on the organization of the outlined R & D effort. There are sufficiently well-established means of doing this.

In conclusion we point out that we have dealt summarily only with the problems of the Arctic Ocean. There are problems on the land, but they are of lesser magnitude and rather well known.

V. AN ARCTIC OCEAN LOGISTICS SUPPORT CONCEPT (for research activity on the arctic pack ice)

The arctic research activity that requires the greatest ingenuity for efficient logistics support is that which makes use of platforms on the arctic pack ice. When surface ships are used as research platforms (e. g., for summer seasonal research or special situations like

North Water or other marginal zones), the logistics are simplified by the self-sufficiency designed into the ship. The same would be true of large submarines conducting oceanographic research. Aircraft operating from land bases to accomplish remote sensing or distribute airdroppable devices for unmanned data gathering would be relatively easy to support. Remote sensing from space satellites would be another method of gathering data. The logistics support concept described here, however, will be for the presently necessary but logistically difficult task of utilizing the arctic pack ice to provide research platforms. Considerable use has been made of a paper presented at the Symposium, "Mobile Laboratories and Work Platforms," by Colin Faulkner as the basis for this concept. Diagrams used in the Faulkner presentation are shown at the end of this section.

The activities visualized here would center around a base camp either on land or on the pack ice. If on land, an existing base likely would be used. If on the pack ice, the base camp would need to be constructed. The base camp would be linked either directly or indirectly with the lower 48 or southern Canada. It would be surrounded by a number of satellite stations, either manned or unmanned. The satellite stations might be for acquiring scientific data, advancing resource exploration, gathering military information, etc.

The base camp would be concerned with the operational management of the system as a whole. It would be the center for logistics and communications with the south. It might contain a limited data and processing analysis capability, but more likely a data management center would be established at a more developed location such as Fairbanks. The satellite stations, manned or unmanned, would most probably be involved in continuous data gathering or activity of some other sort, such as looking for oil. They should be capable of being moved as research expands. If the mobile units that would be used for transportation between the base camp and satellite stations are the right kind of vehicles, they can extend the surveillance or working area beyond the limits that the satellite stations themselves could deal with since the satellites are essentially static. The mobile units also could respond to unusual data inputs; e.g., from one or more unmanned satellite stations that indicate a peculiar situation occurring not at a satellite but between two of them. Thus, there might be a need to respond to such situations on a real-time basis or as close to a real-time basis as possible. There is a need, then, for an emergency transportation capability within the system, as well as the capability to reposition the satellite station as research expands.

A typical flow pattern for equipment, supplies, and personnel would show these items being transported from shipping points in the

south to North American arctic or near-arctic terminals. Commercial sea, air, or land transportation normally would be used, although military sea or airlift might be used for government-sponsored projects. Examples of arctic or near-arctic terminals that would be useful for support of Arctic Basin research are Fairbanks, Barrow, Inuvik, Yellowknife, Resolute, and Thule. In some situations, the terminal may also serve as the base camp. Examples would be the use of Barrow or Inuvik to support satellite stations in the Beaufort Sea that were located within the radius of the mobile satellite support units. In this case use would be made of available facilities at such bases. If satellite stations are to be located outside the radius of a land base, a base camp should then be provided on an ice floe or ice island in the Arctic Ocean.

Materials and personnel would be moved from the northern terminal to the base camp by large STOL aircraft such as the Hercules C-130. An airstrip (with minimal preparation and maintenance) should be provided at the base camp for this purpose, although initial landings could be on an unprepared surface or equipment could be airdropped if necessary. When they are available, C-130 aircraft with air-cushion landing gear would largely eliminate the requirement for a prepared airstrip and would also eliminate resupply problems due to summer seasonal surface conditions.

Housing at the base camp should be modular with minimum personnel requirements for construction. Fuel storage and minimal forward base maintenance facilities should be provided. Diesel or propane generators would be used for power and heat, with waste heat from diesels being fully utilized.

The mobile units operating from the base camp would consist principally of helicopters and SEV's. Light or medium STOL aircraft could be useful in some situations, but for the sake of economical and efficient maintenance the helicopter-SEV mix should be the best combination at present. However, when air-cushion landing gear becomes available for light and medium STOL aircraft, a cost-effective evaluation should be made to determine if such aircraft should replace the helicopter. In the base camp itself, a few construction and materials handling tracked vehicles, such as a medium bulldozer, grader, traxcavater, and pack lift, as well as a few snowmobiles and sleds, should be provided. C-130's with air-cushion landing gear would reduce, but not eliminate entirely, the need for construction-type tracked vehicles.

Presently the helicopter offers the best means for establishing and supporting satellite stations. As SEV's become available this

situation will change. A vehicle such as the Voyager being developed and built by Bell Aerospace, Canada, appears to offer many advantages for support of research on the pack ice. Even when such vehicles become available, however, helicopters should be retained in the transportation mix. They have great flexibility for getting about and for doing a variety of jobs, including, as one example, use as a device for lifting and erecting structures in situations where cranes are not available. Helicopters also are needed for reconnaissance support for the SEV. The automatic hover capability for helicopters, earlier described under STATE OF THE ART, should markedly improve the capability of this aircraft to operate in low visibility.

Satellite stations may be manned or unmanned. If manned, housing might be provided by pre-equipped modular vans, one or more small 8' x 8' x 8' huts, or fold-truss structures such as described under Shelters in Section II. Heat and power would be provided by small diesel or propane generators. An airstrip would be necessary even if heavy equipment for resource exploration is to be brought in. A flying crane helicopter or an SEV could be used for this purpose.

Unmanned satellite stations would, of course, be established by airdrop from long-range aircraft operating from land bases. In the complex being described here, it is visualized that they would be established by helicopters or SEV's. They may consist of a variety of devices for the acquisition of data pertaining to the regions above, in, and under the ice, including the use of unmanned submersibles. A key element will be a reliable, long-life, economical power source. Current power sources (batteries, diesel generators, wind-driven generators), while adequate for many purposes, serve to restrain the full development of unmanned stations. For applications in which the cost is justified, the technology is in hand to provide isotope thermoelectric sources in the lower power ranges up to perhaps several hundred watts and isotope heat engines in the higher power ranges exceeding 1 kilowatt.

Data collection from the satellite station could be managed from the base camp and fed to an Arctic Data Management Center at a location such as Fairbanks. Space satellite communication links could be employed.

The Voyager Heavy Haul Hovercraft is composed of prefabricated modules that can be transported by air to an assembly point. Here, the modules can be bolted together to form the vehicle. Its gross weight when assembled is 40 tons, and its payload is 20 tons under normal conditions. This matches the C-130 capacity. The

forward 40 feet of the 64.5-foot-long deck is flat and open for use in hauling cargo. Again, this matches the C-130 capability; thus the Voyageur is said to be compatible with the C-130.

Various modules can be carried on the cargo deck. Thus a passenger module might be installed, or a workshop, or perhaps a drill. Used for other purposes than described here, the practicability of installing modules on the cargo deck would provide the vehicle an interesting variety of capabilities for use in the Far North.

The Voyageur or similar SEV would be used both to support the satellite station complex and to serve as a mobile station. A safe round-trip distance with a 15,000-pound payload would be on the order of 200 to 250 miles. Cruise speed would be 30 knots. Range versus payload is shown in Figure 4.

To summarize, the logistics concept suggested for support of research activity in the arctic pack ice would use conventional commercial transportation to northern terminals; C-130 (with air-cushion landing gear when available) to base camps in the Arctic Ocean; helicopters and SEV's (when available) for support of manned and unmanned satellite stations; and SEV's to provide mobile research and working platforms. It would be a dynamic, flexible system. The hardware to implement the system without SEV's and air-cushion landing gear for aircraft is available now, and full implementation of the system is expected to be possible by 1975.

It is visualized that research and resource exploration will be proceeding in a multiplicity of areas in the Arctic Basin; it will be conducted by both the U.S. and the Canadian governments as well as by commercial interests. The driving force for this activity will be the oil and gas potential of the Arctic and the military requirements associated with the Arctic. These considerations have been discussed in Sections III and IV of this report. To provide logistics support for this activity most efficiently and economically, a logistics transportation pool, supported by and available to all interested parties, should be established.

A modest beginning toward such a pool might be undertaken with the budget which follows. The budget also includes an estimate of scientific research personnel and institutional backup costs to indicate the scope of the research activity contemplated. The budget is limited to the logistics concept described in this section and does not include costs of icebreakers, submarines, space satellites, etc., that might otherwise be used.

BUDGET

First rough cost estimate, excluding icebreakers and satellites

Acquisition of logistics pool (aircraft, SEV's, helicopters, sundry vehicles, shelters, fuel storage, etc.)	\$30 M
New ground installations	5 M
Navigation and communications networks	<u>5 M</u>
Total first cost	\$40 M

Annual operating costs

400 men on logistics support, communications, etc. @ \$35K	\$10 M
200 researchers, including institutional backup @ \$50K	10 M
One-third of value of logistics pool	10 M
Commercial transportation to northern terminals	3 M
Research instrumentation systems	<u>5 M</u>
Total annual operations	\$38 M

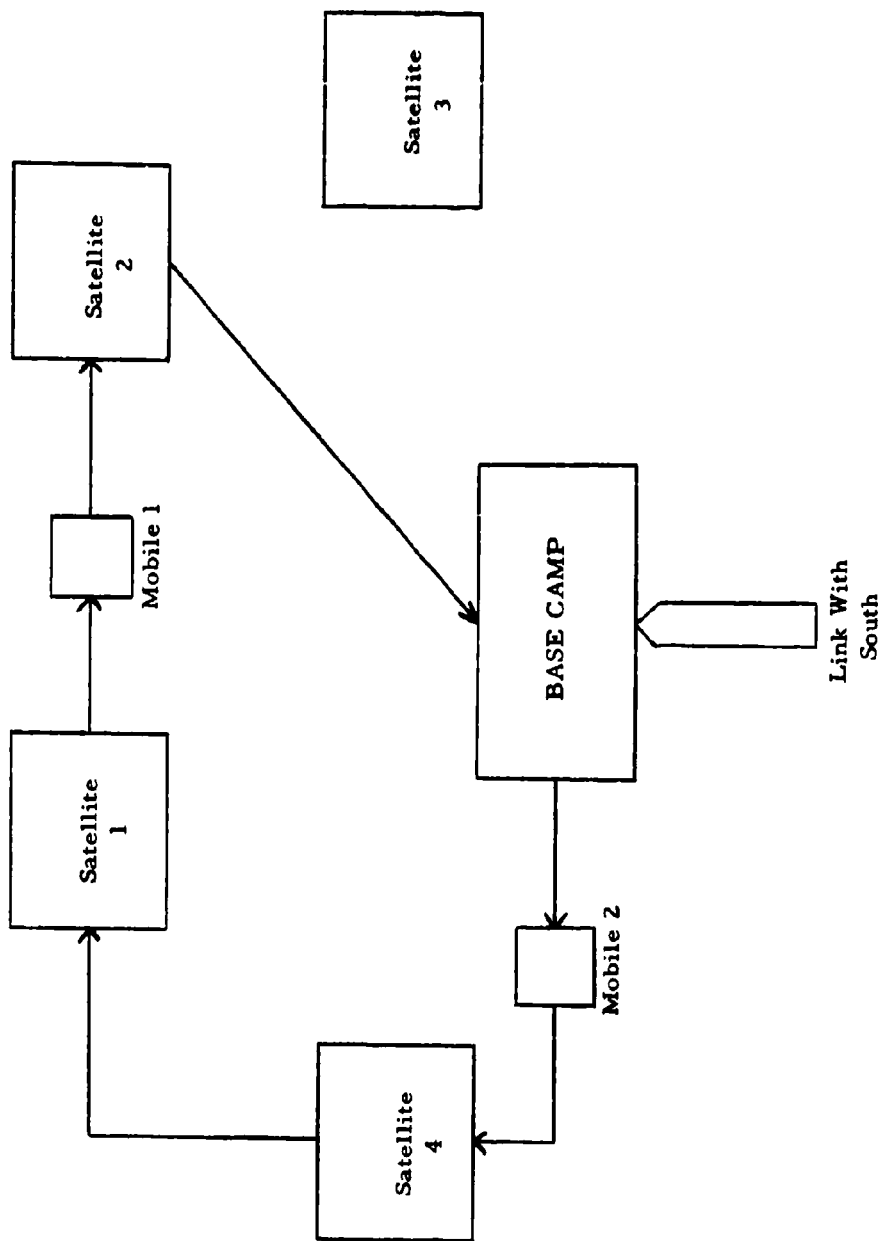


Figure 1
ARCTIC LABORATORY/WORK PLATFORM SYSTEM

BASE CAMP (S)	OPERATION MANAGEMENT COMMUNICATION CENTER LOGISTIC LINK WITH SOUTH DATA PROCESSING AND ANALYSIS SYSTEM LOGISTIC CENTER
SATELLITES	MANNED/ UNMANNED CONTINUOUS DATA GATHERING MOVABLE AS SEARCH MOVES/EXPANDS
MOBILE UNITS	INTERNAL LOGISTIC LINKS EXTEND SURVEILLANCE AREA RESPOND UNUSUAL DATA INPUTS EMERGENCY TRANSPORTATION REPOSITION SATELLITES

Figure 2
SYSTEM UNIT FUNCTIONS

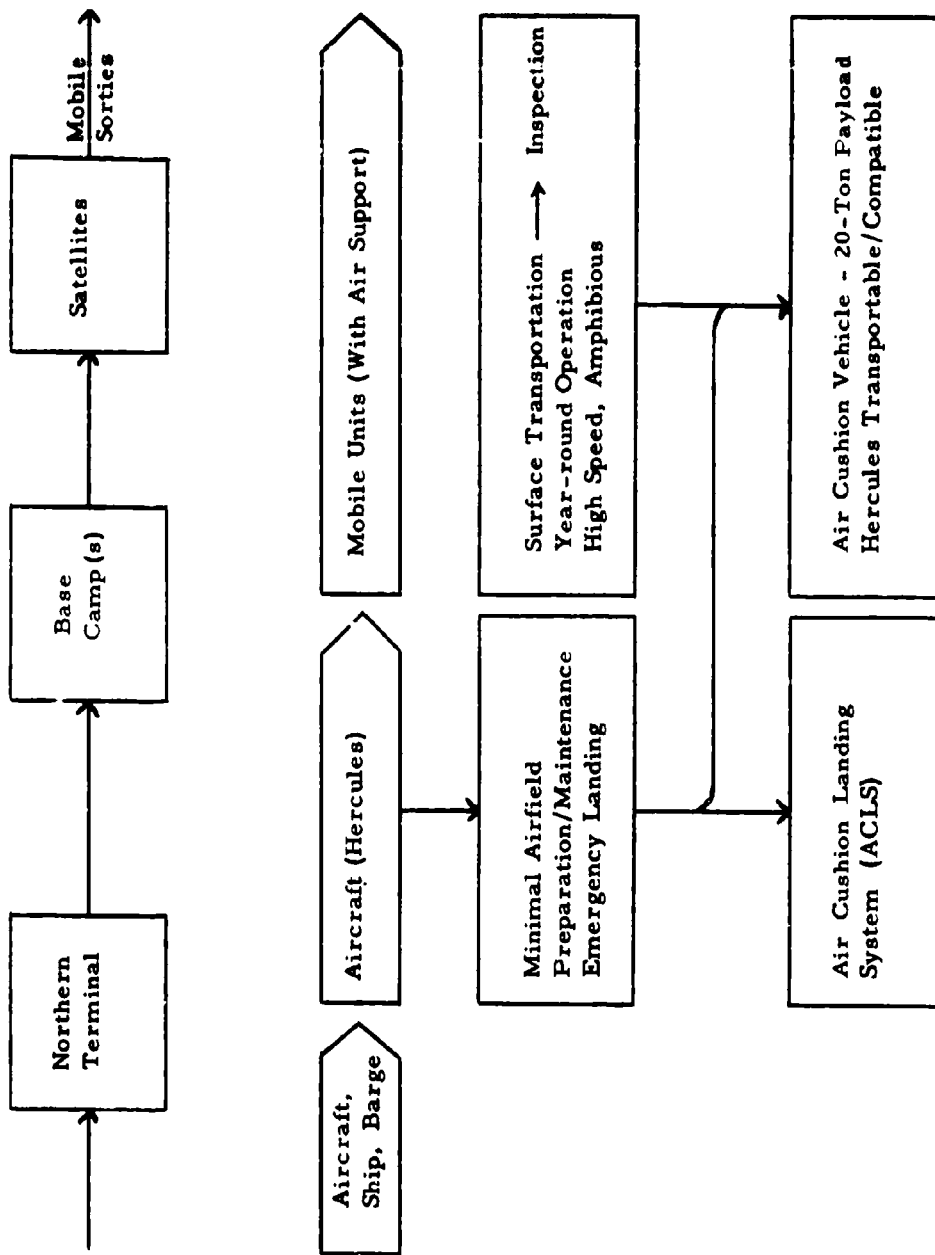
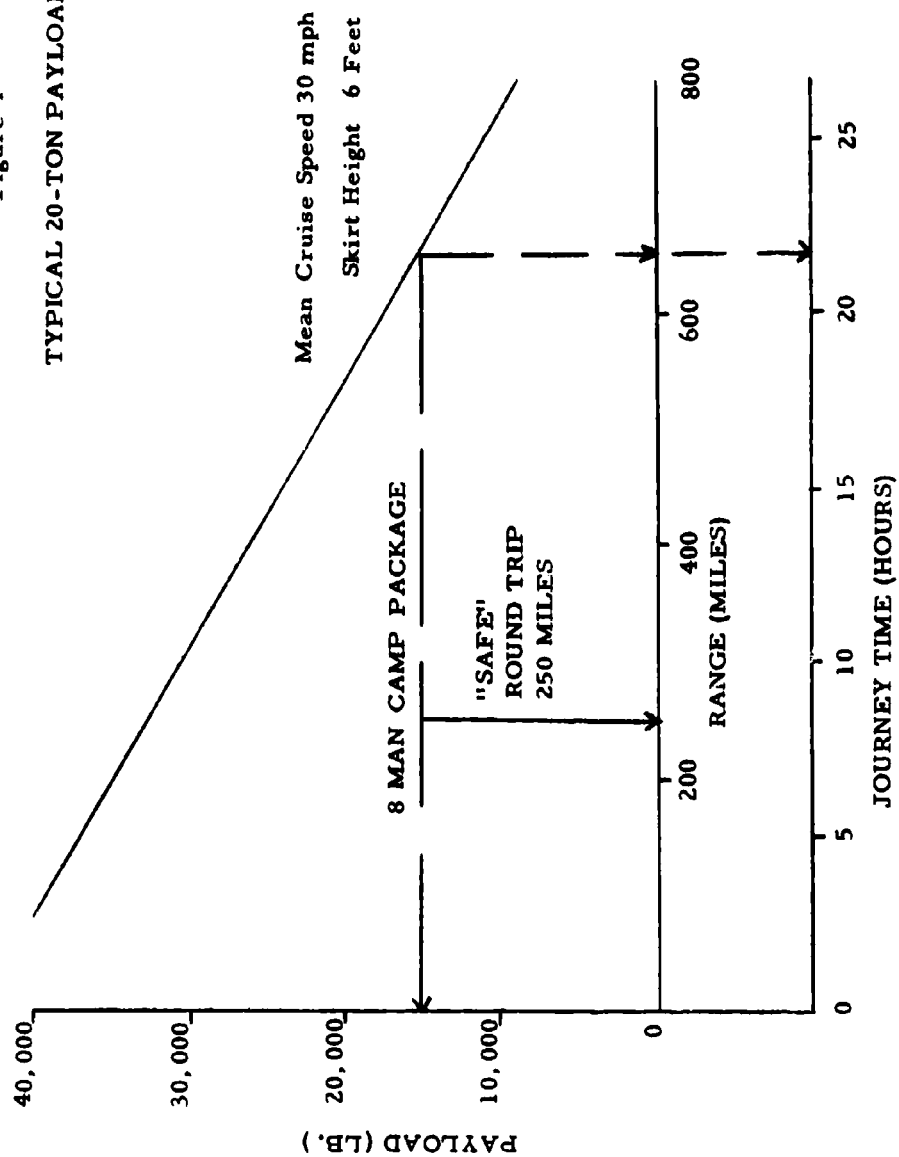


Figure 3
TRANSPORTATION FLOW PATTERN

Figure 4

TYPICAL 20-TON PAYLOAD ACV



Appendix 1

Symposium

Papers and Speeches

Welcoming Address and Introduction of Keynote Speaker	C. J. Wang ARPA
Keynote Address	J. O. Fletcher, NSF
Future Support Technology Requirements of the Arctic Research Investigator - On the Surface and in the Boundary Layer	N. Untersteiner University of Washington AIDJEX
Future Support Technology Requirements of the Arctic Research Investigator - In the Undersea Environment	W. H. Kumm NOAA
STOL Aircraft	R. Taborek, Ministry of Transport, Canada
Long-Range Helicopters	A. J. Rankin United Aircraft Corp.
Use of Surface Effect Vehicles for Arctic Transportation	W. J. Eggington Aerojet-General Corp.
A New Class of Ice Breakers: Its Design and Its Future	H. E. Fallon U.S. Coast Guard
Ships to Transit the Arctic Ocean*	R. P. Voelker, ARCTEC, Inc.
Power and Heat Production Systems	B. J. Tharpe General Electric Company
Modular Shelters for Arctic Application	J. Susnir ATCO Industries, Ltd.

* Read by abstract only

Water Supply, Sewage and Solid Waste Disposal	A. J. Alter Alaska Water Laboratories
Medical Aspects of Arctic Research Stations	P. E. Tyler U. S. Navy
Lightweight Arctic Shelter Concepts	J. A. McGrath, HITCO
Space Aids to the Polar Scientists	E. Stuhlinger, Marshall Space Flight Center
Light and Medium VTOL Aircraft in Present and Future Arctic Logistics	R. E. Lynch Bell Helicopter
An All-Season Vehicle for Sea Ice	K. W. Reimers Outboard Marine Corp.
Surface Effect Vehicles for Arctic Cargo Haul and Distribution	R. H. Miller Boeing Company
Arctic Pack Ice Transportation Vehicle	B. H. Adee University of Washington
Two Remote Arctic Measuring System Concepts under Development	B. M. Buck General Motors Corp.
Use of Instrumentation under Arctic Conditions	R. T. Atkins U.S. Army CRREL
Real-Time Data Presentation of Penetrometer	W. V. Hereford Sandia Corp.
Satellite Communications and Data Transmission	J. G. Puente COMSAT Laboratories
Logistics, Instrumentation and Geophysical Data Acquisition in Northern Greenland*	R. W. Pate Gruman Ecosystems Corp.
E-Phase: A Remote Sensing Technique for Resistivity Mapping and Sea Ice Thickness Measurement*	J. D. McNeill and A. R. Barringer Barringer Research, Ltd.

* Read by abstract only

Some Planning Considerations
for Arctic Data Management*

J. A. Hatchwell, AINA
S.B. Fishbein, Wheeler
Industries, Inc.

Ice and Transport in Arctic
Canada

G. H. Legg, Department
of the Environment, Canada

Mobile Laboratories and Work
Platforms

C. Faulkner
Bell Aerospace Company

The Unmanned Submersible as
an Arctic Research Tool

G. M. Gray
University of Washington

Technology of Man in the
Polar Sea

G. C. Ray, Johns
Johns Hopkins University

A Challenge for New Arctic
Technology

L. Zetlin
Lev Zetlin Associates, Inc.

* Read by abstract only

Appendix 2

The Polar Continental Shelf Project

The Canadian Polar Continental Shelf Project was initiated by the Canadian Government several years ago as a long-term investigation of the continental shelf region north of the mainland of Canada and north and west of the Canadian Archipelago. Conceived and still operated by the Department of Energy, Mines and Resources, the Project includes studies of continental shelf waters, sea floor, and subbottom structures, together with the islands of the archipelago, the straits and sounds between the islands, and the adjacent mainland where relevant.

Mainly, the Project concerns surveys and research efforts for which the Department is responsible, except where such efforts can be more economically and efficiently pursued as a separate, self-contained operation. However, the Project also supports worthwhile research in fields outside those normally undertaken by the Department if such research is in the national interest and could not otherwise be carried out.

One important function of the Project is to coordinate concerted action by agencies whose unique specialities or capabilities can be brought to bear on different but related aspects of a major arctic problem or study area. Another function is to provide continuity of planning and operation for various studies whose separate activities may be short-term and focused on individual problems. The field facilities of the Project are also available under certain conditions to approved university and other nongovernment research groups.

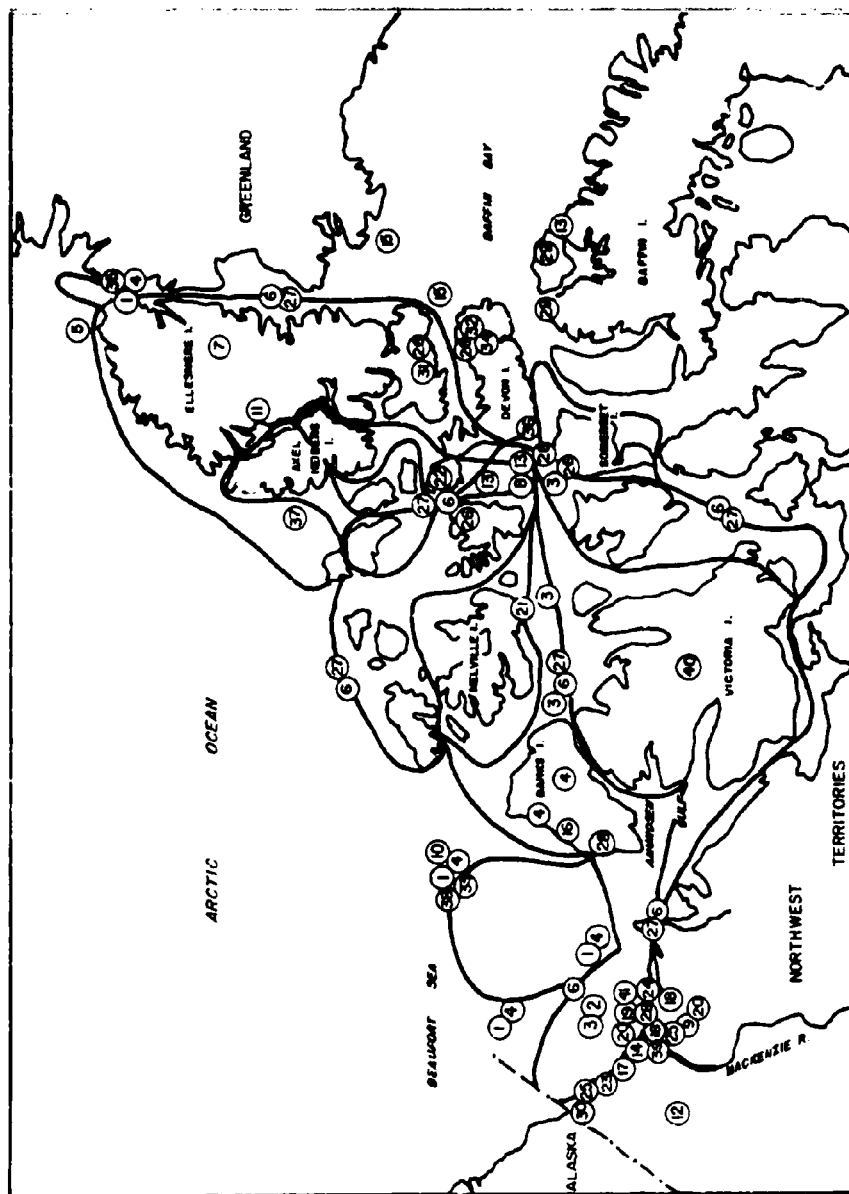
To demonstrate the scope of the Project, during 1970 its geographical spread was from the Mackenzie Delta - Beaufort Sea area to northern Baffin Island and Robeson Channel. (See accompanying map.) In addition to the Department of Energy, Mines and Resources, others involved in the 1970 program included three other Federal Departments; the National Museums of Canada; the National Research Council of Canada; one Province of Quebec Department; one American, one Japanese, one German, and four Canadian universities; the Arctic Institute of North America; and the U.S. Army Cold Regions Research and Engineering Laboratory -- for a total of sixteen agencies and groups.

The Project's staff includes a Coordinator, a Secretariat, a Field Operations Manager, and a Base Camp Administrator, plus

a dozen professionals in disciplines such as ice physics, hydrography, etc. The annual budget is approximately \$2.3 million, representing the direct expenditures by the Project itself. Other agencies supply their own funds, so the total dollar value of research supported by the Project is much higher.

To further indicate the large measure of cooperative work involved, 85 percent of the Project's budget is spent on shared or pooled operations and only 15 percent on any one single activity. Aircraft and fuels absorb 60 percent of the budget. Other types of logistic support and minor equipment procurement absorb 25 percent; and 15 percent goes to salaries and other personnel costs.

This description provides an example of an effective, efficient coordinating operation which can accomplish large-scale and continuing research programs in the Arctic. The Polar Continental Shelf Project might well be a model for a similar United States effort.



POLAR CONTINENTAL SHELF PROJECT
1971 Field Program

1971 Programs of the
Canadian Polar Continental Shelf Project *

- | | |
|---|--|
| 1. Hydrography (Central Region) | 21. Geology (Geomorphology) |
| 2. Hydrography (Pacific Region) | 22. Geology (Stratigraphy and Structure) |
| 3. Hydrography (Atlantic Region) | 23. Geology (Stratigraphy and Structure) |
| 4. Gravity (Regional) | 24. Entomology |
| 5. Geomagnetism | 25. Entomology |
| 6. Sea Ice Aerial Survey | 26. Animal Community Study |
| 7. Glaciology (Mass Balance) | 27. Sea Ice Albedo Study |
| 8. Hydrometric Studies | 28. Polar Bear Research |
| 9. Hydrology (Fresh Water Budget) | 29. Snow Goose Study |
| 10. Wind Stress Studies over Sea Ice | 30. Migration of Ringed Seal |
| 11. Sea Ice Thermodynamics | 31. Marine Botany of Sea Ice |
| 12. Geology (Mesozoic Stratigraphy) | 32. I. B. P. Tundra Ecosystem Study |
| 13. Geology (Geochemistry) | 33. ADJEX |
| 14. Geology (Geophysics) | 34. Arctic Institute of North America |
| 15. Geology (Glacial) | 35. Under Sea Ice Acoustic Study |
| 16. Geology (Pleistocene Stratigraphy) | 36. Geomorphology (Beach Studies) |
| 17. Geology (Geomorphology) | 37. Climatology |
| 18. Geology (Quaternary) | 38. Sea Ice Pressure Ridge Study |
| 19. Geology (Detailed Geophysics,
MacKenzie Delta) | 39. Geochemistry |
| 20. Geology (Quaternary Geophysics) | 40. Geology (Volcanic Stratigraphy and Paleontology) |
| | 41. Sea Ice Dynamics |

* Numbers correspond with those shown on map

Appendix 3

Research Needs and Support of Commercial Development

During the Arctic Logistics Support Technology Symposium, considerable interest was expressed among the participants during informal discussions as to the overlap between research and supporting logistics systems needed for commercial development and the research and its supporting logistics required by the Department of Defense. Thus, we first venture to list some of the main elements related to the development of arctic resources that call for further research:

- a) offshore drilling on the continental shelf
- b) design of pipeline transition from land to deep water
- c) design of offshore tanker and ship loading terminals
- d) ship design (surface ships, true submarines and continually surface-piercing hybrids)
- e) choice of optimal shipping routes
- f) ship traffic surveillance and regulations
- g) meteorological and sea-state forecasting
- h) rescue operations
- i) oil spill handling and other aspects of environmental protection
- j) effect on ice of regular repeated passage of ships

It is immediately evident that the one critical factor in all the listed items is moving sea ice, and it is fair to state that, with respect to sea ice, what we do know is very much less than what we need to know for engineering. In approximate order of decreasing knowledge, some of the pertinent subjects are:

- a) local conditions of formation and degradation of ice
- b) mechanics (strength, deformation under stress) of ice samples
- c) local energy exchange between the ocean and the atmosphere through water and ice
- d) mechanics of small floating ice sheets
- e) energy exchange of ocean and atmosphere over large areas
- f) hull stress of ice on ships
- g) motion induced stress in ice sheets and on fixed structures, such as drilling platforms

- h) techniques of surveying ice distribution on the ocean and development of ice cover statistics
- i) correlation between surface and ice bottom profiles
- j) large-scale ice mechanics, differential motions by wind and ocean current, and ice stress due to ridges and leads
- k) under-ice pressure waves which could affect submerged hulls
- l) prediction of ocean ice distribution for choice of optimal shipping lanes at different times of the year
- m) prediction of climatic changes and their effect on ice thickness and distribution

Obviously, the research subjects listed above are important to the engineer working on military items or on logistics technology as well as to the engineer designing arctic drill rigs, pipelines or ships.

Unfortunately, the need for scientific research as a basis for developmental and construction engineering is not universally acknowledged. We believe it to be in the mutual interests of the United States and Canadian governments and the private sector having arctic interest in both countries to coordinate and, where possible, integrate carefully planned arctic research on a much larger scale than has been carried out heretofore by largely uncoordinated efforts. Costly mistakes could thus be avoided in engineering, and could effect economies in the research itself.

Appendix 4

Welcoming Address

Dr. C. J. Wang

Ladies and gentlemen, welcome to this symposium. We are very happy to see such a large turnout from what is basically a small arctic research community. We sincerely appreciate your willingness to be here tonight, to devote your expertise in support of the Advanced Research Projects Agency programs. We hope you will come up with innovative ideas, and we look forward to your recommendations for new programs. We hope that with your help, our programs can be increasingly effective and productive.

About three years ago, ARPA initiated its arctic research program. Many of you helped in formulating this program and in its progress to date. Since then, we have been getting more and more deeply involved in arctic research programs. Broadly speaking, our effort is devoted to the development of arctic operational technologies with specific reference to arctic mobility, undersea operations, and information gathering. We are addressing the operational problems facing DoD today and those which DoD will possibly be facing in the future. Particular mention may be made of our development of the technologies of arctic surface effect vehicles and of R & D in such problem areas as under-ice acoustics, remote sensing, and cold regions construction technology. These are examples. We are running these programs at the level of something like \$10 million per year. We expect to maintain this level or possibly increase the level slightly in the next few years. Of course, ARPA's programs are only a part of the national program, and a national program must face the broad responsibility of arctic research including operations, technology, and the sciences. Such a program undoubtedly will involve agencies such as the National Science Foundation, National Oceanic and Atmospheric Administration, Department of Transportation, Department of the Interior, Department of Commerce, and National Aeronautics and Space Administration, in addition to the Department of Defense.

A major part of arctic programs is logistics, and it is for this reason that we have convened this special symposium on logistics. A fact of life is that the remoteness of the Arctic and the harshness of the environment make logistics a major part of any arctic operation or research program. This applies from the planning stages right through

to the completion of the operation. The impact of logistics is felt in terms of operations costs -- both dollars and manpower requirements -- and operational constraints. For programs which the Department of Defense is conducting or has considered, the dollar cost of logistics ran from 20 percent to as much as 80 percent of the total program cost. This amounts to many dollars, and some very worthwhile programs could not be carried out because of the great logistics costs that would have been incurred.

Effects of limited logistics capabilities on manpower requirements or feasibility of operations are harder to quantify, but are of no less magnitude. Thus, it is of major importance that new concepts and techniques be developed to reduce the costs of arctic operations and research programs.

It is my personal belief, as I am sure it is yours, that the Arctic is becoming more and more important and so will our arctic research efforts. Undoubtedly, in the coming years, there will be an evolution in our national arctic efforts. The success of this evolution will require the participation and devotion of many people, but in particular we can think of one person whose effort and leadership will have a most critical impact. We are indeed most fortunate to have this man as our keynote speaker tonight. We are gratified that he came here to share with us his wisdom. Ladies and gentlemen, it is my pleasure to present to you our speaker -- a leader and a pioneer in his field -- the new director of the Office of Polar Programs, National Science Foundation, my good friend, Joseph O. Fletcher.

Appendix 5

Keynote Address

J. O. Fletcher

As I look around the room, I see many unfamiliar faces -- scientists and engineers who are bringing new ideas and expertise to arctic operations. I know I speak for us all in saying, "Welcome!" We need you! The challenge is worthy of your efforts. For my part I admit to a certain bias, but I hope I may give at least the appearance of frankness shown by an old Civil War veteran who wrote a book which he called "An Unbiased History of the Civil War, From the Southern Point of View."

My own bias goes back 22 years, late in 1949. I was just a southern boy who had thought snow was a Christmas decoration.

Then I was posted to Fairbanks as commander of a B-29 reconnaissance squadron. We moved the squadron into a place called "Mile 26," because it was 26 miles from Fairbanks. It was later called "Eileson Air Force Base," but it did not really deserve a name up until then because it was just 3 miles of concrete runway and a cluster of quonset huts.

So, we piled in with 12 aircraft and tried to maintain daily missions, 16-hour flights over the Arctic Ocean and over the Bering Sea. It got dark and cold (-50° below) and all the aircraft maintenance had to be done outside or in four old nose docks that cover only the front of the aircraft. Then we were ordered to change all the engines -- there were only 48 of them. It seems some bright, innovative engineer had figured out how to get more power from them by doing things to get a higher compression ratio. It was one of those good ideas prematurely put into action. The modified engines started blowing up in flight. After a few weeks of harrowing engine failures, it was discovered that certain other changes were also necessary at the factory -- so we changed all 48 of them again. By this time it was March and only 35° below. We were so glad to see warmer weather and daylight that we convinced ourselves we liked the Arctic. The old story of it feels so good when you stop. To keep my sense of humor, I was reading Steffansen's book "The Friendly Arctic." It took me all winter to finish it.

Coming to the Arctic at that time in an operational role, I have been privileged to witness the rapid development of our technology over the last two decades.

For example, before World War II, only a few pioneers were flying the Arctic, men like Byrd, Wilkins, and Eileson. During the war our Russian allies accepted aircraft at Fairbanks and ferried them to the front, but no one was doing much on the Arctic Ocean. After the war, we set about adapting our machines to the arctic conditions -- grid navigation, radio communications, celestial reference during twilight, a lot of things that gave us trouble until we learned how to cope with them. On our lone polar flights, we carried two radio operators and three navigators, one taking celestial shots, one working the radar, and one doing computations. Even so, we had some bad situations. One of the greatest advances in arctic navigation was simply the advent of a gyrocompass that did not process rapidly. Two years ago I made the same flight with a California squadron. They flew jets and covered the track in 7 hours rather than 16. They didn't carry any radio operator and the one navigator is resting most of the time. There just aren't any inflight problems.

On the ground jet engines have eliminated most of the cold weather maintenance problems. They love the cold and they keep turning for thousands rather than hundreds of hours.

New materials and improved design have eliminated most of the old problems of leaking seals in fuel, oil, and hydraulic lines. In short, the problems of operating large aircraft from fixed bases seem to me to have been pretty well solved. Unfortunately, the same cannot be said for surface operations. We have not applied our advanced technology very vigorously to conducting operational activity on the surface of land or pack ice or ice cap. The reason is simple, we had no need to! Lacking an arctic population, lacking economic incentives for resource development in nature, the old ways were good enough.

But not any longer! After millenia of no change, followed by a few decades of accelerating change, we now are poised on the brink of explosive development in the Arctic that within a decade will make 1971 seem like a primitive frontier. The immediate reason is oil, but I believe there will be a multitude of other spin-off activities and enterprises that we do not see yet.

I think it is certain that in 1981 we will look back to this day and marvel that we could have stood on the portals of such explosive changes without perceiving either true character or significance any more than the social and economic consequences of the automobile

were foreseen in 1920 or the impact of the federal highway system was foreseen in 1955.

The evidence that we stand on the portals of change is clear enough. In a few months the Alyeska Pipeline will probably get a permit. Present cost estimates go to \$3 billion. More than \$1 billion will be laid out to settle native claims. Two billion dollars have already been invested in the North Slope.

But, this is just the vanguard of the future. Geological evidence is that most of the oil lies in the western Canadian islands. Much of the area is ice-covered sea. While Alaska possess one-third of the total U. S. Continental Shelf, the Canadian islands have a larger share of the Canadian Continental Shelf.

We may ask, is the demand really great enough to justify development in such an environment? If the investment in the North Slope does not convince you, then consider this. The U. S., with 6 percent of the world's population, now uses one-third of the world's energy. If the rest of the world came up to present U. S. energy consumption, it would demand a sixfold increase within 20 years. The demand is there: the problem is how to find it and get it out.

As with all surface operations, this boils down to devising an effective logistics and operational support system for the arctic environment. The key to efficiency is to understand and utilize the environmental factors, using our advanced technology to invent ways of exploiting their features. We must strive to make nature our ally rather than our enemy. Moreover, we must address these operational demands under new and stringent rules of engagement, for in the last two years we have also seen the beginning of the ecological revolution. For the first time in the development of our industrial society, we refuse to accept the degradation of the air and the land and the water. We demand that our technology preserve the quality of the environment.

If we look to the past for parallels, we find that man has a consistent record in anticipating periods of such rapid development -- consistently wrong; he is consistently too conservative. We must try to improve that record. When I see populations doubling and redoubling in a lifetime; when I see rising rates of consumption all over the world; when I contemplate the enormous drain on our nonrenewable resources in the next few decades; when I see man going to the ends of the earth and to the ocean floor to recover needed resources; when I see him unlocking the energy of the atom and harnessing the rays of the sun; when I see him groping for control over his planetary environment; in short, when I comprehend the boundlessness of man's

expectations and the vastness of his challenge, I am certain of one thing: The future is not for men with small dreams; it is not for men who fear innovations; it is not for timid men. No, the future is for men who dare to have great expectations and who have the courage, the persistence, the wisdom, and the patience to transform their expectations into realities. I believe we have such men. We have them here tonight, in this very room, and during the next three days, we will see their talents for innovation shaping the future that we will all share.

We might well keep in mind the old story of the three men who were working in a marble quarry. When asked what they were doing, one answered that he was working in a quarry. The second answered that he was cutting and shaping blocks of marble. The third answered quietly that he was helping to build a cathedral.

Appendix 6

LIST OF PARTICIPANTS

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