SECOND INTERNATIONAL CONFERENCE ON
PORT AND OCEAN ENGINEERING UNDER ARCTIC CONDITIONS
UNIVERSITY OF ICELAND
DEPARTMENT OF ENGINEERING AND SCIENCE

A LOOK AT U.S. ARCTIC MARINE COMMERCE TO THE YEAR 2000

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PREFACE

Recently, the discovery of significant energy resources in Northern Alaska and Canada has increased world interest, both social and economic, in the Arctic region. This is giving the northern region a prominence it has not held for many decades, since U.S.-Canadian concern for North American Defense in the 40's and 50's. World markets are beginning to look seriously to the wealth that the North is known to hold, and Western governments have a growing awareness of the native residents, their lands, and the problems they face.

Since the U.S. Government can predict, at this time, a rising dependence on foreign energy reserves, it is both fortunate and fortuitous that the Arctic Institute of North America was tasked to study the requirements of Arctic commerce, as viewed by industry, and the relationship of these requirements to international factors.

The interests of all peoples involved can best be served when economic progress is achieved in an orderly manner. This integrated study seeks to identify and describe the scope of future marine commerce in the northern areas.

People concerned with the problems of the North are aware of the magnificent scientific and exploratory work performed by many dedicated scientists, engineers, and industrial organizations directed at understanding the economy, the environment, and the problems of the people. These past efforts underscore the fact that

much more needs to be done. This study hopefully will bring attention to the economic factors, as viewed by the industrial community, that can weld the peoples of the Arctic region into a more economically viable entity.

Vast quantities of oil, gas, and hard mineral resources exist in the Alaskan Arctic. The utilization of these resources and transportation to domestic and world markets is dependent upon the demand for energy and raw materials, the cost of extraction and transportation, and the relative costs of other sources of supply.

Since the cost of transportation is a major component of total delivered cost and a constraint which makes some resource concentrations too expensive for certain markets, the development of efficient and economic transport systems adapted for Arctic operations will undoubtedly have an accelerating effect on exploration and the development of critical resources - mainly fuels - in the northern regions. With resource development will come an evolution of population and civilization creating other requirements for transportation services. Since marine transportation has long been one of the lowest cost modes of transportation known to man, it is likely that it will have a vital role to play in the future of Arctic commerce.

The range of topics considered in the Arctic Marine Commerce Study is broad. There is no question that some of these topics are sensitive, controversial, and may be debated at length by special interest groups or by experts of fixed convictions. In all cases the study team has tried to recognize these interests and to inject a professionalism into the work which transcends individual group interests and yet considers the practical viewpoint.

INTRODUCTION

The Arctic Institute of North America, under the sponsorship of the Department of Commerce, Maritime Administration and with the help of the industrial community and the State of Alaska, has performed a comprehensive study to determine the future requirements for arctic marine commerce. Inclusive in the objectives of the study was the definition of the roles of government and industry in the development of marine systems, commercial port facilities, associated intermodal transportation systems and related community centers. These requirements establish a basis for predicting and planning all aspects of marine commerce in the Alaskan Arctic to the year 2000. In developing these requirements, the study was quantitative and analytical with emphases on important and practical economic and social values.

The Arctic Institute performed this multidisciplinary study with inputs and critique from key industry executives from arctic resource and service companies, State of Alaska officials, and representatives of Alaskan interest groups. Inclusion of the industrial viewpoint was considered vital in that it is industry's investment together with an appropriate Federal and State climate that will make the growth of the Alaskan Arctic feasible.

The orderly development of regional resources and supporting activities will have a paramount influence on the economic growth of the region. Therefore, the study includes the examination of those facets relating to the development and production of oil, gas, hard minerals, and other resources in order to determine the mode and level to which ocean and coastal shipping will be required and achieved.

The geographic scope of this study included the entire northern and western coast of Alaska, the Aleutian chain, and the shipping path associated with Herschel Island and the Mackenzie River in Canada, since some 30% of cargoes destined

for Prudhoe Bay in the past arrived via this route.

The advancement of offshore technology in ice covered waters, dealing with the development, recovery, and transportation of resources, prompted the study team to anticipate the magnitude of these resources entering the world market. Estimates for the offshore resources are indeed substantial and will probably surpass those on the mainland in years to come.

The timely development of the Canadian Arctic and its valuable resources will have a decided impact on the economics of the Alaskan region. Therefore, the implications of these growth patterns have also been taken into consideration as well as international regulations and relations associated with such trade.

CARGO FORECAST

The outbound commodities which are likely to move in bulk transport over the time period treated were found to be oil and gas, copper, fluorite, coal, tin, and tungsten. Manufactured industrial and consumer products comprise the inbound movement. Tables 1 and 2 contain estimates of the outbound movement by commodity and time frame. The inbound movement was felt to be too small - even if magnified many times over - to occasion notable new fleet requirements.

As can be seen by inspection of the tables, the order in which bulk commodities are forecast to begin moving out of Northwest Alaska is arranged according to volume (as opposed to time frame). Note too that fossil fuels and hard rock minerals make up the cargo requirement outbound, as neither forest products, agricultural products, nor fish products are forecast to be part of the outbound traffic from this part of the state in quantities sufficient to require additional shipping.

The destinations of Alaskan commodity outflows are seen to be the U.S. West and East Coasts, and Japan. The subregional origins in Alaska are four in number and distinct as to commodities. These are oil and gas from the North Slope of Alaska; copper from the Kobuk valley area; fluorspar, tin, and tungsten from the

TABLE 1-A

ESTIMATED DEMAND, PRICE, SUPPLY, AND PRODUCTION OF

ENERGY RESOURCES OF NORTHWEST ALASKA TO YEAR 2000

Commodity		U.S. Demand	Price a/ In Constant Cents/Unit	Supply N.W. Alaska Resource Total	N. W. Alaska Annual Production			
					World		U.S.	
					Europe	Asia	W. Coast	E. Coast
Oil	1973	774 mt	301¢/bbl.		-	-		
	1985	1055 mt	433¢/bbl.		0	0	.72 b bbl	.45 b bbl
	2000	1402 mt	598¢/bbl.	35 b. bbls.	0	0	.72 b bbl	.792 b bbl
Gas	1973	25 tcf	58¢/1000 cf		-	-	-	-
	1985	33 tcf	79¢/1000 cf		0	0	0	.81 tcf
	2000	44 tcf	124¢/1000 cf	300 tcf	0	0	0	1.25 tcf
Coal	1973		$7.00/ton		-	-	-	-
	1985		$7.97/ton	More than 200	0	3.5 mt	0	0
	2000		$11.00/ton	billion tons.	0	3.5 mt	0	0

a/ Prices are quoted very conservatively in constant 1973 dollars. Oil and gas are undoubtedly low in view of current price fluctuations and could be double the figures shown. Prices are market value and represent the price with which Alaskan commodities must compete.

Iron ore, forest products, and fish products are omitted because these commodities are not forecast to be commercially available in Northwest Alaska north of Bristol Bay.

We assume the Alyeska pipeline operating in mid 1978 and a second oil transport system probably a Mackenzie Valley pipeline, operating in 1982.

TABLE 1-B

ESTIMATED DEMAND, PRICE, SUPPLY, AND PRODUCTION OF HARD MINERALS

OF NORTHWEST ALASKA TO YEAR 2000

Commodity	Demand		Price a/	Supply	N. W. Alaska Annual Production			
	Rest of World	U.S.	In Constant Cents/Unit	N.W. Alaska Resource Total	World Europe	World Asia	U.S. W. Coast	U.S. E. Coast
Copper (1000 tons)				More than 100 mil. tons ore containing at least 1.3% Cu.				
1973	4,912	1,627	52¢/lb		-	-	-	-
1985	9,300	2,900	67¢/lb		0	0	216 th tn	0
2000	18,300	5,400	75¢/lb		0	108	" " "	0
Fluorite (1000 tons)				More than 28 mil. tons ore containing in the order of 18% CaF_2				
1973	6,690	2,600	$66/ton		-	-	-	-
1985	12,525	4,850	$90/ton		0	75	225 th tn	0
2000	24,646	9,700	$100/ton		0	150	450 th tn	0
Tin and Tungsten (Long tons)				Not known				
1973	180,100	49,900	Sn 167¢/lb W 296¢/lb		-	-	-	-
1985	220,000	70,000	Sn 230¢/lb W 325¢/lb		0	3000	6500	0
2000	270,000	90,000	Sn 300¢/lb W 400¢/lb		0	6000	12,500	0
Graphite (1000 short tons)				Probably millions of tons, but individual deposits relatively small.				
1973	378	57	$46.50/ton		-	-	-	-
1985	730	70	$48.00/ton		-	-	-	-
2000	1,380	95	$50.00/ton		0	0	3000 tn	0
Mercury & Antimony				Not known, but probably hundreds of thousands of tons of ore in widely scattered areas.				
1973					(A few hundred tons produced)			
1985					0	0	1000 tn	0
2000					0	0	2000 tn	0

a/Market value.

TABLE 2

ESTIMATED OUTBOUND MARINE CARGO FROM NORTHWEST ALASKA, 1973-2000

(In Thousands of Tons Annually)

Commodity [a]	1973-1976	1977-1980	1981-1985	1986-1990	1991-1995	1996-2000
Oil	0	8,824-55,150 [b]	61,768-172,068 [c]	211,776	211,776-275,039 [d]	275,309
Coal	0	0	3,500 [e]	3,500	3,500	3,500
Copper	0	0	216	324 [f]	324	324
Fluorite	0	300	300	300	300	600 [g]
Tin and Tungsten	0	9.0	9.5 [h]	9.5	9.5	18.5
Graphite	0	0	0	3	3	3
Mercury-Antimony	(Small Production)		1	2	2	2

Notes:

a/ Gas is omitted because it is assumed to move solely via pipeline over this period. Iron ore, forest products, and fish products are omitted because these commodities are not forecast to be commercially available in Northwest Alaska north of Bristol Bay.

b/ Assumes Alyeska pipeline operating in mid-1978.

c/ Assumes second oil transport system, probably trans-Canada pipeline, operating in 1982.

d/ Assumes third oil transport system operating. Possibly marine tanker.

e/ Assumes sub-bituminous coal mined (beginning in 1985) to mix with higher quality coal elsewhere to make coking coal.

f/ Assumes a second copper mine coming into production in 1990 with 108,000 tons annually.

g/ Assumes second fluorite mine coming into production in 1996 with 300,000 tons annually.

h/ Includes also a tungsten placer development starting in 1985 with 500 tons annual production.

Source: Authors' calculations based on U.S. Bureau of Mines price and demand forecasts and most probable Alaska participation in supplying that demand.

Seward Peninsula; and coal from the Cape Lisburne to Point Lay area.

Taking the U.S. Department of the Interior's latest price forecasts for these commodities for the years 1985 and 2000, together with estimated domestic and worldwide demand over the period, it was concluded that exploitation of Alaska's natural resources would become commercially feasible as indicated. Average unit costs of minerals production are expected to decline in Alaska at least relatively, and perhaps in absolute terms. Further, the average yields in certain of the resources, particularly oil and copper, are expected to be high because of the quality of the finds.

THE ALASKAN ECONOMY - OVERVIEW AND PROSPECTS

What will happen in Northwest Alaska depends in great measure, of course, on the dynamics of the overall Alaskan economy. Accordingly, an understanding of the outlines of the State's economy is essential to forecasting natural resource development in that "corner" of the continent, with its attendant requirement for marine shipping.

In addition to the more direct economic factors, Alaska's growth and development will be shaped by its small and geographically concentrated population (sharply divided into Native and non-Native members); the presence of difficult climatic and physiographic barriers to transportation and communication; and a location remote from United States and foreign markets.

From an overall vantage point it is accurate to say that Alaska has barely been subdued as a massive land area, and a modern civilization is only beginning to prevail there. The population is generally located in small communities (25 or more persons) in the coastal parts of Alaska and along the main rivers leading into the interior. Even the major cities, which hold most of the non-Native

citizenry of the state, are seaports or (in the case of Fairbanks) river cities. It is a maritime state which has yet to penetrate inland with a surface transportation network to support interior economic development.

The relation of transportation to economic development has been widely treated in the literature. In the case of Alaska almost all observers would agree that the single greatest deterrent to the state's more rapid development is its limited transportation system. With few exceptions (notably air transport service, the ferry system, and marine service to the Railbelt) the state of transportation in Alaska approximates that of the other states a half-century or more ago.

It is of course questionable to single out any single item as a prime mover (or deterrent) to development. Natural endowments, price/cost structures, world markets, and institutional forces are among other ingredients to be considered. But more than in most cases can the pace of Alaska's economic growth and development be tied to changes in transport capacity and service.

In focusing on the geographic region which is the principal subject of this study, the area from Bristol Bay northward, we find the entire region to have perhaps 45,000 inhabitants, about 85% of whom are Natives. They live in some 80 villages with the largest being 2,000 to 3,000 in population. The area comprises about 150,000 square miles and is the "most Arctic region under U.S. jurisdiction." The climate is adverse, with temperatures ranging from -40° to +60° F. Tundra and mountains characterize the terrain.

As elsewhere in rural Alaska a dual economy exists. Most of the village population is still economically and culturally tied to a subsistence economy - hunting, fishing, berry-picking, and fuel-gathering. Cash incomes for natives here are irregular and temporary except for welfare payments. For thousands of Alaskans - and certainly rural Native Alaskans - poverty has been an accepted fact of

life. During territorial days, particularly until the Second World War, Alaska was a remote and somewhat neglected ward of the federal government, and the initial financial strains imposed by statehood have prevented Alaska itself from correcting the situation. The Alaskan Native Claims Settlement will drastically change this situation, but the exact nature of this change is not known.

The money economy in this region is by and large the province of the non-Native minority in Nome, Kotzebue, Barrow and Unalakleet. Government - federal and state - is the biggest and steadiest source of income and employment, accounting for more than half of the wage and salary payments in the area.

The potential for the economic development of this area lies largely in fuels, minerals and tourism. Presently no mineral production is being carried on in this region. But with the North Slope oil promise; a heavily mineralized Brooks Range and known quantities of high-grade copper ore in the Kobuk Valley; a major fluorspar find at Lost River with associated tin, beryllium, and tungsten; and huge reserves of bituminous and sub-bituminous coal underlying the area from Cape Lisburne eastward, this may change. This study assumes that some of each of these commodities will be extracted over the given time frame. Spectacular developments in the mineral industries could take place, but there is, at a minimum, an assured modest economic impact from continuing growth in exploration and development activities.

Assertions are sometimes made of a future Northwest Alaska dotted with major cities in the mode of Soviet northern development. The more likely case is that of highly self-contained, modern work camp communities, small in size, and with high-speed transport substituted for a major resident citizenry - all staged out of Fairbanks or Anchorage. In this vision, North Slope oil communities would be less than 5,000 people in size, a mining town in the Kobuk area would have

fewer than 2,000 inhabitants, and a mining town and port community at Lost River would be of perhaps similar or slightly larger size. Furthermore, the multiplier effect, in terms of secondary labor demand, even with large-scale mineral development, will likely be very small (less than 1.2) since the local economy has little to sell the mining companies or their employees. While such propositions are of the chicken/egg variety, it does seem fair to say that the lack of either a skilled in-place work force or an economic infrastructure in advance of proved mineral discoveries is a serious hindrance to the speedier growth and development of the region.

Alaska's political economy is shaped by federal-state-industry interest groups revolving around the critical issues of land use, resource development, and environmental conservation. The attitudes, beliefs, values, and pressures brought to bear by these diverse interests have, in the past, developed structural imbalances which have acted as bottlenecks to economic growth.

The emergence of new forms of regional governments in rural Alaska, however, has been stimulated by the land claims settlement interacting with associated economic, social and political forces. The effectiveness of this movement (based on passage of the Alaska Native Claims Settlement Act of 1971) has already had significant impact on the shape of future development. The act promises to have even more profound and as yet imperfectly understood impacts in the future.

Geographic location and resource endowments have given Alaska an international dimension. Comprising two-thirds of the total U.S. coastline, it has potentially ready access to the cheapest mode of bulk transport, ocean shipping. Located on the polar routes between Asia and Europe, it presently participates heavily in international air transport of passengers and goods and may in the

future participate in surface transport of world commerce as these technologies advance. It is at least a day-and-one-half steaming time closer to the Orient than other West Coast points and is connected with the U.S. East Coast by the Northwest Passage. The Great Circle routes from the western United States make parts of Alaska very close to the sea lanes of the North and East Asia-U.S. trade.

At present Alaska's commodity trade is largely confined to Japan and Canada, with Japan clearly the major foreign market for Alaska's products.

It is entirely possible, of course, that Alaska's trade with other countries besides Japan and Canada could become substantial over the time period of this study. Korea and Formosa in the near term, and perhaps China and the USSR, conceivably could enter into trade relationships with Alaska.

PORTS AND INTERMODAL SERVICE

The primary need for ports centers on the highly mineralized Seward Peninsula. Potential sites narrow to two alternatives in the Lost River area to service the proposed fluorspar mining operation, but with additional consideration of the regional development aspects for the whole Seward peninsula and perhaps the Kobuk Valley. These ports were treated in substantial detail from the engineering, economic, and operational points of view. The candidate sites for regional port development (40' depth) were:

* Near the mouth of Lost River ($15 million investment) and
* Brevig Mission - inside Port Clarence ($7 million investment - without considering the cost of supporting roads).

Other port sites considered in detail were:

* 30' depth port at the neck of the Baldwin Peninsula in Kotzebue Sound (copper) - estimated $32 million.
* 30-35' depth port at Wainwright (coal) - estimated $40-$50 million.

The general policy of port development must obviously be guided to a considerable extent by financial considerations and not only the economic characteristics of the region. Funds for investments are scarce whether they come from outside sources or from local reserves.

Final justification of major port projects can seldom, if ever, be sought in direct profits. Most port administrations are public trusts and their aim is to provide adequate services to shipping and commerce and not to make a profit. But from a purely financial viewpoint, port development or modernization can represent considerable savings in costs associated with congestion or delays, as well as the reduction of cargo handling costs. Funds spent on port projects, therefore, represent a certain contribution to economic progress. Port development and marine access should be an integral part of the inland distribution system and coincide with the development of communities. The matter of financing of port development, and the federal responsibility in relation to the established state/developer relationship, should be examined in detail.

PIPELINES

Considering the level of capital already invested in the Prudhoe Bay to Valdez pipeline system, completion of the pipeline will result in the least cost delivery system to the West Coast of the United States.

Although Canadian oil and gas pipeline plans are progressing in a process similar to the U.S. one (legislative, environmental, etc.), proven reserves of these Canadian resources are not sufficient to justify the cost of building a

pipeline from the Mackenzie Delta to southern markets at this time without involving the shipment of the Alaskan resources. At the time of this writing, no pipeline permits in Canada have been requested, but this may change. The critical energy shortages experienced may, in time, force both countries to reevaluate the situation (including the advanced technology to overcome environmental problems) with the result that both pipelines may be built. Such pipeline construction, however, will not meet the anticipated market requirements for these resources and therefore does not preclude the need for marine delivery systems.

INTERNATIONAL LEGAL AND REGULATORY CONSIDERATIONS

Many problems and broad questions exist in international law which have a particularly Arctic reference. The upcoming Law of the Sea Conference will tackle many of these; others, however, will remain. They involve ice, floating or fast ice, baselines around archipelagos, or straight lines between headlands; they involve the status of channels, off-shore installations, and many other questions on which the law at present is sufficiently imprecise to warrant international attention. The rules or agreements that might emerge from a special Arctic conference of concerned states would need, of course, to have some consistency with the general law of the sea, toward which the nations of the world are now aiming. Nevertheless, the special features of the Arctic and the need to avoid acrimonious or even friendly bickering over rules suggest that Arctic questions should not simply be submerged in the general search for agreed international law of the sea and the seabed.

The future of arctic marine commerce will be affected by many rules, requirements, and freedoms which are not now included in the universally accepted rules of international law; but, more likely, solutions will come through regional and local actions or special agreements.

ADVANCED ARCTIC MARINE TECHNOLOGY

Advanced arctic marine technology, as it applies to Arctic marine commerce, includes vehicle technology, terminal technology, environmental sciences, and offshore technology, which cuts across the first three technical areas. There are, in fact, intertwining relationships between all four areas.

Vehicle Technology

Ships of appropriate size and power can transit the Arctic Ocean. With respect to the design and construction of large displacement ships there are no major knowledge gaps in Arctic ship technology. The problem is one of improving a vessel's capability to operate in ice, rather than developing new capabilities. Toward this end, studies should be undertaken on speed and power prediction in ice, design of propellers for ice service, development of ship hull loads, and a rational structural design methodology.

Conditions in arctic areas and in Alaska's interior river valleys indicate that surface effect vehicles may have inherent advantages which could lead to their wide application in this environment. The most frequently voiced objection to the surface effect vehicle derives from its high capital and operating costs. The historical evolution of the automobile and aircraft, however, would tend to support a prediction that the surface effect vehicle will become cost competitive within the time frame of this study, at least for specialized missions.

Preliminary economic studies indicate that total submarine tanker systems will not become economically attractive with other potential systems for arctic marine transport before the end of this century. Therefore, nuclear and non-

nuclear commercial submersibles and their special terminal requirements should be studied to verify their use for very deep exploration, drilling and transportation.

Terminal Technology

In this critical component of an Arctic Transport System there are major technology gaps which must be addressed as part of a technology development strategy.

First, there is a need for a state of the art engineering evaluation to compile, review, digest and evaluate data on the design, construction and operation of arctic marine terminals. The need is for readily available data and environmental or other information presented in such form as to be useful to the engineer.

Based upon the state of the art and incorporating the results of research into parameters such as ice loads, water loads, thermal effects, other environmental factors, and investigations of unique solutions, including materials for problems peculiar to the Arctic, a series of design criteria applicable to various types of terminal facilities should be developed.

The transfer of shore produced oil from shore to tanker and of offshore produced oil to land pipelines are significant problems. Not only is the mooring or docking facility susceptible to dynamic ice movements, but pipelines may be subject to ice scouring from bergs moving close to shore. There is also the question of laying hot oil pipelines in permafrost. Ballast water treatment may be part of the function of the terminal.

Experience with LNG terminals, while sparse, has indicated several potential trouble spots, e.g., mechanical reliability, icing on the loading arms, etc.

There are many unknowns associated with submarine loading methods. Until satisfactory submarine terminal capabilities are developed, submarine cargo operations will remain questionable.

The logistics support problems of arctic construction necessitate the use of native materials where possible. Ice islands and the dredging up of materials for gravel islands are being explored as ways to develop unique, fixed arctic marine terminals.

Early in the terminal design process, attention should be given to ecological impact and constraints on terminal construction and operation at selected potential arctic marine terminal sites.

In the early stages of planning the construction of a marine terminal, it should be known how the terminal will be operated and maintained for its useful life period. This includes safety, life support, fire protection and things of this nature. Terminal procedures and equipment should be developed to permit safe, economical and environmentally conservative operations in the arctic coastal zone.

While permanent fixed structures are envisioned for large volume resource production requiring frequent shipments, or for lesser projects involving infrequent shipments, a single-point mooring system could be more cost effective.

ENVIRONMENTAL FACTORS

The need for environmental information was reviewed in the context of the requirements of vehicle types, terminal design, and general environmental effects. There is a need for information on the surface roughness of the ice as a function of both season and geography, distribution of leads, and forecasts of times when icing might be expected. Also, data for the development of anti-icing technology and techniques is required.

In addition to high quality meteorological information, there should be a means of remotely characterizing the ice, e.g., numerical characterization of ice properties, concentration, distribution, thickness, ridging and velocity of the ice field. A means of numerically modeling to project future movements of the ice field should be provided as well as real time transmittal of ice data to ship operations. Development of more advanced radar techniques to improve shipboard characterization of ice is needed. Hydrographic and cartographic data need to be upgraded. High accuracy non-satellite navigation systems for the Arctic are required.

A major requirement is the need for detailed oceanographic and bathymetric data, particularly in a marginal sea-ice zone on potential routes. There is a need for improved statistical information on ridging frequency, ridge depths, the properties of ice in the lower portions of ridges, and forecasts of thin ice and open water along tracks. Research should also be performed into problems related to the defraction of sonar signals around obstacles such as icebergs.

Detailed local environmental information must be developed by on-site investigators for any area selected for port development.

High quality research programs such as AIDJEX should continue inasmuch as the basic data so collected is essential to developing a capability for monitoring and forecasting the physical environment of the Arctic. AIDJEX eventually could be expanded into the operational forecasting system required for marine operations.

Resource development, especially oil and gas, and all the attendant activities of construction, transportation, operation of modern living centers, and other new additions to the environment are a potential threat to its quality. The environmental implications of these activities and other uses of the area

should be analyzed in depth and assessment made of their impact on the ecosystem. This is necessary to identify the vulnerability of the system to various types of disturbances, to establish where the critical gaps in knowledge exist, and to make recommendations on needed research in both environmental and engineering fields. Resource development with environmental protection entails potential conflicts of responsibility and authority on scales from international to local which will have to be resolved.

FLEET REQUIREMENTS

Requirements for ships have been developed based on the best market analyses, cost estimates, and analytical methods presently available. Prices and cost estimates are changing constantly, thus making projections somewhat speculative. These projections are mathematical in nature and do not reflect fully all political and social factors which may enter into the decision-making process to build ships for operation on various arctic trade routes. Nevertheless, it is believed that our analyses are the most extensive to date, and that the results are sufficiently accurate to identify options and priorities for planning future marine transportation systems for arctic regions.

The Trans-Alaska pipeline as it is presently planned is the least cost system for delivering North Slope oil to the U.S. mainland considering "sunk costs" already expended. A Bering Sea tanker route to the West Coast using 125,000 DWT icebreaking tankers and Coast Guard icebreaker assistance is possible but extremely treacherous and more expensive than the Trans-Alaska pipeline.

Arctic tankers of the 245,000 DWT size can be operated through the Northwest Passage to the East Coast at substantially lower costs than a Trans-Canada - U.S. pipeline to the East Coast. This holds true for various transshipment

combinations using smaller coastal tankers and for subsidized and non-subsidized options. There is a requirement for 21-33 245,000 DWT arctic tankers for this service depending upon whether a transshipment mode is selected.

Submarine tankers were found to be more expensive than surface tankers in most cases. It is very difficult to assess the role of undersea tankers and undersea terminals. If this mode of transportation becomes economically competitive, it will occur beyond the time-frame considered in this study.

A Northwest Passage tanker route to the East Coast and transshipment by pipeline to the Midwest appears less expensive than a Trans-Canada pipeline. However, the Trans-Canada pipeline could deliver oil to the Midwest before the marine system, and the East Coast market would easily consume all the oil delivered by the marine system, and hence the marine system would undoubtedly be dedicated to the needs of the East Coast. The Trans-Canada pipeline is therefore probably the preferred system for the Midwest, considering all factors.

Natural gas price levels, particularly import prices, will be the primary determinant of the need for LNG ships and terminals in the Arctic.

If the price of LNG imports on the East Coast rises to $1.50/MCF in 1973 dollars, then North Slope gas can be competitively delivered to the East Coast in arctic LNG tankers via the Northwest Passage. A 25% market share of projected LNG imports would mean twenty 125,000 cubic meter vessels in the 1980-1985 time frame. Careful attention should be given to Canadian gas potential of the Canadian Arctic islands also. It may be possible for arctic LNG tankers to run in convoy behind the arctic icebreaking oil tankers projected for the East Coast oil market.

On the West Coast a Trans-Alaska gas pipeline to Valdez and LNG tanker route to the West Coast is thought to be very competitive with the projected prices for LNG imports on the West Coast.

There will be a requirement for LNG ships in the sub-arctic regions whether the LNG is moved from Vladivostok, USSR or Valdez, Alaska, or both. It is highly probable that there will be major gas finds on the U.S. and Soviet sides of the Bering and Chukchi Seas which will be developed and require transport by arctic LNG ships. Certainly the Murmansk to East Coast route will require ice-transiting LNG ships, thus reinforcing the requirement to develop an LNG ice-transiting ship capability for any possible arctic or sub-arctic shipping route.

The planned fluorite and copper mining activities of the Lost River Mining Company and the Kennecott Copper Company indicate that there may be an ore exporting port in the vicinity of Port Clarence on the Seward Peninsula. If these mining operations proceed as planned, there will be a requirement for two to three 35,000 DWT arctic ore carriers in the late 1970's, and an additional ore carrier in the mid 1980's.

Japanese coal exploration efforts in the Point Lay/Cape Lisburne region of Northwest Alaska suggest that there may be a need for up to three 62,000 DWT dry bulk carriers to transport coal to Japan after 1985.

Because of the lack of deep water along most of the western and northern coasts of Alaska, most inbound cargoes will continue to move by shallow-draft tug-barge systems. There is a near-term requirement to extend the operating season in order to support distribution of incoming cargoes to smaller communities. If tug-barge systems are not designed for some ice-transiting capability, Coast Guard icebreaker assistance may be required to extend the shipping season.

SUMMARY

The 18-month study by the Arctic Institute of North America in cooperation with industry has foreseen the possibility of a viable arctic marine commerce

system by the year 2000. There is no longer doubt that the oil and gas resources are in sufficient quantity to support a multiple transport system including pipelines and ships. Whereas a few years ago liquefied natural gas did not appear to be feasible for moving energy resources out of the Arctic, it is now beginning to appear price competitive.

While there appear to be no major technology problems with respect to operating ships in the Arctic today, there are major technology gaps associated with building offshore terminals and deep water ports in arctic Alaska. If the energy demands of the U.S. and the economic situation coupled with the political and social implications point toward the development of an arctic marine commerce system, there should be a national effort directed toward the development of marine terminal technology and environmental assessment capability to support offshore terminal construction and ship operations in the Arctic.

A tremendous opportunity exists for the scientific community, State of Alaska, the resource industries, the shipping industry, and the U.S. government to work together toward advancing the technology of arctic marine terminals for handling oil and gas. Although this study was restricted to the American situation, it is obvious that the program should be North American in scope and give careful consideration to international interests.

This paper has attempted to deal with a wide variety of topics. It could only scratch the surface of such a broad spectrum of subjects. It is based entirely on the contents of the complete report titled, "Final Report, Arctic Marine Commerce Study," prepared for the Maritime Administration, U.S. Department of Commerce, by the Arctic Institute of North America. The study is in four volumes and, even in such voluminous form, deals only with an overview of the many problems involved.

Of the fourteen recommendations made in the report, one is of primary importance to this Conference. The Arctic Institute recommends that, "The U.S. Government (perhaps in concert with Canada) should sponsor a demonstration project (with operational capabilities) to design, construct and operate an Arctic terminal facility. This project would present the opportunity to exercise the talents of designers and constructors in a real-life situation, including the development of operating procedures and sound conservation practices. This facility would provide proof of the adequacy of design criteria and permit their refinement for greater economy in future structures. The facility itself, in addition to performing in an operational mode, would be a test platform for studying such important factors as ice action on full scale structures, which otherwise can be studied only in a limited way. Additionally, the facility could provide a base from which to conduct Arctic scientific and engineering investigations over a period of many years."