GREAT LAKES TRANSPORT:
TECHNOLOGICAL FORECAST
AND
MEANS OF ACHIEVEMENT

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ABSTRACT

We propose here a program of research and development aimed at the rejuvenation of the Great Lakes maritime industry. The program is set within a framework of the commercial needs for transport. We suggest many potential technological advances that can help waterborne trade survive land-based competition. We emphasize that research and development is but one prerequisite to survival. The others are the removal of institutional constraints, a willingness to innovate, the availability of risk capital, and the employment of qualified personnel.

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INTRODUCTION

We have put these thoughts together not as an academic exercise but to stimulate imaginative thinking about the future of commerce on the Great Lakes and through the Seaway. Unlike Gilbert's sorcerer, we are not avowed necromancers. We are, however, confident that complacent leadership within the Great Lakes shipping industry will inevitably bring about a continuing long-term decline in competitive position and will cause shipping on the Lakes and through the Seaway to suffer in a direct and painful manner. The secondary impact on the economy of the entire Midwest will have greater ultimate significance. We are equally confident that astute and vigorous leadership can lead to prosperity in Lakes shipping. Thus, to the extent that this paper can lead to positive thinking and thence to positive action, we may count our mission a success.

We have arbitrarily put our thoughts into four major divisions:

I. Commercial Needs.

II. Technological Forecast.

III. Prerequisites to Progress.

IV. Profitable Areas for Research and Development.

All four subjects are intimately related. For example, if technological progress allows a shipowner to cut freight rates in half, the commercial demand for his services will appreciably increase, in turn allowing him to effect economies of scale, resulting in further savings in freight rate, and so on.

Predicting future developments is difficult enough, but to put exact time schedules on them is nearly impossible. To give some inkling of timing, however, we have in mind developments that we believe are feasible within the present century.

One other boundary is the restriction of this discourse to waterborne commerce. Vehicles for fishing, recreational boating, and lake-floor mining are excluded.

I. COMMERCIAL NEEDS

Our statements about future commercial opportunities for transportation on the Great Lakes and through the Seaway are not altogether firm predictions but rather a set of rational suppositions. These are as follows:

A. Bulk Commodities

The need for moving bulk commodities between points on the Lakes, and between Lake points and points beyond the Seaway, will continue. This traffic will not automatically move by ship. The extent of waterborne participation will be materially affected by the marine industry's willingness and ability to implement the prerequisites to progress outlined in Section III.

B. Manufactured Goods Through the Seaway

The overseas trade of the Great Lakes region will increase. Development of Seaway trade in manufactured goods through the Seaway will be slowed, however, by competing container systems moving overland to East Coast ports. Nevertheless, much of this trade may be recaptured by ships operating through the Seaway provided that Great Lakes ports are vigorous and bold in promotion and in capital investment for servicing unitized cargo. Transshipping of containers into seagoing ships at Montreal is a possibility. This is discussed at greater length in Section II-F.

C. Manufactured Goods on the Lakes

An efficient unitized cargo fleet developed for Seaway service could stimulate and support a revived package trade on the Lakes. Terminal facilities built primarily for the overseas trade could serve interlake traffic at low marginal expense. Increasing congestion of land modes will put water transportation in a more favorable position, especially for ferrying trailers.

D. Lake and River Interchange

Traffic between the Great Lake and Great River systems should increase, and this increase will be certain if the connecting links can be improved both in size and in number. Most of such traffic would be in bulk commodities. Our national goal should be to make these two systems into a single vast intracontinental network of inland waterways serving Canada, the United States, and Mexico.

E. New Cargos

Cargos hitherto only insignificant or not heard of are certain to appear. We have such confidence in science and engineering that we do not hesitate in predicting new agricultural products, development of new uses for conventional raw materials, exploitation of raw materials not now considered to be in commercial demand, and exchange of novel finished products in large quantity. Many of these cargos will require special ships, and their very development will depend on attainment of cheaper transportation.

F. <u>World Trade</u>

Experts predict that world trade will increase at least fivefold by the year 2000. Whether the proportion moving through the Seaway will increase or decrease, the absolute amount is almost certain to increase.

II. TECHNOLOGICAL PREDICTIONS

For convenience, this section on technological developments is divided into several subsections. Again, all are interconnected, and the impact of change in any one category will be felt elsewhere. Conversely, failure to advance in any one category will inhibit progress elsewhere. Subsections are as follows:

A. Trends in Ship Size.

B. Special Carriers.

C. General Technological Developments.

D. Ship Technology.

E. Shipbuilding Technology.

F. Ship Operations.

G. Miscellaneous Developments.

A. Trends in Ship Size

Any boundaries at present limiting the size of ships exist not because of engineering deficiencies but because of the circumstances in which ships operate. These are either the availability of cargo or the physical limitations on size imposed by harbors, locks, canals, and shipyard facilities. Where cargo is practically unlimited (as for most bulk trades) ships are built to the maximum length, breadth, and draft allowed by the channels transited and by the ports served. In trades where cargo is limited, ships will become larger as traffic increases. The result will be that freight rates will go down because of economies of scale. Trade will increase because of lowered costs, and ships will become larger again. This will go on to the point where the added cost of harbor improvements can no longer be justified by the saving in cost of transportation.

Seaway Restrictions on Size: No matter how great the cargo available at any ports on the Great Lakes, the St. Lawrence Seaway will always place an upper limit on the size of ships trading to the Lakes. The publication, Report of the Technical Subgroup, St. Lawrence Seaway Task Force, prepared by the U.S. Coast Guard (November 1968), describes the following alternative dimensions being considered for the Seaway (dimensions in feet):

Alternative	Lock Size			Allowable Vessel Dimensions		
	Length	Width	Depth	Length	Beam	Draft
Present	800	80	30	730	75	25.75
Proposal 1	1200	110	33	1000	105	29
Proposal 2	1400	125	34	1200	115	30
Proposal 3	1600	140	36	1400	125	32

The new Poe Lock at Sault Ste. Marie has the size and capability of Proposal 1 above. A ship of this size, built to the typical fullness of Great Lakes bulk carriers, would displace about 85,000 short tons of fresh water and would lift about 60,000 short tons of payload. Its construction cost would be significantly less than twice that of present Great Lakes ships lifting half as much, and it would require actually less crew complement (because of technological improvements) than existing ships of half its capacity.

Size of Bulk Carriers: The truth of the assertion that ships will be built to the maximum size allowed by environmental circumstances, provided that sufficient cargo is available, is proved by the current construction of one ship of the maximum length and breadth allowed by the new Poe Lock. More of them are scheduled for building. One of these ships will do the same work in a season as two of its predecessors. Because neither supply nor demand can immediately double the trade, the prediction must necessarily be made that the number of ships needed in that trade will at first tend to decline as fast as the large ships are put into service. If supply and demand remain static, this decline in the number of ships will proceed until all the small ships have been replaced. It is reasonable to expect, however, that lowered transportation costs will stimulate an increase in the amounts of traditional commodities carried by water, discourage competition from foreign ores, recapture trade that would otherwise have gone by land modes, and even attract new trade made possible by lower cost. There are justifications for expecting that the total capacity of the Great Lakes fleet will increase.

It is to be expected that in the next quarter century the locks on the St. Lawrence Seaway will be rebuilt to at least the size of the new Poe Lock. Even if the Seaway is improved to the maximum dimensions now being considered, however, the large seagoing bulk carriers will not be able to trade profitably in the Lakes, because of draft restrictions.

The prospect therefore is that bulk trade through the Seaway and interlake will largely be by ships especially designed and dedicated to the service.

Size of Container Ships: Although the limited depth of the improved Seaway locks and channels will continue to discourage large seagoing bulk carriers, the draft limitation will not necessarily impede container ships. All factors in the container system tend to keep the draft of the ships from increasing proportionally with other dimensions. The container ship requires greater breadth than other ship types, because its high deck load would otherwise produce instability. The number of containers allowed in a stack being restricted, the capacity of the ship can be increased most economically by increasing beam or length. Stowage of containers leaves a great deal of void space, resulting in low density and consequently low displacement in proportion to ship volume. The fact is that one of the most elusive problems in design of a container ship is to obtain enough draft for propeller immersion without permanent ballast. The allowable draft through the Seaway, if any of the proposed alternative improvements is consummated, will have little effect on the size of container ship that can enter the Lakes, but allowable beam will ultimately keep out the largest container ships. At present, Sea-Land Services, Inc. has contracted for construction of container ships having the following characteristics:

Length overall	944	feet
Breadth	105.5	feet
Designed draft	30	feet

The above ship, while extraordinary in size, is to be built immediately and presumably will be profitable at today's volume of trade. Even larger ships will be appropriate in the future.

Size of Break-Bulk Cargo Ships: There is no doubt that a growing proportion of cargo will be unitized, especially into standard containers. Predictions of the proportion of general cargo shipped in containers a decade hence have run as high as 75 or 80 percent. Nevertheless, as overseas trade expands to the five-times-present level, predicted by some experts for the year 2000, there will still be as much break-bulk cargo to move as is moved today. There is no apparent reason to believe, however, that the size of the break-bulk cargo ship will increase. This shipping serves a function similar to that of the parcel post system or the system of local truck lines around the continent. Hence there is a possibility that general cargo ships may on the average become smaller rather than larger. Those able to stand the competition of consolidated general cargo shipped by container will have to possess the advantages of low capital and operating costs.

B. Special Carriers

The most common special type of ship is the carrier of the single commodity. There is nothing novel in this. As soon as the volume of traffic in a commodity becomes great enough to support one or more ships especially adapted to its peculiarities in cargo handling and stowage, such ships appear. The ore ship is the most common example on the Great Lakes, but several ships have been built to carry newsprint exclusively. Volkswagen sends special automobile ships through the Seaway. A number of lakers can carry nothing but Portland cement in bulk. All over the world, such specialization is increasing--molasses tankers, wine tankers, grain ships, automobile carriers, sugar ships, and wood pulp carriers. A growing number are built for commodities held at extreme temperatures during transit--molten sulfur, anhydrous ammonia, liquid asphalt, and liquefied methane. Almost all cargo liners have heretofore carried some perishables in relatively small cargo holds; but generally these will lose out, not to special refrigerator ships, but to refrigerated containers. The container at once solves the problems of refrigeration, protection from damage, sanitation, cargo handling, and fluctuation in demand. The banana boat may disappear. So, while in some areas specialized carriers take over, in others they are replaced by containers. These mutations in marine transport heretofore have developed slowly; but in the future they will have more revolutionary effect than in the past.

Alternative Cargos: The first result of conversion from breakbulk equipment to shipment by specialized carrier is that the special ship must go home empty--a glaring inefficiency. Bulk carriers (called OBO ships) capable of moving alternately oil, ore, and other bulk commodities are appearing. The owner of a ship with a use-factor of only 50 percent naturally looks for some way to increase the productivity of his investment by obtaining a backhaul cargo. But ports and regions could justifiably look for such opportunities, too. The Great Lakes basin can supply the cheapest coal and the most abundant grain surplus in the world. Increased markets for these resources depend chiefly on the cost of delivering them to the customers. Surely, additional markets for the abundant products of this region exist if backhaul cargos can be developed. It would be proper for ports, states, or compacts of states to support research for the discovery of such opportunities and ships of suitable type.

Convertible Ships: Beyond cleaning of cargo space, the ship capable of transporting alternate cargos requires no conversion. Convertible ships, having built-in facilities for being adapted to several types of cargo, are being promoted especially by German builders. Container cells can be installed or removed, 'tweendecks erected or lowered, in a fairly short time. Such a ship can be adapted to lift one hold load of containers, another of grain, another of break-bulk, etc. The owner must feel a considerable security in the expectation that he will always have fair sailing no matter which way the economic winds blow. Yet he must also be aware of definite discomfort from the extra capital required for all these facilities and for the certainty that every time the ship is converted a palpable measure of expense must be endured. In spite of the ship's versatility, there is no job it can do better than a specialized ship. Except in a few cases, there will always be a specialized ship to compete with him. Some special situations may be to his advantage, but he must go to them, for in our opinion they will seldom go seeking him. If he survives, it will be because of his wit and alertness, but he will not move any appreciable share of the world's commerce.

Multipurpose Ships: Permanent facilities for carrying several types of cargo have always been fairly common--high bulwarks for carrying deckloads of timber over dry cargo below, refrigerated holds, cattle pens, tanks for edible oils, and whatnot. Then there is the combination break-bulk-container ship. A few containers and sometimes trailer vans are being shipped as deckloads on regular break-bulk cargo ships, and this practice will continue. The volume of trade by such means is not significant now and will become even less so. The ship equipped with one or two container holds and cradles on deck can carry a few more containers, but it is still a break-bulk cargo ship offering no real competition to the container liners. Strict scheduling, rapid turnaround, and fast transit are principal attractions of container service, and these cannot be supplied if the ship has to fool around with break-bulk cargo. Even if such ships are put into service, they will never capture more than a negligible share of the trade.

C. General Technological Developments

Ship technology exists in a general environment of industrial sophistication and draws upon other technologies not only for hardware but most importantly for skills in design, production, and operation. A few of the more important expected developments in related fields are reviewed below.

Structural Materials: We foresee continuing improvements in the supply and use of low-cost, easily welded, high-strength steels. Aluminum alloys could conceivably supersede steel for shipbuilding, although their chief effect may simply be to give steel a sharper competitive thrust. As a result, steel mills may offer rolled shapes suitable for welded ship construction (already long overdue) and, eventually, integrally rolled plates and stiffeners. Further into the future, composite materials (such as metallic fibers in plastic bonding) may have a role. New materials may derive their chief benefit from ease of construction rather than from the usual considerations of strength, weight, and unit price. We can visualize, for example, a central plant within the shipyard pumping freshly mixed materials to the building ways, where modular, reusable forms would cast the material into any desired hull configuration. Materials science will free the design engineer from making the structure suit the available material. In the future, the materials engineer will design the material to suit the structural requirements.

Propulsion Machinery: Competition between steam turbines, diesel engines, and gas turbines will lead to continuing improvements in all three types. Machinery systems will experience trade-offs between fuel economy and first cost, simplicity, ease of automation, standardization, and reduced size and weight. In the long term, improvements will be effected in all of these categories, and any trade-offs will be in relative degree of improvement.

Innovation in marine machinery seems to hinge on the ability to burn essentially unimproved residual oil without impairing the reliability or maintenance cost of the system. We expect to see such capability very soon in both medium speed diesels and in gas turbines. These two types may well predominate by the end of this century. Nuclear power is apparently still a long way off. The possible exceptions to this are ships and services not applicable to the Great Lakes and the Seaway.

Material Handling: The spectacular improvement in material handling systems during the past 30 years should not be considered finished. Faster systems are under constant development. These may be applied to dry bulk cargo, slurries, and unitized cargos. Cargos themselves will be re-adapted for easier handling. The transition from shipping grade to pelletized ore offers rich opportunities to speed up ship turnaround time--a necessary first condition to exploit the full economic benefit of larger ships.

Managerial Methods: The quietest and yet the most important cognate development is not in hardware or material. It is in methods of management. Increasing skill in application of logical methods to business programming, planning, strategy, and control will mean more to the maritime industries than any material or hardware innovations we can foresee. Moreover, we believe that the effectiveness of human motivation and human organization will improve through training in leadership, the general level of education, and the re-adaptation of social and economic institutions to evolving circumstances.

Computers: Systems analysis--application of logical disciplines in planning, design, construction and operation of ships--is made possible by the ability of the computer to handle a large array of variables and an enormous volume of data. Exploitation of the computer is only beginning, especially as a tool for management information and decisionmaking. Preprogrammed numerical control will more and more execute predictable and sequential decisions.

D. Ship Technology

In all likelihood the displacement-type ship floating on the surface will continue as the predominant vehicle for waterborne commerce, at least for the next 50 years. More exciting types may carry some passengers, particularly in short ferry service, but they offer little credible promise of economic viability in cargo transport. As pointed out in the Litton report to the Department of Transportation (Oceanborne Shipping: Demand and Technology Forecast, June 1968) the displacement ship is here to stay. It is important, then, to put aside dreams of air-cushion vehicles and to concentrate our thoughts and efforts where our future lies. We foresee the following developments:

Increased Beams: The trend toward self-unloaders provides strong economic incentive to increase the beam of future Lake ships. This will result in a demand for wider locks at the Soo and in the Seaway.

Adaptability to Lake and Ocean: The chief difference between Great Lake and seagoing bulk carriers is in the greater length, relative to hull depth, appropriate to the Lake carrier. In order to increase the use factor of Great Lake bulk carriers, we foresee the use of removable holds. These could be unbolted, or otherwise uncoupled, to allow the shortened ship to operate in salt water during the winter season or during periods of depressed business activity on the Lakes.

Dynamic Structures: We already have an example of dynamic structure in mechanical hatch covers, in which a mechanically operated structure changes its configuration to suit changed conditions. Other possibilities include a retractable bow bulb, possibly in the form of an inflatable bladder.

Wave Suppression: If some system can be devised to suppress hull-generated waves, then large carriers could move through rivers at high speeds without damaging shore property.

Maneuvering: Large modern ships are disgracefully awkward. We expect to see much wider use of various maneuvering devices: steering Kort nozzles, Motora braking rudders, cycloidal propellers, bow and stern thrusters, and controllable pitch propellers. Other devices and methods will no doubt come along--a side-thrusting controllable pitch propeller is one possibility. Safety, reliability, and high use factors all demand continuing improvements in ship maneuverability.

Barges: We expect to see at least a few push-tug and barge combinations. New coupling devices will allow pushing even in large waves. There are several secondary advantages to the pushed barge system. (See McAllister, et al, "Rationale of Tug and Barge Transportation," N.Y. Metropolitan Section, SNAME, 1967.) Nevertheless, the main advantage of the system is that it circumvents outmoded restraints on crew reduction. Once the pushed barge system makes the irrationality of such restraints transparently plain, we may hope for their removal. Also, barge flotillas or take-apart ships offer economies of operation in certain multiport trades. The extent of demand for such a development remains problematical, however.

Structures: Aside from the availability of better materials considered above, we expect to see many improvements in the design and analysis of ship structures. These will lead to important savings in weight and cost.

Hull Forms: Two major influences on hull form development will be ice operation (treated later) and the extreme beams that we may see on the Lakes in the future. True icebreakers have sloping sides, but we doubt that Great Lake bulk carriers need make that sacrifice in displacement and deadweight--unless the locks are made wider than we anticipate, or the ship is in a service that does not involve passage through locks. We may, however, see icebreaker bows or, less extreme, ice-working bows. There is talk, too, of modifying an Inui bulb to serve as an ice plow or an Alex bow.

Extreme beam-draft ratios may lead to abandonment of shipshaped sterns in favor of raking barge-type sterns. Bows, too, may become spoon shaped or simply raked as in river barges.

Propellers: We have already mentioned the potential role of controllable pitch propellers in ship maneuverability. As power is increased commensurate with increased displacement, we have already found ourselves forced to adopt twin screw propulsion with its inherent losses in efficiency. The switch to twin screws is not necessarily inevitable, however. One alternative is contra-rotating propellers, although the added first cost and the mechanical complexity of such an arrangement are discouraging. Barge-type sterns would, of course, remove some of the inherent wake advantage of the single screw and at the same time lend themselves easily to a tunnel shape, allowing a larger propeller.

The Leitrad propeller system, recently proposed by Professor Grim of the University of Hamburg has potential application in Great Lake bulk carriers. The Leitrad is a free-turning propeller mounted abaft the regular propeller. It is larger than the regular propeller and opposed to it in pitch. The Leitrad obtains energy from the rotational momentum of the propeller race and converts it into added thrust. The idea seems to be particularly applicable to service conditions such as those on the Lakes, where propeller diameters are limited by shallow draft.

Bottom Dumping: Pelletizing has made iron ore easy to unload by bottom dumping. Low density gangue has been removed from the ore so that no objectionable turbidity should arouse the anti-pollutionists. The resulting speed-up in turnaround time is obvious.

Plastic Bladder Tanks: If tanks could be lined with pliant (perhaps disposable) plastic bladders, much expense and lost time in tank cleaning could be saved.

E. Shipbuilding Technology

Reducing the cost of U.S. shipbuilding is of the greatest importance to the entire water transport system. High capital costs remain the single most important economic deterrent to a competitive U.S. merchant marine. Outlined below are some developments that may lead to important savings in shipbuilding cost and time.

Integration of Design and Production: Great emphasis must be placed on designing ships that are easier to build. In the future, designing will be done by teams including production planners as well as design engineers. Simplified hull forms, modular design, and standardized components all deserve widespread use.

Production Management: Sophisticated production planning techniques are needed to maximize the productivity of shipyard labor. A dissertation on the need for improvement here could become a book.

Cost Analysis: Improved cost accounting, cost estimating, and project cost control methods will allow designers to make decisions based on accurate knowledge of the relative economies of all alternatives. Most such decisions today are purely guesswork.

Computers: Computers will take over the routine dog work, allowing engineers to concentrate on the creative and imaginative aspects of planning and design. Computers will be used for cost estimating, for production planning and control, for material inventory, for mold loft work, and for the control of steel fabrication. The list is almost endless.

Adhesive Bonding: Welding, with all its advantages over riveting, still leaves much to be desired. Within the next few decades, we may hope to see welding replaced by adhesives that will bond steel or aluminum (or even steel to aluminum) with 100 percent effectiveness. Such methods are already being used to some degree in aircraft.

Structural Design: A better understanding of the loads imposed on a hull and of the reactions within the hull will lead to appreciable reductions in the weight of hull structures. Computer-assisted analytical techniques will allow equally important savings in the cost of hull construction.

Contracts: Wider use will be made of multiple-ship contracts. Consortia of shipowners will be able to place orders for a dozen or more identical ships in a single contract. In general, owners will give shipyards functional, rather than detailed, specifications. Shipyards will become merchandizers of performance packages designed to the customer's needs and to the builder's capabilities. The shipbuilder as a contractor, waiting passively for a live one to come along, will not prosper.

Shipyards: New shipyards will revolutionize shipbuilding procedures. Ships will be put together from a couple of dozen major assemblies, each built out of the weather and already outfitted. Assembly sheds will be heated in winter and air-conditioned in summer.

Work Practices: Artificial jurisdictional labor restraints must be removed, allowing individual workmen to master and practice a variety of trades. The problems of job security, labor motivation, antagonism and distrust between labor and management, and restraint of technological progress must be solved in this country, else we are doomed. The solutions must be fair, and they must increase, not destroy, the freedom of the individual.

F. Ship Operations

Developments in ship operation will be aimed simultaneously at maximizing transport efficiency (which means to keep the ships moving) and increasing safety and reliability.

Extended Season: There is today much interest in extending the operating season on the Lakes and through the Seaway. The economic benefits to the shipowner and to his customer are strong and fairly obvious. (See Benford, Thornton, and Williams, Transactions, SNAME, 1962.) What is less obvious is the proper way to share the cost. The owners would naturally like to see the government provide such complete service that the private fleet could operate long into the winter with minimum possible added expense for its protection. Public servants naturally take a different view. Whatever the outcome, we look forward to a season of 10 or possibly 11 months before the end of this century.

Scheduling: Computer-assisted scheduling techniques will allow better integration of water and inland transportation and with barge traffic in the river system. Terminal congestion will be reduced.

Harbor Control: Ships moving through rivers or harbors will be as rigorously controlled as aircraft at an airport.

Return Cargos: Because of economic pressures to increase ship productivity, we should expect marine managers to intensify efforts to win return cargos for ships now engaged in one-way trades, and Lake ports also should participate in this development.

Locks: Locking operations as we know them today are relatively primitive. We expect to see ships and locks so integrated in design that the operation will be handled by a single controller without benefit of deck crews and mooring lines. Even a reduction of one minute per lock through all the locks on the St. Lawrence system would result in such a total saving in ship-hours as to warrant a substantial research effort.

Mooring: As with locking, today's mooring systems (whether at anchor or at pier) are primitive. Anchors, chains, and windlasses are anachronistic monstrosities, quite out of keeping with today's technology. There simply must be a better way. Shoreside mooring will presumably be done by shoreside crews--or become fully mechanized.

Barge Couplings: Universal mechanized coupling methods for barge flotillas will be found.

Crew Productivity: We may expect to move toward rational work practices, low-maintenance expense, highly reliable mechanical components, mechanization, and automation on shipboard. By the year 2000, the typical new cargo ship should have a crew complement of fewer than a dozen men.

Collision Prevention: Navigation lights will become orders of magnitude more visible than those found today. Turn signal indicators will be commonplace. Electronic detection and collision avoidance devices are already under development. Such devices, plus traffic control and greater maneuverability, will make ship collisions rare indeed.

Cargo Handling: Some loading and off-loading of dry bulk cargo will be done at off-shore stations--granting a much greater degree of freedom in determining ship dimensions.

Stress Indicators: Automatic strain gauges will warn the ship's crew when loading or ballasting patterns are imposing undue stresses on the hull. Statistics obtained from large numbers of ships will show where structure is underdesigned and where material can be saved.

Seaway Shuttle Service: Seagoing container ships will be unsuited to the Seaway, and few Lake ports will be able to supply the volume of container cargo required to support liner service. We suggest the concept of a container-carrying ship to shuttle between Montreal and one or two central ports on the Lakes (possibly Monroe and Chicago). Consolidation and distribution of boxes overseas would be carried out by seagoing ships serving Montreal. The same function on the Lakes would be served by inland carriers and by smaller container ships. The latter would have deck cranes and could handle boxes at any port, with little need for elaborate terminals.

G. Miscellaneous Developments

Many additional developments cannot be put into any of the categories above. Some are mentioned here.

Dredging Systems: We need a new approach to dredging methods. We can hope for the development of revolutionary new systems, making deeper channels and new canals economically feasible.

Lake Levels: By the year 2000, we may expect that water levels on the Lakes will be held at a high and nearly constant level throughout the navigating season.

Obsolete Ore Carriers: Ingenious uses will be found for obsolete ships. Some have already been used for breakwaters. Others may be jumboized. (See Trevor White, "Three Dimensional Enlargement of Great Lake Bulk Carriers," GL & GR Section, SNAME, 1969). Several old ships might be taken apart and reassembled to form a floating dry dock large enough for the new ships.

Fleet Replacement: Improved analytical techniques will assist managers in planning fleet replacement programs.

Ecology and Pollution Control: Engineers and business managers are increasingly aware of pollution and other ecological problems brought on by advances in technology and by the increase in population and commerce. Decisions will be more and more influenced by these factors.

III. PREREQUISITES TO PROGRESS

To this point we have spelled out many improvements that seem well within our technological grasp within the next 20 or 30 years. We cannot hope to attain them, however, unless we first satisfy several prerequisites. From our particular vantage point we see all too little reason for optimism that these prerequisites will be met. Indeed, our principal purpose in preparing this paper is to stimulate the Great Lake marine industry to overcome its apparent complacency and to build the economic muscle of which it is capable. We apologize in advance for any ruffled feathers these paragraphs may arouse.

A. Institutional Constraints

The U.S. marine industry is hog-tied by the most ridiculous collection of institutional constraints of any industry in the country. Labor union attitudes, federal regulations, and unethical railroad rate practices all demand reform. We realize this is easier said than done. We are not experts in how it is to be done. We simply know that it must be done. We wish the Lake Carriers Association good luck.

B. Willingness to Innovate

Business managers must show more willingness to try new technology and methods of operation. They must be willing to take chances and to accept an occasional mistake. They must be willing to educate themselves in the most advanced management methods. In fairness to business managers, however, we must also recognize the obligation of engineers and analysts, not only to exert their creativity, but to present complete and credible evaluations for management's final judgment. Engineers must learn to be competent and trustworthy economists.

C. Risk Capital

The major technological advances we envision will require major outlays of investment capital. Shipyards and shipowners who cannot nerve themselves to go all-out for change will condemn themselves to economic strangulation. Investors, however, will not supply the capital if the prospect of return is insufficient. It is up to both of us--engineers and managers--to attract them.

D. Personnel

Nearly all of the required advances will demand a lot more brainpower than is now on the scene. The Great Lake marine industry must go to great lengths to attract new blood both in management and in engineering. The way to begin is to lend generous support to education through scholarships, fellowships, faculty grants, and active participation in training the next generation. Accountants won't believe this, but wise business managers must learn that no investment pays off as well as education. Management in some industries (not the marine industry) has proved it. Let us quote Servan-Schreiber in The American Challenge:

> Behind the success story of American industry lies the talent for accepting and mastering change. Technological advance depends on virtuosity in management. Both are rooted in the dynamic vigor of American education. There is no miracle at work here. America is now reaping a staggering profit from the most profitable investment of all--the education of it's citizens.

E. Research and Development

The final prerequisite is a healthy, well-financed program of research and development. We use the word program advisedly. We believe in a large degree of freedom in carrying out research. Nevertheless, some level of central guidance is needed to give direction (few researchers see the whole picture) and to minimize duplication. There exists no agency to give such guidance. May we suggest that the Lake Carriers Association invite us and others to get started on one?

The cost of the R&D program we envision is hard to estimate. We can be sure, however, that the research end should cost in the hundreds of thousands of dollars per year. A model basin for ice-breaking studies might cost one or two million dollars. Development costs would be in the millions. And, sad to relate, there seems little immediate hope for help from Washington. Which means that private industry must muster its courage to pay its own way for now and perhaps hope for matching funds later.

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One important fact is so obvious that it may be overlooked: that all five of the foregoing prerequisites are interrelated and inter-dependent. If one fails, all will fail. If one succeeds, all will benefit. Industrial support of research brings in new blood as well as new ideas. An industry that is willing to innovate will attract innovative people. Removal of institutional restraints will stimulate the investment of risk capital. And so forth.

IV. PROFITABLE AREAS FOR RESEARCH AND DEVELOPMENT

Section II on technological forecast implies many areas of ignorance. This final section will merely regroup the ideas already expressed and outline them within appropriate categories of R&D. Almost any R&D aimed at improving marine transport would have at least indirect implications for Great Lake commerce. We list here only those of most immediate interest, however. They are in random order. All promise economic benefit; all are important.

A. Jumboizing Old Ships

Alternative methods. Strength. Costs. Profitability. Market value of old ships as is. Repowering requirements. Speeds. Maneuverability. Mooring and ground tackle requirements. Manning and required alterations to accommodations.

B. A Series of Full Hull Forms

Extensive model tests of hulls having block coefficient of 0.80 to about 0.95. Variations in entrance and run. Wake surveys. Hull efficiency. Bulbs. Parametric curves for selection of optimal design.

C. <u>Subdivision of Great Lake Bulk Carriers</u>

Historical survey of casualties due to non-subdivision. Practical alternatives in subdivision. Actual effect of subdivision on transportation costs if required in large bulk carriers.

D. <u>Maneuvering of Large Great Lake Carriers</u>

Stopping a low-powered 1000-foot ship of 70,000 long tons displacement. Wind effects in confined waters. Turning diameters.

E. <u>Unitized Cargo on Great Lakes</u>

Optimal design of container ship systems capable of transiting St. Lawrence Seaway. Pallets versus containers. Effect of other types of unitization. Feasibility of unitized interlake shipping. Feeder systems. Possible transshipment at Montreal.

F. <u>Barging on Great Lakes</u> (both flotilla and single units)

Invention of new methods. Intensive experimentation in new Michigan wave basin. Economic analysis. Universal couplings.

G. <u>Uses of Obsolete Great Lakes Ships</u>

Alternatives to scrapping or jumboizing. Invention required. Economic evaluations.

H. <u>Pollution</u>

Problems of air and water pollution. Economic solutions. Other ecological problems.

I. Dredging Systems

New approaches to an old problem. Better dredging methods, better waste removal methods. Silting prevention.

J. Ship Structures

Application of high-strength steels or aluminum to Great Lake bulk carriers. Simplified structures for ease of construction. Improved methods of stress analysis.

K. Canals

Connecting all-water links to Ohio and Mississippi Rivers. Alternative routes and characteristics. Georgian Bay-Lake Ontario Canal. Trade forecasts.

L. Removable Holds

Economics of allowing Great Lake bulk carriers to remove one or more holds for winter operations in salt water. Design alternatives.

M. Impact of Possible Policy Changes

Benefits and disadvantages of alternative federal policies affecting Great Lake waterborne trade.

N. Propulsion Machinery.

Application of automotive type diesel engines. Intermediate-speed diesels. Automation.

O. Bulk Material Handling

Slurries. Offshore loading and unloading. Hopper-bottomed bulk carriers. Cargo handling speed and capital investment tradeoffs. Ship versus shore equipment and integration.

P. Ship Size

Benefits of larger locks at Soo and in Seaway. Feasibility of 30-ft channels.

Q. Extended Season

Ice-breaking and ice-freeing methods. Navigating problems. Impact on ship design: hull form, structure, deck gear, accommodations.

R. Wave Suppression

Minimization of damage to river front property from ships moving past at moderate to high speeds.

S. Take-Apart Ships

Economic merit. Design studies. Scheduling problems.

T. Twin- versus Single-Screw

Economics and intangible benefits of twin screw propulsion for Great Lake bulk carriers. Application of Leitrad propeller.

U. Shipyard Production

Application of advanced industrial engineering techniques. Integration of designing and planning for production. Improved cost estimating methods.

V. Ship Operation

Rationalization of work. Shipyard versus shipboard maintenance. Increased reliability of mechanical systems. Minimization of maintenance requirements. Traffic control. Computer-aided scheduling.

W. Ship Locking and Mooring

Methods for mechanizing the locking and mooring functions.

X. Basic Research

Undirected research in areas of technology related to marine transport: materials, fuels, ice formation, analytical techniques, etc., leading to practical developments in more distant future.

Y. Central Economic Research

Continuing fact-finding, trend analysis, and forecasting for port managers, shippers, and shipping companies.

Z. Market and Cargo Analysis

Market opportunities for products of Great Lakes region. Back-haul cargos. Modification of cargos to promote faster handling.

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A few cynics will presume that the motivation of the foregoing text has been to promote the prosperity of The University of Michigan. We certainly do have that in mind. We cannot separate the prosperity of our University from the prosperity of our region. We expect to continue serving the Great Lakes shipping industry as we always have, but we are not the only educational and research institution with that same deep interest. To avoid a long list, we will simply call attention to the Argonne Universities Association and to the number of very capable centers in Ontario and Quebec.

The first advantage of sponsoring research in these institutions is the obvious familiarity of investigators with the people and the structure of the Great Lakes scene. A long-range advantage is the stimulation of young minds and the inducement to stay here and enjoy the challenge of a vigorous region.

Let's quit exporting our talent.