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OCEAN TRANSPORT: THE DECADE PAST AND THE DECADE AHEAD

by

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for

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FOREWORD

A little over ten years ago I was rash enough to present before a British audience a paper dealing with the future of merchant ships. The paper, entitled "Ocean Transport, an Extrapolation to 1985," should, I believe, make a good starting point for a new extrapolation: to A.D. 1995. I shall therefore replicate the old paper here and append commentary and new projections on a page-by-page basis.

You will find the old paper (identified by the date 1974 at the top of each sheet) on the even numbered pages. The commentary and new projections (identified by the dates 1985-1995) will be found right across on the odd numbered pages.

1985-1995

Abstract

My purpose remains the same, and so does the central conjecture. I still maintain that there is more room for improvement in management than in design.

1. Introduction

Technology continues to develop at an accelerating pace. Looking ahead to the middle of the next decade is even more important than it was ten years ago.

to start thinking about what technological improvements may be incorporated in the newbuildings of that date. If nothing else, we may conclude that, between radically changed conditions and radically improved technologies, today's best-of-all-possible ships may be so technologically inferior as to be a real money loser by 1985. If so, we had better plan now for appropriate rates of capital recovery, tax depreciation schedules, and so forth. My purpose in writing this paper is to call attention to the rapidity of change we are undergoing in ships and shipping, and to make a few estimates of some specific changes we may expect within the next ten years. The main order of business is not in the details of this contemplation, but in conveying some sense of the inevitability of change so that shipowners and suppliers may prepare themselves for survival and a fair share of the returns from an expanding commerce.

As we look at world shipping today, we see enormous changes, both in problems and in potential solutions. The volume and variety of commodities carried are increasing exponentially; new ship types and cargo handling systems are coming on stage; suddenly elevated fuel prices are demanding a reevaluation of propulsion systems; measures for protecting the environment are steadily forcing changes in ship design and operating methods; and shipowners almost daily run into new problems in finding and retaining competent seagoing crews. In the next decade we can expect an ever-increasing number of new problems to arise before the old ones are solved. Fortunately, we can also expect appropriate solutions in the form of better managerial methods and better technologies, if we are willing to go after them. We cannot say for sure what these problems and solutions will be, but we must expect them in large numbers and we must learn to live with change.

Prominent writers like Peter Drucker, Herman Kahn, and Alvin Toffler have called attention to the personal and organizational stresses that we must undergo as unfortunate by-products of our changing times. Two lessons seem clear. One is that we must prepare ourselves for change through broader and continuing education. The other is that we must be selective in the potential changes we choose to adopt. What I mean to say is that we have more technological improvements on the shelf than we can properly manage or learn to live with. We must embrace the really valuable changes that

1985-1995

In the past decade commerce did <u>not</u> continue its rapid expansion. As we are only too well aware, shipping has gone into a severe depression. The worst is apparently over, and I trust we shall find better days ahead. The slump, by slowing down shipyard orders, also slowed the rate of technological progress. As a result, many of my 1974 predictions are now seen to be too advanced. They may, however, serve--only slightly warmed over--as valid predictions for 1995.

Most of what is said in this second paragraph is still true. The exceptions are (1) the failure of world trade to continue its exponential growth (as mentioned just above), and (2) the resulting easing of the problem of finding and retaining competent seagoing crews.

The advice here still seems worthy of attention.

The organization of the paper remains unchanged, aside from the addition of these annotations.

Let me explain that a necromancer is a supposed sorcerer who predicts the future through claiming to communicate with the dead.

Those predictions have proven true, and should still be true ten years hence.

supply and demand will still be with us, as will the shortage of qualified seamen. Insurance rates will still be based on past history rather than rational assessment of reliability (other than the simple yes or no of the so-called classification societies) and the orderly development of ocean transport will still be hampered by a maze of governmental interventions. Environmental protection will continue to affect our decisions but this will become a routine consideration and extremists on both sides will have faded away.

We can be thankful that there are at least these few constant factors. Even those that are undesirable have the virtue of being familiar.

3. A catalog of changes

Recent history shows that the majority of changes that occur in any given ten-year period were quite unforeseen at the start. Thus, although I am about to suggest a dozen probable discontinuities in marine commerce and technology, one should expect at least an equal number of surprises.

Looking first at the demand for ocean transport, we can expect changes to result from the emerging nations' aspirations to process their raw materials, to provide their own transport services, and ultimately to engage in the production of finished goods. At the same time, new commodities plus sheer growth in volume of trade should lead to the development of new kinds of specialized ships.

New ice-clearing systems will open the mineral wealth of the Arctic to commercial exploitation; the Great Lakes will benefit from nearly year-round navigation and ten to eleven months of operation through the St. Lawrence Seaway.

Manning practices seem sure to face radical change, as qualified seamen increasingly find shipboard life (as we know it today) intolerable in comparison to life ashore. Solutions range from completely unmanned ships to family-run ships like those on the rivers of Europe. A likely intermediate approach is the semi-automated ship with a crew of about a dozen

That prediction about cyclic imbalances (started on page 6) has certainly proven all too true. The shortage of qualified seamen is temporarily abated, but the problem is likely to recur.

The major suprise, of course, has been the slump in ocean trade.

The emerging nations' aspirations to provide their own transport services now have a solid start in UNCTAD's so-called 40-40-20 law.

Winter navigation in North America has not developed as expected. The decrease in demand for transport services, coupled with heavy political pressures from environmentalists, has brought it to a temporary stand-still. We can expect at least halting progress when times improve.

Manning practices do, indeed, continue to change at a radical pace. This is particularly true in the fleets of Japan and northern Europe. Crews of two dozen are not at all uncommon, but the twelve-man (or woman) crew may not come much before 1995.

men and women rotated ashore at full pay in alternate time periods. One may hope that by 1985 rational thinking will have led to the dissolution of shipboard departments and the multitudes of competing labor unions that hinder progress in so many fleets today.

Computer systems, satellite communications, weather routing, and better methods for maneuvering and control (e.g., side thrusting propellers) will all make our ships considerably safer, more reliable, and more efficient. Better scheduling methods will increase transport productivity and good sea speed may be maintainable in spite of heavy weather.

Barge carrying feeder vessels, such as the Bacat, will continue to evolve, and trains or flotillas of barges will operate in ocean commerce. A few multi-hull ships will appear, and perhaps some of a semi-submerged configuration. Submarine and dynamic lift (e.g. air cushion) cargo carriers will still be manifested more by talk than by hardware. What should be stressed is that the transport efficiency of the conventional displacement type surface ship seems simply unbeatable, and that kind of ship seems certain to remain dominant in the decades ahead.

Significant changes may or may not arise from increased cost of fuel, from factors limiting further growth in ship size, and from developments in propulsion machinery. These matters are discussed in the next three sections.

4. Echoes from the energy crisis

I am sure we all realize that last winter's fuel shortage arose from political rather than economic pressures. Yet, while the political situation is much improved at this writing, and the fuel shortage has been laid to rest, the high prices still remain. Our first reaction is to lament the interference with free trade that has led to these artificially high prices. Yet, on more mature thought, we may approve of the pricing action if not necessarily the motives behind it. The global supply of recoverable oil is only finite. There are other sources of energy to fall back on, but once our oil is gone we shall have lost the most convenient fuel of them all. We must therefore exercise great care that we do not waste this particular heritage. Today's seemingly outrageous prices must result in greater

The hope for the dissolution of shipboard departments is still alive; many fleets are moving in that direction with general purpose crews and dual-capacity officers. Labor union reform is proving more difficult.

Progress here continues, although side-thrusting propellers have failed to develop, and heavy weather speeds show little improvement.

Trains or flotillas of barges still lie far in the future. On the other hand, the final sentence (regarding the dominance of conventional displacement type surface craft) would seem to be a safe prediction for 1995, if not well into the start of the third millennium.

economies in the use of oil, and so assure reasonable supplies for more generations in the future.

From a more parochial point of view, higher oil prices widen even further the competitive advantage waterborne vehicles have over all other modes of transport, including pipelines --- and, most pronouncedly, including aircraft.

Is there any reason to think fuel oil prices will return to their pre-crisis levels within the next decade? One could argue that current price levels are inducing an extraordinary worldwide scramble to find new deposits of petroleum; so we may expect more sources, hence lower prices, within the next few years. On the other hand, when corrected for inflation, today's oil prices are perhaps not too far out of line with where they stood twenty years ago. Moreover, the demand curve for oil still continues its upward curvature, despite the jump in cost. All things considered, then, I see no overwhelming reason to predict any appreciable shift in prices --- up or down --- over the next decade (subject to correction for overall inflation). Beyond then, the inevitable trend would seem to be upward and that, I think, is what we should prepare for. Given that surmise, we can expect more care in evaluating design alternatives in marine machinery, as discussed in the next section. But what other effects will be felt in ship design and operation?

The naval architect's traditional approach to saving fuel is to minimize hull resistance through seemingly never-ending hull form refinements aimed at reducing energy lost in creating waves. This has been a fruitful line of endeavor for a legion of hydrodynamicists and has more than justified the investment in all the world's model basins. Nevertheless, it seems to me inevitable that we must now devote a commensurate share of our research funds to reducing frictional resistance, which tends to be far larger than wavemaking resistance in most merchant ships. A good place to start is to rid our ships of the lowly barnacle, the ubiquitous creature that has done more to sell bunker oil in his passive collective way than all the advertising agencies on Madison Avenue.

Oil prices remain high, but are, at least for the moment, dropping (particularly when corrected for inflation). Fortunately, the petroleum industry has reacted to the high prices by increasing efforts to find and exploit new oil fields. At the same time, the economic pressures of high prices have resulted in a pronounced flattening in the demand for oil. OPEC is in semi-disarray and we may hope for its collapse by 1995. I think most of us could agree that the eventual depletion of the world's oil supply seems further off today than it did ten years ago.

In the past decade we have seen much progress in techniques for reducing frictional resistance. Prof. Robert L. Townsin of the University of Newcastle Upon Tyne has been the outstanding leader in this development. His numerous publications explain practical methods for measuring hull roughness, for maintaining smooth surfaces, and for weighing the relative merits of alternative approaches to minimizing frictional resistance.

The growth in speed of cargo liners and ever-increasing fullness of form of bulk carriers have both magnified the economic benefits of hull form refinements. Now, however, our concern with energy conservation may tend to bring us back to lower speeds in cargo liners and modest reductions in both speed and fullness of form in bulk carriers. I recently did a rough study to find the impact of increased fuel costs on the economics of a steam-driven 45000 DWT oceangoing bulk carrier. In the first phase I dealt with the case of a ship still in the design stage and optimized the design on the basis of minimizing the required freight rate. Initially, I assumed a fuel oil cost of $2.10 per barrel ($14.15 per tonne) and then reworked the analysis at several higher levels of cost up to a ten-fold increase. With oil at $2.10 per barrel, the optimal speed turned out to be 15.6 knots. At an arbitrary five-fold increase in unit fuel costs, the optimal speed dropped from 15.6 knots to 14.0 knots (a 10% drop). At a ten-fold increase, the optimal speed became 12.7 knots (a 19% drop). The required freight rate increased linearly up to 153% at the ten-fold fuel price level. Under the constraints of the analysis, I had to hold the block coefficient constant. A sensitivity study would presumable show some advantage in reducing the fullness of form at the higher fuel price. That being the case, the speed decrements reported above represent extremes. Future developments leading to gains in propulsive efficiency and fuel economy will also attenuate the advantages of lower speeds.

In the second phase of the study, I considered the case of an <u>existing</u> bulk carrier designed for a speed of 15.6 knots, which would be optimal with oil at $2.10 per barrel. With a manifold increase in fuel price, how far should the owner cut back his ship's speed? I assumed that he would select the speed that would maximise his annual returns. I also assumed that, as fuel prices increased, income would rise according to the required freight rates derived in the first phase of the study. In an existing ship the investment in horsepower is already fixed. This means that economic gains from lowered speed are less pronounced than in the case of a ship still in the planning stage. In this particular instance, I found that a five-fold increase in fuel price should be met by dropping back in speed from 15.6. knots to 14.6 knots (a 6% drop). At a ten-fold

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In 1980 my colleague Robert M. Scher did a comprehensive analysis of the effect of fuel prices on the optimal design characteristics of panamax size bulk carriers. He found that a doubling of fuel price would reduce the optimal speed from 13 knots to a little over 11 knots. At the same time, the optimal block coefficient would increase from 0.845 to 0.880.

increase, the speed should be cut back to 13.5 knots (a 13% drop).

The figures cited above are valid only for the specific circumstances surrounding that one operation. They should not be taken as universal. Nevertheless, they indicate to me that higher fuel prices should have a rather modest impact on major ship characteristics.

In the case of cargo liners the question of optimal speed is complicated by the machinations of the conference system. The true economic speed (i.e., the one making best use of scarce resources) receives little thought because the conferences do not allow free competition to set natural prices a la Adam Smith. As a result, owners fight their competitive wars, not through lowering their prices, but through improving their services --- notably through increased speed of delivery. Some of this increased speed comes through better management: more frequent sailings, door-to-door service, etc. The rest comes through ever-escalating sea speeds, which have reached a stage where energy is consumed at a prodigious rate. I admire the entrepreneurship and engineering boldness embodied in today's 33-knot containerships; but I deplore their daily fuel bill of about $44,000 per ship. That cost is the owner's business, but all of us have a right to question such a squandering of the world's finite supply of oil. Worse yet, there is no end in sight; competitive pressures have led to 33 knots but who is to draw the line even there? Nuclear power may take over in the next generation of containerships, but I suggest a more rational solution leading to greater transport economies: namely, some change in the conference system that will allow free market conditions to bring sea speeds down to their most economic level. I leave it to others to suggest the mechanics of effecting the change. My role is simply to point out that continuing along the present path will benefit no one except the air-freight industry. Our customers may appreciate fast sea speed, but, I dare say, the majority would appreciate lower freight rates even more.

Another contribution to energy conservation would be to assess harbor fees, etc, not simply on net tonnage but on some more accurate measure of earning capacity. Such a measure should certainly recognize speed or horsepower as well as tonnage.

Those 33-knot containerships have been sold to the U.S. Navy and are being converted to carry military supplies.

Nuclear power seems even more remote today than it did ten years ago.

High fuel prices have reversed the trend toward ever-higher sea speeds. The need for reform in conference rate setting practices still exists, however.

A recent change in U.S. laws now allows U.S. shipowners to pool cargos. This leads to better economy of operation, with more tons of cargo delivered per ton of oil burned.

We can expect technical developments that will help the cause of fuel economy. One example is the Tymponic Corporation's ultrasonic oil and water emulsifier. Tiny particles of water within the oil explode into steam as the mixture enters a burner, shattering the oil into extremely fine particles. This leads to more complete combustion and claimed savings of 25 to 50 percent in fuel. Moreover, with water replacing air as a source of oxygen, most of the noxious nitrogen oxides are eliminated from the exhaust.

Some experts believe that economic nuclear marine propulsion is so far off that we may see a return to coal in the period when oil is on the way out. Others envisage a return to wind propulsion as the ultimate in cheap, non-polluting energy. Whether either coal or sail effects a revival, it will certainly be in a configuration little resembling historic forms.

But we have drifted into the realm of propulsion machinery, and it may be well to seek the wisdom of some unwitting consultants.

5. Machinery in a borrowed crystal ball

P. A. Milne and M. F. Craig, of Swan Hunter Shipbuilders, have recently presented a carefully prepared paper on trends in ship propulsion machinery.*

* "Machinery Trends with Particular Reference to Large Energy Carriers," West European Conference on Marine Technology, Delft, May 1974.

Their study includes an analysis of ocean transport needs, and resulting ship types, since 1960 with projections to 1985. From there they go on to predict cumulative newbuilding deadweights and horsepowers, also to 1985. The paper contains an imposing quantity of data that we need not repeat here. The major points of interest in the present context are summarized below.

Milne and Craig do not expect "any radical change in the types of machinery used in ships within the next ten years." Rather, they predict "that new developments will be concentrated on improving the reliability of installations

A few coal-burning ships have been built within the past five years. Australia has led the way in this, followed by the United States.

A few experimental sail-assisted ships have been built, notably in Japan. The feasibility of a return to primarily wind-driven ships is being debated. In a 1982 study Yang Siyuan (from the People's Republic of China, then a visiting scholar at the University of Michigan) concluded that there seemed no pronounced economic incentive to abandon mechanical propulsion in favor of sail. He did, however, find some mild promise of commercial success for auxiliary sails. He also pointed out that political forces and questions of environmental protection were on the side of sail. Studies by the Wind Ship Development Corporation have reached more optimistic projections for the future role of commercial sailing ships.

This new commentary on marine machinery is based largely on recent discussions with my colleague Prof. John B. Woodward III.

In truth, the new developments have been concentrated on fuel economy more than on reliability.

with ships regarded as an integral part of a total transportation system." They show curves of the cumulative kilowatts of power installed each year 1963-1973, with reasoned forecasts to 1985. From these we can infer that the four major types of machinery should divide the total power in about the following proportions:

	Year	
	1975	1985
Steam Turbines	39%	26%
Slow Speed Diesels	42%	44%
Medium Speed Diesels	18%	24%
Gas Turbines	1%	6%
Total	100%	100%

Milne and Craig recognize that increased fuel costs will lead to new emphasis on reducing specific fuel consumption. Nevertheless, they feel that overall economy and crew shortages will lead to a stronger and often opposing tendency toward simplified, more reliable plants. They expect greatly increased investments in design engineering and shore prototype testing, more use of standard modular components, and more generous power margins --- the last in opposition to current trends. In design and operation, particular emphasis will be given to minimizing down time for repairs. Planned maintenance programs will feature travelling squads and a large proportion of components easily removed for shore repairs or renewal. Automated devices and computers will provide not only efficient controls but also a flow of feedback information to be used in predicting proper overhaul times.

As regards fuel, Milne and Craig see few significant changes within the next decade. Mideast oil, with its generally acceptable levels of vanadium and sulphur, will continue to dominate the market and most shipowners will continue to use light marine fuel oil of 370 centistokes. Perhaps the major change they foresee is that fuels suitable for aircraft type gas turbines will become available worldwide as a result of greater use by naval craft.

Milne and Craig predict that environmental concerns will include minimization

The July 1984 issue of The Motor Ship carries statistics on powering systems for merchant ships then currently on order worldwide. From those figures we have derived this summary, based on share of total power:

	1984
Steam Turbines	0.5%
Diesel engines	99.5%
Gas turbines	0
Total	100.0%

Although the data do not differentiate between slow and medium speed diesels, the trend is clearly in favor of the former.

The relatively poor showing of steam turbines is at least partly explained by the currently depressed market for large tanker construction. Today's high fuel prices have pretty well killed interest in further immediate application of gas turbines except in the most specialized applications.

The current emphasis on fuel economy has led to the continuing development of longer-stroke, slow speed diesel plants, and many schemes for using diesel exhaust gas energy.

"Heavy" fuel seems to command the largest share of the market these days.

of noise and vibration, as well as overboard discharge of cargo and effluents. Finally, they look to ever-greater sophistication in the decision making process, including computer-assisted economic analyses, dynamic system simulation, feedback from ships in service, and an integration of problems inherent in ship design, construction and maintenance.

Milne and Craig have presented a well-reasoned and objective view of present and future trends in marine propulsion systems. I have given only the most superficial review in the preceding paragraphs, but urge interested readers to peruse the paper for themselves.

As for thoughts of my own, I have already mentioned a few in Section 4, dealing with the impact of elevated fuel costs. To these I can add that before 1985 we may see the first experimental development of satellite monitoring and control of ships. This should allow a single shore-based engineer to take readings and initiate appropriate actions in control of almost any number of ships. Reduction gears may become passé with the development of superconducting electrical transmission systems. As for nuclear power, I foresee no great impact within the next decade. Current fission reactor systems seem fundamentally unsuited to most merchant ships. By 1985, however, we may see under development laser-triggered fusion reactors --- a concept that promises a safer, more convenient form of nuclear power that may prove economically attractive in commercial ships.

6. Any limit on size?

The question is frequently asked: "Where will current trends in tanker size bring us?" or: "When will we reach the upper limit?" I do not intend to answer either question here. I can, however, propose the following outline of a procedure for finding the most profitable size of ship for any given trade.

My major thesis is that, in general, ever-increasing tanker size will lead to ever-increasing economies for the water-borne leg of the transport system.

Satellite monitoring and control are still in the future, but may well have a start by 1995. Superconducting electrical machinery and nuclear power are apparently still far away. Fusion reactors may one day become feasible for merchant ships, but are unlikely to do so within this century.

Off setting this, however, are the countervailing costs of the shore interface system: harbors, quays, and storage tanks. In addition, we must remember that extremely large ships face extra costs such as those arising from a scarcity of suitable repair facilities, or from limited opportunities for alternative services. In short, our economic analysis must embrace all those parts of the transport system that are affected by the size of the ship. It must also recognize the disadvantages as well as advantages of size in developing the economics of the ship itself.

Let us start with some simplifying assumptions that can be re-examined later if desired. We shall assume that we are asked to select the proper size of tanker to carry crude oil from Port A to Port B. This will be either a new trade or a projection of traffic sometime in the future; in any event, we need not concern ourselves at the moment with phasing-in with existing ships. The annual transport demand has been projected to some planning horizon, perhaps twenty years, and is essentially constant. Freight rates are also predictable and may or may not be constant over the planning horizon. Our primary measure of merit is net present value (which can be manipulated later to predict net present value index, yield, or required freight rate).

Given the above scenario, we can propose a menu of half a dozen tanker designs, each of which is optimized around some arbitrarily varied external limitation on size: probably harbor depth. We then estimate the annual transport capability of each size of tanker, not forgetting that the larger units may have to travel longer distances to avoid draft limitations imposed by canals or straits. They may also face longer port times, particularly at the loading port. In estimating annual costs of repairs, we must not forget that the larger ships may face extra costs implicit in a scarcity of suitable drydocks: fewer bids and longer diversions. On the other hand, the larger ships are less likely to be delayed by sea conditions, and we should crank that into our calculations as well. Having carried out the above estimates, we can easily deduce the number of units required in the fleet --- assuming in sequence each of the half dozen arbitrary sizes of ship.

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The severe overtonnaging of the tanker market has halted the construction of large crude carriers. This in turn has halted the growth in tanker size.

Within a few years we may hope to see a revival of tanker newbuildings. The question will then re-arise: What are the upper limits on tanker size? I have no reason to revise the rationale of my proposed method for answering that question.

We are now ready to estimate the construction cost and annual operating cost of each proposed ship, from which we can deduce the same for each of the proposed fleets.

Next we must consider the shore interface part of the system. To begin with, we can probably assume that our decision about ship size will have no appreciable impact on the capital or operating costs of the loading port. That assumption seems justified because most loading ports serve many off-loading ports and could routinely handle any size of tanker we care to send in.

At the other terminal, however, we had better recognize that larger ships will probably involve increased costs that must be borne directly or indirectly by our transport system. We may have to dredge channels to and alongside our quay, and this dredging will have to be maintained in the future. The terminal quay, if it already exists, may have to be enlarged and strengthened or rebuilt --- depending on the size of ship proposed. This will involve increases in annual insurance and maintenance costs, as well as in initial costs.

Then we come to the impact of ship size on the storage tanks required between the quay and the refinery. Clearly, the bigger the ship the bigger the storage capacity required. For each arbitrary ship size, we had better estimate the investment required in providing storage tanks, including costs of real estate and site preparation, as well as tanks and pipes. There will be differences, too, in annual operating costs and in the annual inventory costs (i.e., working capital tied up in idle oil).

I believe we have now covered the most essential factors that we need before we can understand the overall economics of our transport system. There may be others. We may find that storage tank size has some impact on the cost of operating the refinery. We had better talk to our friends at the refinery before going too far. What about the limitations the owner may face in selling or in finding other uses for part of his fleet if demand drops off? What about the relative environmental catastrophies potentially implicit in tankers of different sizes? These factors may defy accurate analysis, but merit serious consideration even though the numbers finally used are little more than guesses.

Since the ship is probably the most complicated link in the distribution chain, I believe we naval architects should provide leadership in optimizing the complete transport and storage system.

The rest of the computation is mechanical. For each year between now and the planning horizon, summarize the capital costs, revenue, operating costs, depreciation, tax, and finally after-tax return. Then apply an appropriate discount rate to find the net present value. Repeat the procedure for each alternative fleet. The overall results will provide a curve of net present value (or other criterion) versus ship size. This curve should show a region of optimality that will probably be rather broad, allowing the decision-maker a good deal of latitude in selecting the size of ship for the trade.

The analytical procedure described above may seem complicated. It does indeed contain a multitude of individual judgments and arithmetical steps. In principle, however, it is exceedingly simple. But, if actually carried out, it would apply to only a single trade; it would be subject to selective variations in each of the simplifying assumptions; and it would allow the decision-maker considerable choice at the end. For all of these reasons I consider it impractical to volunteer any absolute answer to the question raised by our section heading: ANY LIMIT ON SIZE? We may expect that records for tanker size will continue to be broken but at a diminished rate. I doubt that we shall reach any plateau before 1985.

7. By time machine to 1985

If we were shifted ten years ahead in some time machine, and could examine the ships just coming out of the yards, what would we find? Initially, we should feel right at home; today's conventional ship types would dominate the scene, and the differences (e.g. tanker sizes) would represent smooth extrapolations of current trends. There would be several rather freakish configurations to baffle our imaginations, but, on the whole, the visual aspects of the fleet would be reasonably familiar. The truly significant differences would be less visible and would become apparent only after more careful investigation. These would reflect a manifold increase in the care given to design and management. Manning practices would be vastly changed (and varied) and that factor would explain a major share of what we should find new and different in those ships.

1985-1995

The current leveling-off in tanker size is only an apparent plateau. We can expect renewed growth once demand begins to exceed supply.

That ten-year look ahead seems good for another ten years.

Fuel economy would still receive careful attention. Barnacle-free hulls, slightly finer lines (in bulk carriers), and improved machinery would, however, allow 1975 speed levels to be maintained or bettered, despite continuing high costs of fuel. We should feel at ease in those 1985 engine rooms, although we might be surprised at many new items of equipment, the lack of clutter, and the ease of repair or replacement.

We should find our new ships safer, more reliable, and more easily maneuvered and controlled. Faster port turnaround, better scheduling, and reduced times out of service would increase each ship's productivity over today's standards. We might be impressed with the role of computers in the design, construction, and management of the ships. Computers would consider the owner's functional requirements and --- with suitable human interaction at various stages --- select the major design characteristics, design the ship, issue the purchase orders, plan the production, keep track of inventory and handle the payroll. By 1985 production control methods may have reached a stage where non-standard ships can be produced as a matter of routine. Engineers and production planners would not be displaced; on the contrary, they would be busily engaged in incorporating new technological developments and new requirements into the computer programs. By virtue of the care put into the programs, the computer would successfully integrate all pertinent considerations (e.g. fuel economy, environmental protection, habitability, reliability, maintainability, and ease of construction) so as to produce the most profitable possible ship for the trade.

In the area of ship management we could expect to find some ships totally unmanned between pilot stations. Satellites linked with shore-based computers and personnel would be used to navigate the vessels, to control their machinery, and to modify their course when required to avoid collision. Travelling maintenance squads, rotated from ship to ship, would minimize time out of service for repairs. All major ports and their approaches would come under traffic control, with groundings and collisions pretty much a thing of the past.

But, the gods have special punishments for mortals who venture detailed opinions about the future, especially in print. (I have friends who can be counted upon

Most of these predictions have proven true, although average sea speeds have probably dropped somewhat. The general trends should still be true in 1995.

Developments in safety, reliability, maneuverability and control still continue; but so have the human errors that always tend to offset technological improvements. We can, however, be optimistic about continuing gains in ship productivity (faster port turnaround, etc.) and a growing reliance on computers in design, construction, and fleet management.

The predictions for the role of computers are proving true, although the attainment of the specified goals might better be assigned to 1995.

The totally unmanned ship (between pilot stations) is technically feasible, but institutional constraints, inertia, and reasonable prudence have all served to veto such a development. Perhaps by 1995? We shall see.

Traveling maintenance squads are beginning to take hold in some fleets. Traffic control is still in its infancy, but should continue to develop. Groundings and collisions still occur, I much regret to say, but we may hope for decreasing incidents in the decade ahead.

to exhume this paper in 1985). Let me close then with this suitably broad conclusion: Although we may expect some technological surprises, the typical new ship of 1985 will be generally similar to those we see coming out today. The majority of visible modifications will be the result of innovative manning practices. The most significant differences, however, will be in methods of design, production, and management. Although not apparent to the eye, these are the coming changes for which we should try hardest to prepare --- starting right now. Those who do so can expect generous rewards in the expanding world of ocean commerce; those who do not have at least the alternative of collecting brochures from retirement homes.

My overall conclusions for 1985 now seem eminently reasonable and should still hold true in 1995. True, the continuing expansion of ocean commerce that I implied has suffered a severe set-back. This is but another phase in the unpleasant ups and downs of our industry. In the long run we can be confident about our future. The world economy is sure to place increasing demands on the services our industry has to offer. Those of us who take the long range view and prepare for tomorrow's world can expect to find prosperity between now and 1995.