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and Its Implementation in the Maritime Industries
Marine Board
Commission on Engineering and Technical Systems
National Research Council (U.S.)

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FOREWORD

This report, prepared at the request of the Maritime Administration (MARAD), addresses the question of the health and status of research and innovation* in support of enhanced productivity and international competitiveness of U.S. maritime industries--shipbuilding, ship operating, marine terminals, and inland waterways. The facts marshalled in the report on trends in the maritime industries are widely known. In the view of many, the plight of the maritime industries is not dissimilar from that of other key industries, such as steel, autos, and textiles, where there is concern for competitiveness, unemployment, and communities in crisis.

The United States is increasingly dependent on foreign trade; more and more U.S. industries are finding that they must compete internationally in order to survive. These industries must now be termed world-scale industries. They need to be managed in that context, and public policy needs to reflect the reality of a growing and more pervasive international competition.

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*These terms encompass all of the following in this report:
Technology is in its broadest sense the organization of both empirical and theoretical knowledge into a consistent and systematic entity. The entity may take the specific form of equipment or devices, but also encompasses "how-to-do," including the organization of work and also computer programs.
Research and development (R&D) is the effort that creates the organization of knowledge into devices or systems previously defined as technology.
Innovation is a very broad term that generally means the introduction of something new with a particular connotation of the commercial application of an idea. There is a natural association of the term innovation with R&D because potential applications for technology are so pervasive in our society.
Technology transfer means the adaptation of technology into practical use independently of the source. In this sense, technology transfer is an element of the R&D process.

Strengthening competitiveness in the U.S. maritime industries is all the more essential because of their potential importance to national security. Three special factors complicate the systematic use of research and development (R&D) as part of a "cure" for the maritime industries. First, the maritime industries are beset with poor economic conditions, some (e.g., overcapacity) of their own making, others (e.g., inadequate revenues) also the result of government supports available in other countries but not in the United States. In such a poor economic climate, there is very little interest in pushing R&D. Second, the federal government is systematically trying to get out of any involvement in maritime R&D. Third, the U.S. maritime industries have undergone fundamental changes as they have become integrated into more comprehensive transportation and manufacturing systems. These fundamental changes have not been matched by changes in the controlling federal executive and legislative functions. Despite the complicating factors, Congress should consider maritime research and innovation as an element of federal transportation programs and U.S. competitiveness.

This report was prepared by a committee appointed by the National Research Council and operating under the auspices of the Marine Board. Members of the committee were selected with regard for the expertise necessary for the assessment and to achieve a balance of experience and viewpoints on transportation technology development and application in general and in the maritime industries in particular. Committee members' backgrounds span the fields of research and development management, users of technology (ship operation, shipbuilding, ports and terminals, and inland waterways), technology development (industry and academia), technology transfer, government maritime policy, and R&D in other industries. Biographies of the committee members appear in Appendix A. The principle guiding the constitution of the committee and its work, consistent with the policy of the National Research Council, was not to exclude the bias that might accompany expertise vital to the study, but to seek balance and fair treatment.

The committee sought to identify how R&D can contribute to increased competitiveness of the maritime industries in the international marketplace; and, it tried to determine how R&D can contribute to enhancing the availability of the commercial maritime industries and their assets to potential military needs in the future.

In the first phase of its assessment, working groups of the committee prepared background papers on the state of technology development and application in the shipbuilding, ship operating, marine terminals, and inland waterways industries. The background papers reviewed industry status and identified needs. The development and application of technologies relevant to the needs, and the roles of industry and government in addressing these needs, were then assessed. The results of this phase were published in an interim report* in March 1986. Two

*Copies of The Roles of Government and Industry in Research and Development for the Maritime Industry are available from the National Academy Press, 2101 Constitution Avenue, Washington, DC 20418.

chapters of the interim report, which substantiate much of the discussion of motivations and mechanisms for R&D in this report, are reprinted herein as Appendix B.

In the second phase of the project, documented in this report, the committee identified and assessed the motivations of U.S. maritime companies and the government to sponsor and implement R&D. It reviewed mechanisms employed in other industries in the United States and in the maritime industries of other countries to stimulate and to implement R&D. The committee synthesized a set of predictions as to who the future sponsors of maritime industrial R&D might be (or might not be) and what the expected business and national benefits of such R&D might be (or might not be). The committee also considered the role of current or new incentives, existing or new organizations, and also more aggressive government, industry, or collaborative sponsorship and facilitation of maritime technology development and application.

SUMMARY AND RECOMMENDATIONS

At the heart of the maritime industry's economic distress is its inferior competitive position relative to shipyards and steamship lines in other countries. As a result, U.S. shipyards exist primarily to meet Navy requirements, while government and protected cargoes make up an important share of the business of ship operating companies. In the other parts of the maritime industry, U.S. ports increasingly compete among themselves for a market share of the U.S. foreign trade. Finally, deregulation of rail transportation and falling demand for bulk movements have put the inland waterway segment into a deep depression. Thus, the U.S. maritime industry is very competitive within itself, but much less so with foreign companies.

It is the national policy to have a strong U.S. maritime industry but also to accomplish this at a reduced or minimal level of federal expenditures. The national interest is to assure sufficient maritime capability to meet defense and other international objectives. It is not necessary to quantify precisely what such needs are in order to recognize the value to the country of some maritime activities. One of the elements of maintaining national maritime activity is research, development, and innovation.

Maritime research, however, must be embedded in the overall context of U.S. industrial evolution. Many observers, including the authors of this report, have concluded that the U.S. maritime industries--shipbuilding, ship operating, marine terminals, and inland waterways--are increasingly becoming integrated elements of larger transportation and manufacturing systems. Restructuring maritime promotional programs, including maritime research and development (R&D), to take advantage of this insight is the responsibility of the U.S. Department of Transportation and its legislative oversight committees. This report contributes to this task by establishing an improved basis for identifying and addressing the R&D needs of the maritime industries. The important task of placing these needs in the context of the overarching transportation and manufacturing systems of which they are a part was outside the purview of this study.

PUBLIC AND PRIVATE ROLES IN MARITIME RESEARCH AND DEVELOPMENT

For at least 25 years, the maritime industries' research and development effort has been accomplished by both the private and public sectors, acting both separately and collaboratively. Private sector research has been motivated by competition and has resulted in such innovative concepts and proprietary developments as containerization, lighter aboard ship, container-stacking systems, intermodal systems, and shipbuilding process improvements. Public sector research has disclosed basic knowledge of specific segments of the industry, such as the economic impact of U.S. ports, or has been catalytic in nature, such as the exploration of maritime applications of satellite communications through demonstration projects.

Many maritime issues require technical expertise in assessment and formulation of public policy. In other technical areas of government activity, such as military and energy, the government maintains large in-house laboratories with the need for technical competence and currency as a major justification. A maritime R&D program can fulfill a similar purpose for the Maritime Administration (MARAD).

Furthermore, there are roles and functions of government that cannot be assumed by or passed through to the private sector. Establishing the technical basis for modernizing regulations is an example, as is development of inland waterways and the improvement of ports and harbors, where the sovereign powers of government have been and must continue to be integrated with the evaluations and predictions of modeling and environmental technology.

Some areas of knowledge concerning the maritime industry are important to the nation but most likely would not be examined by the private sector. MARAD-funded studies of the economic impact of the port industry on the United States created an economic model. Some ports have employed this model to analyze their capital programs and to justify them to local and state authorities.

Many R&D and innovation areas are well within the scope and resources of the private sector, but some areas can be enhanced by public sector involvement either independently or in a collaborative manner. The program to promote more effective manning of U.S.-flag ships is an example of an effort where the involvement of a government agency has been considered by many as necessary. MARAD's participation enhanced the acceptance of the concept by both the U.S. Coast Guard and the involved labor organizations. Over the past decade there has been increased appreciation of the significance of private and public sectors acting in concert. Cost sharing between industry and government is a particularly effective form of collaboration. For private sector companies that cannot justify more substantial R&D investment, it offers the considerable advantage of financial leverage. Cost sharing with industry is attractive for the government because it provides reassurances that government programs are addressing real needs and that developments and innovations are likely to be used.

> Recommendation: MARAD should broaden its efforts to stimulate industry to form collaborative mechanisms for the support and

conduct of research and innovation. Viable alternatives for R&D sponsorship must be created beyond those already existing for individual companies seeking proprietary advantage.

Where U.S. maritime industries have become more competitive or enhanced national security, it has been for one of two reasons. Either they have increasingly integrated their maritime activities into an overall system (manufacturing system in the case of shipbuilding, integrated transportation system in the case of shipping and ship operating), or they have reaped maximum benefits of technology transfer from other U.S. industries and from abroad, or both. Keeping up the momentum for systems integration and technology transfer will continue to be important. The government can be a catalyst for this.

PRIORITY AREAS FOR RESEARCH AND INNOVATION

The top priority should be systemic investigations, especially those addressing management, labor, and information management activities that might facilitate linking the various maritime segments together more effectively. However, given the fragmented nature of the maritime industries, a really comprehensive approach is likely to come only with government initiative and support. Under the conditions of stress current in the maritime industries, the government in general and MARAD in particular should exercise greater leadership.

<u>Recommendation</u>: MARAD should significantly intensify its proactive policy to promote R&D and innovation in the maritime industries. The statutory basis for this, contained in the Merchant Marine Act of 1936 and the Merchant Marine Act of 1970, continues to be relevant. MARAD should seek out and pair common motivations (for R&D and innovation) of interested parties, and also create and promote mechanisms to foster research and innovation, especially cost-shared ventures.

The committee identified a number of promising areas where R&D and innovation can contribute to increased competitiveness of the maritime industries in the international marketplace, or where R&D and innovation will enhance the availability of the commercial maritime industries and their assets to potential military needs.

Important areas where there is significant potential for collaboration with industry, provided government assumes or continues a catalytic role, are:

- Shipbuilding technology. Collaborative shipbuilding research has been supported by private shipbuilders for nearly 15 years and has achieved significant improvement in shipbuilding processes, with resulting savings in shipbuilding costs. Government involvement has been crucial in organizing this cooperative approach and fostering applications of the results. Continuing government involvement, including that of the U.S. Navy, is essential if these advances are to be maintained for the benefit of the U.S. Navy, for national defense industrial preparedness, and for local area labor forces.

- Ship operation research, especially vessel manning practices. Technology has been developed here and abroad that enables more efficient manning of ships. Other leading maritime nations have taken greater advantage of these opportunities. Recently, joint management and labor initiatives in several U.S. ship-operating companies with essential facilitation by MARAD have started to bring these gains to the U.S. Merchant Marine. This area promises significant improvement in U.S. competitiveness and indeed is essential to prevent the United States from falling further behind foreign competitors.
- Maritime safety. Safety of persons, property, and the marine environment is a major and costly issue in ship operations. The industry has supported research to improve its safety record, most recently to ensure its ability to operate with reduced manning under conditions of increased safety requirements. The public interest in safety is clear. Public leadership is needed in safety research.
- Intermodal cargo handling. The separate transportation industries--rail, truck, air, and maritime--have been progressively deregulated so that they compete more intensely among themselves and across modes. However, many aspects of government involvement, such as control of procedures for freight clearance and documentation, remain. Substantial opportunity exists for facilitating management of intermodal cargo transactions. Collaborative research could be directed to simplifying commercial and government documentation requirements and developing automated documentation information management systems.

An area of considerable opportunity where government interests are paramount (and government should therefore bear the majority of the cost of advancement) is increased capability of state-of-the-art commercial vessels to load and efficiently transport military cargoes. Because of the growing divergence between military needs and commercial requirements of ship operators, research is urgently needed to develop vessel cargo-handling and other systems that are flexible, commercially useful, and responsive to sealift requirements.

> <u>Recommendation</u>: The government should maintain a judiciously selected R&D program to continue to satisfy its unique requirements and to address the most fertile collaborative areas, identified above. Both MARAD programs and the Navy sealift capability would be strengthened by this.

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EVOLUTION OF THE MARITIME INDUSTRIES AND MARITIME TECHNOLOGIES

TRENDS

The U.S. maritime industries--shipbuilders, ship operators, port industries, and allied industries--are undergoing unprecedented change as the result of erosion of the U.S. competitive position in world shipping and trade, deregulation of the transportation industries, and increasingly fierce competition for discretionary government funds. The response to these trends will have far-reaching implications for the national defense and economic security.*

The traditional technology and organization of the maritime transportation industry had a substantial degree of separation and independence from other industries and transportation modes. Shipbuilding was an industrial process with few commonalities in its technology and organization with other manufacturing. The terminal industry and the ship operators were attuned to cargo patterns in which sharp transitions occurred where cargoes were in effect handed over from other transportation modes by relatively primitive and unspecialized shoreside facilities and ships. The growth of containers and intermodal transportation and the development of highly mechanized facilities for bulk cargoes have produced a qualitative change in the integration of the maritime

*Implications for national defense. Commercial decisions, such as investment in specialized versus multipurpose vessels, have hampered U.S. sealift capability. The military's concern over this situation has been shown in testimony before Congress and in programs to purchase and modernize obsolete commercial vessels to provide reliable available logistic capability. But these programs, as vital as they are, do not effectively address the problems of sustaining U.S. forces in a remote theater. The Falklands crisis provided a modest preview of logistic problems the United States would face given an emergency in the eastern Mediterranean or Southwest Asia. Other scenarios that would require timely military sealift include conflicts in Africa and flare-ups in Central America. The aging National Defense Reserve Fleet and dwindling Merchant Marine are falling increasingly short of the minimum requirement. The availability and time responsiveness of shipyards and the industries into the whole national transportation complex. In shipbuilding the reorganization of product definition and manufacturing work flow and the adoption of computer-based design and work scheduling have created a new level of commonality with other industries.

These trends have been recognized in part by the inclusion of the Maritime Administration (MARAD) in the U.S. Department of Transportation (DOT), by the creation of port authorities with a broad range of facility and transportation responsibilities, and by the ownership of some shipbuilding and ship-operating companies as subsidiaries of industrial companies with broad interests in a variety of industrial and transportation interests.*

This has not been matched by a corresponding reorganization of the congressional oversight functions, which have continued the divisions of responsibility of an earlier time. Congressional oversight of maritime policies and programs has historically emphasized subsidies and regulatory structures and has largely ignored the importance of innovation. Hearings held for DOT review do not cover MARAD. Hearings concerning MARAD do not appear to recognize its interaction with naval ship construction programs or military sealift readiness. This state of affairs has inhibited the full recognition of the importance of innovation by private sector management, especially since the cost of unproductive operations has been borne without complaint by Congress, acting for the public, by means of direct and indirect subsidies (Jantscher, 1975).

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industrial base, the availability of mariners, and the efficiency of ports are collateral questions, as are the availability of U.S.-owned, foreign-flag vessels, NATO and other allied fleets, and sequestering of hostile shipping.

Implications for economic security. The United States is the world's largest trading nation. Even though maritime transportation is essential to world trade, U.S. maritime capability has been declining for years (see Table 1). At issue is whether the maritime industries should be allowed to decline further or whether U.S. economic interests require federal attention to arrest that decline. The committee's hypothesis is that the position of the United States as a major trading nation requires competitive, though not necessarily dominant, maritime industries. Furthermore, the committee believes that the utility of the Merchant Marine for national defense and economic security rests in part on the health of the technical base--the technology, research and development, and innovation in the maritime industries.

*Other reasons can be marshalled to explain these developments. The transfer of MARAD to the Department of Transportation also can be attributed to an agreement between two cabinet officers, one who wanted to consolidate all transportation modes in one department, and the other who wanted to be rid of a troublesome industry sector. The acquisition of shipbuilding and ship-operating companies by outside corporations was stimulated by corporate diversification policies and potential tax benefits.

TABLE 1 Status of Shipbuilding and Ship-Operating Industries, in 1970[a] and 1985

Industrial Sector	1970	1985
Shipbuilding		
Merchant ships on order	62	11
Employment (U.S. Navy active, shipbuilding base)	133,900	115,000
Ship operating		
Number of general cargo companies	21	9
Privately owned U.S. flag vessels (number)	632	393
Privately owned U.S. flag vessels (carrying capacity, dwt)	23,280	24,737
Seagoing employment (billets)	37,600	17,887

[a]The year 1970 was selected as the base year since it was the year of passage of the most recent comprehensive maritime legislation, the Merchant Marine Act of 1970.

SOURCE: Adapted from annual reports of the Maritime Administration and Statistical Abstract of the United States.

The maritime industries have been studied many times. Recent major reports include: the U.S. Congress, Office of Technology Assessment (1983), An Assessment of Maritime Trade and Technology; the U.S. Congress, Congressional Budget Office (1984), U.S. Shipping and Shipbuilding: Trends and Policy Choices; and, the National Advisory Committee on Oceans and Atmospheres (1985), Shipping, Shipyards and Sealift: Issues of National Security and Federal Support. Congress, in 1984, established a commission to examine national security aspects of the merchant marine; the commission is scheduled to report its findings in 1988. The House Committee on Merchant Marine and Fisheries established, in 1985, an advisory group that called for an overhaul of maritime subsidies. These and other studies have documented change in the maritime industries (see Table 1).

Much has been accomplished in the last 15 years to improve the health of the technical base of the maritime industries. A list of the most significant technology developments and applications of the last decade would include: advances in shipbuilding industrial processes, improved utilization of the seagoing work force leading to more effective manning and crew reduction, introduction of fuel-efficient diesel engines into U.S. commercial vessels, utilization of state-of-the-art technology in cargo handling and the operation of marine terminals, and a trend toward truly intermodal freight transportation networks in part as a consequence of government deregulation. Many of these innovations were developed or improved by the U.S. maritime industries' foreign competitors and were put into practice in the United States as the result of government-funded technology transfer.

Ports also have sought aggressively to modernize, but they have encountered obstacles in part as the result of federal control of the waterways serving them. Remedies, including cost sharing of waterway improvements, were passed by Congress in 1986 after more than a decade of debate in which no new channels (or deeper or wider channels) were authorized. These developments, the driving forces behind them, their principal benefits, and suggested roles of industry and government in the past and in the future were summarized in the committee's interim report (see Appendix B) and are repeated in Table 2.

The process of technology development and application in the U.S. maritime industries is further illustrated by the following examples.

- American President Lines (APL). This company, a subsidized U.S.-flag general cargo ship operator, has transformed its operations in the last decade, largely as the result of innovative applications of technology. It still operates traditional steamships with relatively high fuel and manning requirements, but a portion of its fleet is state of the art with diesel propulsion, automated engine rooms, and reduced and more effective manning. A recently announced purchase of five new, large container ships from German shipbuilders will enhance the state of the art in some respects. Manning innovations have been introduced by means of a trial program supported by MARAD; the impartial involvement of MARAD was a critical factor in obtaining the involvement and support of the labor unions and the Coast Guard in more effective manning. Management has also capitalized on publicly supported advances in satellite communications and environmental prediction to modernize maritime communications and scheduling.

Concurrent with modernizing its ocean fleet, APL is modernizing its marine terminals. Much work on crane design, terminal systems, and other technical elements has been proprietary; however, APL has participated actively with other companies and MARAD in the Cargo Handling Cooperative Program, a cost-shared, cooperative program of ship-operating companies, which is dedicated to improving marine terminal technology. Conducting its own market and systems research, APL has embarked on a bold, new intermodal strategy employing larger containers and double-stack trains. In time, these strategic developments can completely integrate maritime operations into a worldwide freight transportation system.

- Todd Shipyards Corporation. An economic-lot-size purchase of frigates by the U.S. Navy in the mid-1970s enabled this company to make several important strategic advances in ship production processes. Profit was invested in a capital improvement program, most notably a ship lift system (synchro-lift) at its San Pedro shipyard. Series production of ships enabled the company to transform its ship production

TABLE 2 Overview of Research and Development in the Maritime Industries and the Roles of Industry and Government

Industry Sector	Current Driving Forces	Key Technology Developments	Principal Benefits	Principal Developers and Their Roles	Future Needs	Future Roles
Shipbuilding						
Commercial	Reduced government support Lack of cost and financing competitiveness	—	—	MARAD-sponsored collaborative program with industry-facilitated technology transfer	Improve price competitiveness More economic-lot-size production	Government and industry need to address national policy issues of industry support and competitiveness
Navy	Fleet expansion Cost control	Improvements in shipbuilding process technology	Savings in hundreds of millions of dollars in the construction of naval vessels in the last 5 years	Shipyards developed and applied technology Navy provided contract incentives to improve MARAD-sponsored collaborative program with industry-facilitated technology transfer	Further computer applications and advances in process technology Reduce overcapacity Promote management-labor cooperation	Navy should continue contract incentives Navy should collaborate with industry on advances in process technology and computer applications MARAD should continue collaborative program with industry
Ship operating						
Liner	U.S.—largest trading nation creates market Deregulation of freight transport opened competition Expansion of antitrust immunity Overcapacity	Containerization Effective manning Fuel-efficient engines Management systems/schedule rationalization Jumbo ships Inland feeder systems	Favorable impact on operating expenses	Containerization has been led by U.S. entrepreneurs Manning, engines, and management systems development have been led by foreign companies. MARAD has facilitated technology transfer and labor-management cooperation	Further operating, cost, and service improvements Modernize pertinent regulations to make them supportive of fleet modernization Control labor costs	Industry will pursue incremental improvements as a result of competition MARAD should document need and be catalyst for rationalizing regulations
Bulk	Overcapacity Aging, expensive U.S. fleet	Fuel-efficient engines Management systems	Favorable impact on operating expenses	See above	See above	See above

TABLE 2 Continued

Industry Sector	Current Driving Forces	Key Technology Developments	Principal Benefits	Principal Developers and Their Roles	Future Needs	Future Roles
Marine terminal	Labor-management conflicts High cost of terminal labor Increased competition Trend toward intermodal transportation Deregulation of freight transportation Local-federal, public-private cost-sharing	Terminal automation Incremental improvements in intermodal terminals and technologies Waterway improvements	Most competitive port wins greatest share of trade in deregulated operating environment	Terminal operators and equipment manufacturers have been responsible for incremental improvements MARAD-sponsored collaborative program with industry is emphasizing automation testing and technology transfer Corps of Engineers has been national agent for waterway improvement	Further automation of terminals Further intermodalism Further automation of paperwork Management-labor cooperation, more effective use of human element Improve national waterway deepening situation by pushing national planning and priority-setting, improving national decision-making/permitting process, and relying more on cost-sharing Multipurpose terminals Utilization of dredge spoil as a resource	Industry will pursue technology improvements as a result of competition. MARAD can facilitate technology application by addressing management-labor improvements, similar to role in effective manning Customs needs to collaborate with industry on paperwork automation. MARAD can possibly facilitate this Waterway improvements continue to be primary responsibility of Corps of Engineers, although cost-sharing increases local interest in cost-effective improvements
Inland waterways	Depressed demand Overcapacity	Waterway infrastructure Vessel and fleet productivity, as a result of improvements in technologies and management systems	Still cost competitive, although competition from rail and pipeline is gaining	Infrastructure is the responsibility of the Corps of Engineers Vessel-operating companies have been responsible for technology and management system improvements	Reduce overcapacity Modernize infrastructure Improve industry-wide data on trade and operations to enable strategic planning	Infrastructure remains responsibility of Corps of Engineers MARAD-led industry collaboration on data and planning needs may be appropriate because benefits of R&D for any one operator are overshadowed by risks of investment

process from traditional methods to modern manufacturing methods based on group technology principles. To facilitate this transformation, the company actively participated in the collaborative, cost-shared industry-government (MARAD) National Shipbuilding Research Program. Corporate officials estimate that these two developments, one proprietary and the other partially collaborative, reduced shipyard labor input to its products by 30 percent over a 5-year period.

- Port Authority of New York and New Jersey. As public bodies, port authorities need to demonstrate their importance, or economic impact, to the region they serve. A MARAD research and development (R&D) project in the late 1970s sought to quantify the national economic impact of the port industry. With MARAD support, the Port Authority of New York and New Jersey developed an input-output model of the economic impact of ports. This model is now in use in the port industry and has been used effectively by other ports to demonstrate their regional economic impact and to justify capital improvements.

OVERVIEW

Consideration of the advances in technology that have been accomplished calls into question some of the negative statistics that have been used to characterize the maritime industries. The number of ships has declined since 1970 in part because of changes in demand for vessels. Petroleum, the single largest commodity (measured by volume) carried by water, is transported mostly by fewer but much larger vessels than were employed 25 years ago. The trend of fewer vessels with greater cargo capacity replacing more numerous, smaller vessels is now ubiquitous in shipping--general cargo as well as bulk cargo. Fewer ships means less demand for mariners and fewer billets. While this may concern the military because modern commercial vessels are ill-suited to carry odd-sized military cargoes or to call in undeveloped ports, it means lower fixed costs for the ship operators.

The nation's ports and shipyards have modernized as well. Some investments have been made in both of these industries. Since 1970, the U.S. shipbuilding industry has invested about $3.7 billion in plant modernization and improvements; $100 million was planned to be spent in fiscal year 1986. The public ports of the United States will spend about $3.26 billion on facilities improvements between 1983 and 1989.

The U.S. maritime industries have been and continue to be modernized and concentrated. In these ways, the U.S. industries are not much different from their foreign counterparts. The technical base of these industries is being developed in many countries; U.S. developments need to be considered in their global context.

Concern for the health of the technical base needs to be directed less at the possibility of industrial neglect and decline than at the motivations of U.S. companies to identify and address worldwide conditions and to conduct R&D, or the mechanisms that they employ to do so. These motivations and mechanisms may be in harmony with or in opposition to the supporting government policies. A case in point concerns the maintenance of adequate logistics capability in the Merchant Marine to satisfy national requirements in an emergency. In principle, U.S. maritime policy calls for U.S. merchant ships to be designed and built with a dual purpose: to provide a competitive, private sector asset to shipping companies, and to have this same vessel meet defense requirements in the event of a national emergency. Achieving a practical and functional solution to these objectives has been very difficult; efforts to this end have all but been abandoned.

If the Navy were to design its ideal merchant vessel today, it would most probably be moderate in size, have high speed, and have roll-on/roll-off, break-bulk capability. It would also be self-sustaining. In contrast, current merchant cargo vessel designs, driven by the need for economic survival, are for large, moderate service speed, nonself-sustaining container vessels. This dichotomy in technical requirements is a major policy dilemma of U.S. sealift capability today. If there is a need to integrate government policy objectives (i.e., merchant ships with defense capabilities) into commercial practice (where there is otherwise no commercial incentive), then it is appropriate for the government to pay for this (as contemplated under the Merchant Marine Act of 1936).

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2

MOTIVATIONS FOR MAINTAINING OR STRENGTHENING R&D IN THE MARITIME INDUSTRIES

Research and development (R&D) includes three sequential activities--basic research, technology demonstration, and system development.

The initial activity, basic research, consists of activities primarily aimed at producing physical understanding, new concepts, design data, and validated design procedures. It consists of activities ranging from theoretical analysis to laboratory investigations to testing of experimental systems. These activities tend to have a large degree of uncertainty in their outcome.

The second activity, technology demonstration, is aimed at demonstrating improved system or subsystem characteristics to provide the decision maker with the confidence that the anticipated improved level of performance is indeed achievable in a new system. The technology demonstration efforts are characterized by testing configurations similar to the intended applications and by a modest degree of uncertainty in outcome. These efforts are the final technology activity before system development, but before a decision to develop a specific system is made.

The third activity, system development, consists of activities aimed at producing specific systems for operational use. This is the segment of the R&D process that has the highest cost, and thus receives the most management attention.

The three activities represent a continuous spectrum of related activities in which technology is generated, demonstrated, and transferred into system development. Figures 1 and 2 characterize the costs and risks of the R&D process. The figures show that investments in basic research are characterized by relatively low financial cost but high technical risk, whereas investment in systems development is, in general, low technical risk but high financial cost and risk. Rational management looks at the entire spectrum of activities in its decisions about investing in the technical base. The following sections assess the motivations of the private sector and the government to conduct R&D, both separately and collaboratively.

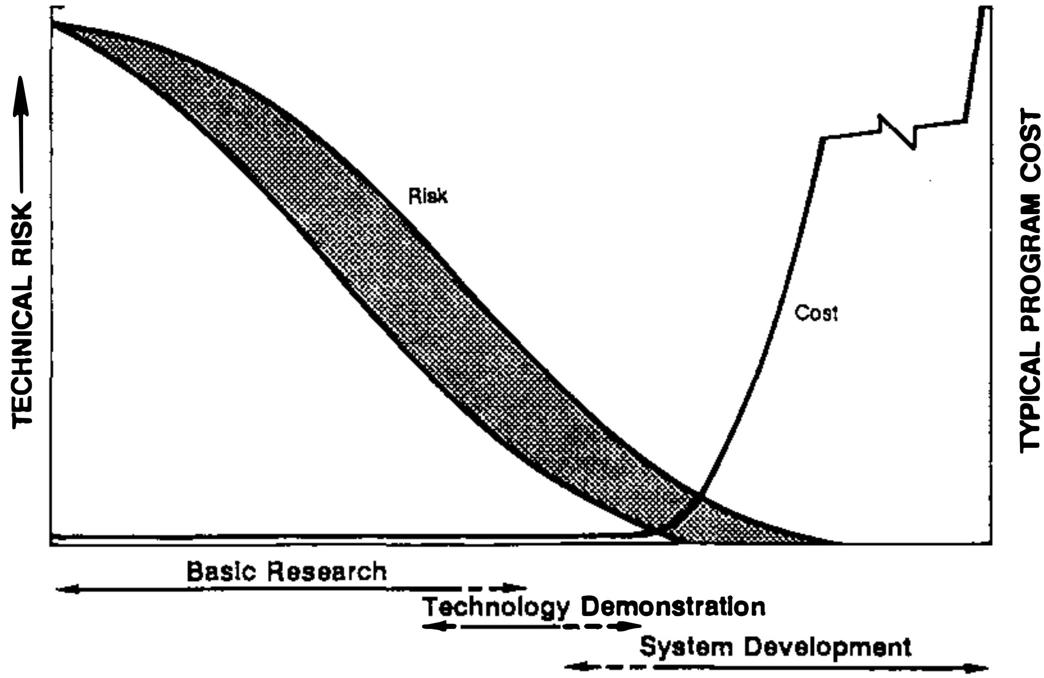

FIGURE 1 Costs and risks of the research and development process.

SOURCE: Adapted from Executive Office of the President, Office of Science and Technology Policy, "Aeronautical Research and Technology Policy," Volume 1, 1982.

PRIVATE SECTOR MOTIVATIONS

Research and development is undertaken in the private sector for the purpose of improving the performer's competitive position relative to his competition. A special case is to prevent the decay of the performer's position relative to his competition when the competition has in some fashion gained in market share, product performance, or cost advantage. Proposals for group-sponsored R&D will generally fail to be supported unless some special circumstance exists, such as the threat of government regulation. In jointly funded operations, such as the Microelectronics and Computer Research Consortium, the perceived competition is the Japanese.

Another reason for maintaining some in-house capability is to provide an avenue for bringing new ideas into a company.

There is a considerable spectrum of competitive advantage and disadvantage that R&D has the potential to create. Cost is one element of that spectrum. It is not difficult to perceive how R&D might decrease

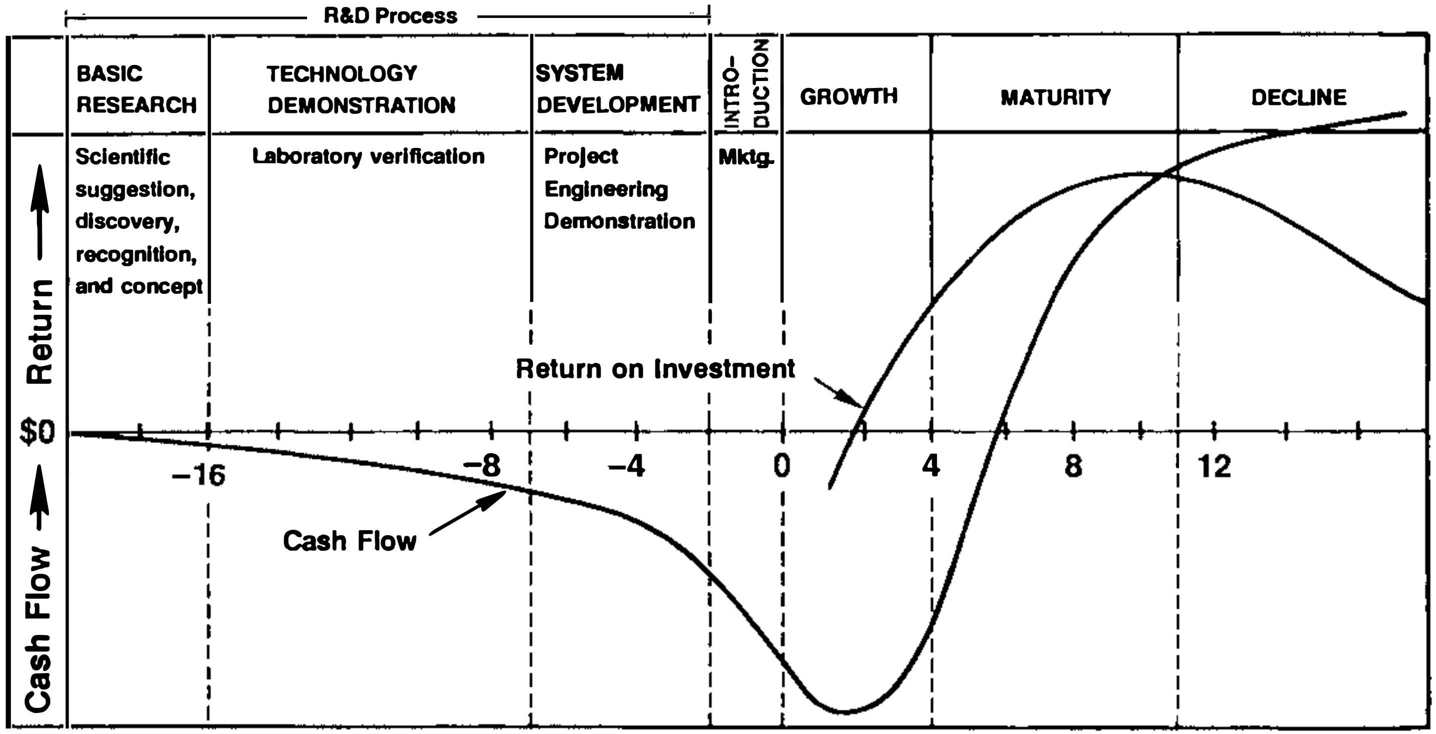

FIGURE 2 Innovation life cycle. The figure is also applicable, in a general way, to operations research, although the curves would have a somewhat different shape.

SOURCE: Adapted from W. G. McLoughlin, "Fundamentals of Research Management," 1970.

the material or labor inputs to a product, process, or service. An important factor is the degree to which the advantage gained can be sustained. An improvement made through decreased manning of a ship, for example, can be quickly copied by all competitors since little proprietary information would be involved. Concessions made by labor unions and changes in government regulations are rapidly known to and accessible by all competitors.

GOVERNMENT MOTIVATIONS

Government sponsorship of R&D is one way to support the public interest in security, public safety, and ports and waterways planning and development, to ensure that the base of scientific and technical knowledge exists to support existing laws, and to promote international competitiveness. In support of these needs, the government:

- Acquires data, conducts feasibility and other analyses, and supports demonstration projects.
- Conducts R&D in support of policy or program development, such as the assessment of technology and implications of current or proposed laws, rules, or standards. The Maritime Administration (MARAD) is uniquely qualified to conduct analysis of government regulations that constrain or prevent industry from implementing innovative changes that would lead to improved operational productivity. Such regulations include the manning requirements of the U.S. Coast Guard and Federal Communications Commission. Many other regulatory constraints deserve analysis.
- Sponsors R&D that directly benefits the government, such as efficiencies in the handling of government-impelled and preference cargoes or advances in naval shipbuilding technology, which reduce the cost (to the nation) of naval ship acquisition.

Government R&D in collaboration with or in support of industry can be <u>desirable</u> where it acts as a catalyst to achieve broad national benefit to industry and the nation. Government collaboration with industry is especially appropriate where the benefits of R&D are likely to be applicable across an industry (and will benefit the nation as a whole), and where, whether because of unacceptable risk or for other reasons, proprietary incentives to conduct the R&D are lacking. Areas, such as vessel manning, where government rules need to be modernized as an element of improving the technical base are especially suitable for industry-government collaboration.

COLLABORATION: MOTIVATIONS

Collaborative research efforts may involve companies in similar businesses (e.g., shipbuilders or ship operators) or companies with related interests (e.g., truck, rail, and shipping interests all support development of automated systems for processing freight documentation).

Or, these efforts may link universities and companies, as has been the trend in biomedical research, or they may involve joint effort of government and industry. This latter form of collaboration, which often takes the form of government money linked to industry manpower or facilities, has been the mainstay of the R&D program of MARAD in recent years.

A weakness perceived by industrial management in collaborative R&D is that the advantages gained are often not proprietary and therefore not sustainable. The conventional approach by government of treating R&D results as a public good will preclude sustainable competitive advantage and thus fail to achieve substantial industrial cosponsorship.

The government can supply encouragement, motivation, tax incentives, oversight, manpower, management, laboratories, technology, and a number of other stimulants to collaborative R&D. In all these, cost-sharing is likely to be the primary factor.

3

MECHANISMS FOR R&D STIMULATION AND COLLABORATION

Increased management attention to the maritime technical base will take the form of setting objectives for improvement and providing the resources necessary to achieve objectives. Whatever the objectives or resources, the means will also need to be identified. The motivations cited in the previous chapter dictate the preferred means:

- Private sector action (where proprietary advantage is a possibility)
- Government action (where public interests are paramount)
- Collaboration (where common interests are identified)

This chapter describes mechanisms for research and development (R&D) stimulation and collaboration employed in the maritime industries of other countries; collaborative R&D in other industries in the United States; and government and industry cost-sharing as a mechanism for stimulating R&D and innovation.*

R&D IN THE MARITIME INDUSTRIES OF OTHER COUNTRIES

The maritime industries are accorded special status in many countries because of their important contributions to national economies (skilled jobs and foreign exchange) and national prestige. Notwithstanding this, the degree of support for the maritime industries in other countries runs the gamut from extensive and/or increasing (Korea, Taiwan, Japan) to once-extensive but declining (United Kingdom, Scandinavia), which is not dissimilar from the state of the maritime industries in the United States. Those countries where the degree of support for the maritime industries is or once was strong tend to have more mature national policies and supports, including R&D institutions.

*The role of tax policy in stimulating R&D and innovation is an important related issue. The committee did not address this topic, in part because of major changes in the tax laws during the course of the study.

The major maritime nations have collaborative R&D programs among industry, government, and research or academic institutions. Japan, England, Germany, Norway, France, Holland, and many others have government/industry sponsored, academic/independent shipping research institutes that foster research, development, and innovation. Examples are*:

- Japan Maritime Research Institute. Sponsored by the Ministry of Transport, Maritime Development Promotion Fund, Japanese Shipowners' Association, leading shipping and shipbuilding companies, and various foundations.
- Norwegian Institute for Shipping Research. Sponsored by the government, Norwegian Shipowners' Association, Det Norske Veritas, and various foundations.
- Shipping Research Institute (Germany). Receives both government (federal and state) as well as industry support.
- Netherlands Maritime Research Institute and the Shipping Economics Institute. These institutes, located in Rotterdam, are government- and industry-supported research organizations.
- There are a number of different shipping research institutes in the United Kingdom. The University of Liverpool's Maritime Research Institute and the Shipping Research Center at the University of Wales are just two of the academic shipping research institutes. There are others in Southampton and Glasgow. In addition, the British Ship Research Association, which receives government and industry funding, performs shipping policy and economics research.
- Many other countries, such as Spain, Brazil, East Germany, Poland, the Soviet Union, China, Korea, France, and Italy, maintain shipping research centers. The purpose of the centers is to study shipping economic and policy issues and maintain data banks to guide government and industry decision making.

Ship design and shipbuilding research is somewhat more fragmented in most maritime countries, with academic, government, and industry-supported institutions involved. Ship design research in England, Japan, Germany, Sweden, Holland, and elsewhere is performed by government- and industry-supported ship research organizations, such as the British Ship Research Association, the British Maritime Technology Corporation, and the Japanese Ship Research Association, as well as by academic, private, or industry research organizations.

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*For purposes of comparison, the U.S. has a National Maritime Research Center at Kings Point, New York. The facility includes the Computer-Aided Operations Research Facility as well as an automated information retrieval service, although funding for programs has been curtailed. A number of states maintain port and waterway institutes associated with state universities or maritime colleges. Additional port and waterway research is undertaken in major public universities under the National Sea Grant Program.

Considerable ship design and shipbuilding research is performed in Japan with the central joint government/industry research organization performing about 30 percent of total national research by value ($70 million out of a total of $260 million in 1982).

The Spanish government maintains a central ship research facility, as does the Brazilian, Argentinian, Italian, Mexican, and other governments. In Germany, the major public ship research centers are owned by state (provincial) governments such as the ship and shipbuilding research centers in Hamburg.

In most of these countries, there are also university-owned or affiliated ship and shipbuilding research laboratories. In all the countries mentioned, except the United Kingdom, the national ship and shipbuilding research centers obtain government operating budgets covering 30-40 percent of their operating costs or the equivalent of their fixed facility, staff, and related costs. Additional funding is usually provided by shipbuilders, foundations, or ship operators and owners for specific research projects. In most countries, maritime research is planned by joint government and industry committees or standing research advisory groups that also supervise the performance of the publicly owned research centers.

COLLABORATIVE R&D IN OTHER INDUSTRIES IN THE UNITED STATES

University and Industry Cooperative Research Programs

Many research universities have created programs with which companies can affiliate. These programs provide for some combination or all of the following:

- Annual seminars on campus to acquaint senior members of the affiliated industries with new and exciting developments in relevant fields of science.
- A few days of private consultation with selected staff members of the university to discuss problems of specific concern to the company.
- Special arrangements for the company to request short courses for its staff on current issues.

These programs are regarded with great favor by many companies. However, most of those companies have made a major commitment to research. They have a staff in the company particularly effective in doing research that can take the advanced concepts and put them to work. These programs are best suited to companies that are near the center of advanced technology.*

*In fairness, it should be noted that some U.S. maritime companies support and interact with research and training programs based at state-supported maritime academies and elsewhere.

Group Research Programs

Many of the large independent industrial research laboratories have organized group research programs. These programs have been established to pursue scientific or engineering opportunities defined by the staff of those institutions and considered appropriate for support by groups of companies. Individual companies are invited to participate at a fixed fee per company. The joint sponsorship gives a company access to information for a small fraction of the total research expenditures. However, the company is not able to have individual proprietary rights to the information.

Companies have supported such programs with enthusiasm on the grounds that they could ensure getting research results in given fields of work for a far smaller budget than otherwise would be required. The success of these programs is evident in the satisfaction that companies have with them.

These programs are not suitable, in general, for low technology companies. The translation of the findings into useful programs and products requires an in-house staff of sufficient research and technical competence to make use of the cooperative research findings.

Association Research

During this time of marked reduction in orders for steel manufactured in the United States, there has been a sharp reduction in steel research sponsored by U.S. companies. The United States Steel Corporation closed its fundamental laboratories more than a decade ago and recently reduced its technical staff by more than 1,000 scientists, engineers, and technicians. In many fields, the U.S. steel industry is no longer in the forefront of development as it was for more than half the twentieth century. To prevent a total collapse of innovation an industry association, the American Iron and Steel Institute (AISI), has channeled funds from its steel industry member companies by contract to a number of institutions, particularly research institutes and universities. The projects have generally been dedicated to the development of further understanding of relatively fundamental phenomena. These range from the relationship of microstructure to properties to studies of the basic reactions in the making and refining of iron and steel. The findings have then been applied by individual companies as appropriate and as feasible considering the state of their technology and capital resources.

The Edison Electric Institute studied a number of issues critical to the utilities, but no major step was taken to organize research on electric power generation and distribution by the utilities themselves until the Electric Power Research Institute (EPRI) was established. This institution provided a vehicle for the utilities interested in sponsoring research. About 70 percent of the industry is currently affiliated. With a program of more than $200 million per year to invest in research, EPRI has sponsored work on energy conversion systems, environmental control systems, transmission systems, materials, and many other issues crucial to the reduction of power generation costs in an environmentally compatible manner.

The Association of American Railroads has had a research facility for testing and experimentation for 50 years. It took a major step forward in becoming a major sponsor of research in 1970 when it reorganized its research programs and began systematic increases in funding.

The research sponsored by the Association of American Railroads, with 70 percent conducted in its laboratories and the balance by universities and others, addresses critical issues in safety, operational efficiency and productivity, and environmental response. Current analyses (Association of American Railroads, Research Department Statistics for 1985) suggest that the rate of return from this research is 5 or 10 to 1 including the costs of implementation of the findings.

Despite these high rates of return, the investment necessary to utilize the research is so great and the net earnings of the railroad industry are so small (below 5 or 6 percent in the best years) that the amount invested in research ($20 million per year) cannot be expected to grow more than inflation in the next few years.

Without the results of these research programs, it appears that the railroad industry would be incurring significantly higher costs from accidents and would not be operating as efficiently. Furthermore, without the research, the competition from other modes would be an even more serious threat to the financial health of the industry.

There has been great success in organizing cooperative research programs between the railroads and the supply industry and government. There have been many useful exchange programs with other railroads around the world.

Cooperative Programs By Selected Companies

In the last decade, there have been many ventures into joint research with the initiative coming, in part, from individual companies. These companies recognized that they could not fund as much research as was necessary for them to remain competitive in world markets. They understand that joint research will have to be translated into their own companies, but they have concluded that the chances of doing that are greater if the research is done by a consortium in which they participate. Their affiliation helps to direct the work toward the kinds of problems of concern to them. Their awareness of work in progress means that they can start application programs years before the work is published.

Notable among these ventures is the Microelectronics and Computer Technology Corporation. The member companies joined to create a budget of up to $70 million per year for 10 years. Facilities have been created at the University of Texas in Austin, Texas. Some of the projected 400-person staff will be drawn from member companies at least in the beginning. Others will be recruited from universities or other competent institutions.

The objective is to retain U.S. leadership in computers by exploring advanced computer design concepts, advanced microchips, and related matters.

Other ventures include:

- A software productivity group aimed at improving software for military programs. The work will be done by the staff, hired and borrowed.
- An international consortium to develop strong and lighter glass products to compete with plastics. The work will be done at selected universities.
- A guided-wave fiber-optic technology group to develop advanced manufacturing methods. The work will be done by Battelle Memorial Institute.
- A group to develop improved boiler pumps. The work will be done by member companies.

Results are not yet available to permit full evaluation of the effectiveness of these latter programs. The fact that all of them are being supported by major companies indicates that their findings will be subjected to very critical evaluation.

COLLABORATION: MECHANISMS

In the government support of R&D, cost-sharing by the private sector is a well-established method of government and industry collaboration. As earlier noted, the feasibility and mechanisms of cost-sharing are based on a coincidence of motivations on the part of the government and the private sector organization participating. The government is usually the R&D organizing entity based upon its determination that the public at large will benefit and the organization performing the R&D will benefit in the form of products or services that can become a part of its ongoing business. The government may have the additional motivation of wanting to increase the likelihood of the dissemination and implementation of the R&D results so that the perceived public benefit will actually be obtained. It seems evident that as the sphere of the private sector entity's contribution increases, so does its motivation to recapture its investment by later activity in the marketplace. Certainly, this is the case at high levels of industrial cost-sharing (i.e., 50 percent or greater).

The government may also increase the contractor's inducement for implementation by granting it proprietary rights to patents. Successive administrations have issued policy memoranda enabling such grants, and this policy has later been incorporated into procurement regulations covering the various federal agencies. The most recent case is a memorandum issued February 18, 1983, that has been implemented in Chapter 18 of the Federal Acquisition Regulations. It extends first patent rights to contractors, in the hope that they will do a better job of commercializing inventions than federal agencies.

Elements of the government have become concerned that R&D results not covered by patents, which are published as government reports or scientific papers, become the basis for initial implementation overseas. In some cases, contract language creates requirements for government approval of all disclosure of the research results. This disclosure control often acts to improve the contractor's proprietary position beyond that associated with patents.

The benefits of cost-sharing to the general public are the economic activities that come from the implementation of the R&D results. The contractor benefits from reduced cost of the R&D work and the competitive advantage he may obtain from implementing the results. The government benefits from increased assurance of implementation and a reduced cost in carrying out its policy objectives.

4

PRIORITY AREAS FOR RESEARCH AND INNOVATION

The discussion of motivations and mechanisms to strengthen research and development (R&D) and innovation in the maritime industries provides a basis for considering whether important R&D and innovations should be addressed through collaboration with industry or directly by the government. Even in those instances where government interests are paramount, some collaboration with industry may still be possible, especially if there is potential for a company to gain some strategic advantage.

Certain institutional and environmental factors are conducive to successful collaboration.

First, important needs or opportunities should be identified that R&D can address. The needs should have major rather than marginal impact on the profitability of the industry.

Second, there should be a commonality of motives among the collaborating parties, and the collaborating parties should be healthy or stable enough so that adequate funding can be generated and invested in R&D over the years necessary to reap financial returns.

Third, the managers and investors who would participate should have sufficient motivation to collaborate; this will be the result of discernible and quantifiable benefits.

Fourth, there is a history or precedent for collaboration in the industry in R&D or other common endeavors.

Fifth, industry leaders, particularly the chief executive officers of the major commercial enterprises, but also those of labor, government, academia, and other institutions, are enthusiastic or at least supportive of the value and concept of collaborative R&D.

Sixth, private institutions and talent exist to provide infrastructure for planning, conducting, and transferring the results of R&D to users and implementers.

The committee identified a number of promising areas where R&D and innovation can contribute to increased competitiveness of the maritime industries in the international marketplace, or where R&D and innovation will enhance the availability of commercial maritime industries and their assets to potential military needs. These areas are assessed from the standpoint of attractiveness for direct government action, or for government collaboration with industry, in Table 3.

TABLE 3 Assessment of Important Research and Development/Innovation Areas

		Nature of Government Role		Potential for Successful Government–Industry Collaboration				
Area	Important Needs Exist	Government Needs Paramount	Government Action Is Catalyst	Shared Goals/ Healthy Industry	Benefits from R&D Can Be Projected	History of Collaboration	Supportive Leaders	Private R&D Institutions Exist
Shipbuilding technology	●		●	◒	●	◒	○	○
Ship operation research	●		●	◒	◒	◒	○	○
Government cargo preference	●	●		◒	●	○	○	○
Military sealift cargoes	●	●		◒	●	○	○	○
Maritime safety	◒		●	◒	◒	○	○	○
Intermodal cargo handling	●		●	●	◒	○	○	○
Port development	◒		●	●	●	◒	○	○
Market research	◒		●	◒	○	○	○	○
Waterway development	◒	●		○	◒	○	○	○

Key: ● Yes, strongly ◒ Some or moderately ○ No or limited

AREAS WHERE COLLABORATION IS ATTRACTIVE

Shipbuilding Technology*

Over the past 15 years, research in shipbuilding technology has been devoted not only to steel fabrication and assembly, but also to the overall control of shipbuilding processes.

Initiatives by the industry and government National Shipbuilding Research Program (NSRP)[§] during the past decade have created a basic understanding among U.S. shipbuilders that addressing the elements of the shipbuilding process separately is not effective. More attention is being given to the systemic nature of manufacturing aimed at shipyard operations for a great variety of activities, including warship overhaul and modernization and the building of products other than ships, all with the same management approach.

The basis for such flexible manufacturing is a product work breakdown structure that features integrated hull construction, outfitting, and painting through focus on interim products, i.e., parts, subassemblies, and assemblies, that are classified by problems inherent in their manufacture (group technology). Such work is performed on both virtual and real production lines harmonized by other disciplines, such as statistical control of accuracy variations and line heating for accurately forming curved hull parts.

Among the prerequisites for more successful implementation is need for the shipyard to control, or at least negotiate, contract designs. This is a logical outcome to the increasing significance of product liability and also is necessary to the continued development of a manufacturing system. Heretofore a shipbuilding contract described only

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*This section primarily addresses new ship construction. The ship repair industry involves different markets and technologies, and was not addressed in this study, except by implication.

[§]The National Shipbuilding Research Program is a cooperative venture between the shipbuilding industry and the Maritime Administration. It provides financing and management of research projects to improve the productivity of U.S. shipyards and their competitiveness in the world shipbuilding market. The program, initiated in 1971, is financed by both industry and government and provides for industry involvement in technical management and execution through involvement of the Society of Naval Architects and Marine Engineers' Ship Production Committee (SPC). The SPC collaborates with MARAD in the management of the program, especially to set program priorities, assign responsibilities for projects, provide technical direction, and assist in demonstrating program results. Panels of the SPC work to exchange technical information, identify new problems and recommend opportunities for R&D, oversee ongoing projects, and demonstrate completed work. The costs of research projects are shared by the participating shipyards and the government, often on a fifty-fifty basis.

what the performance and design specifications of the ship would be. In today's competitive market, specifying the required quality of the completed ship and the build strategy that shall be used is vital for complete understanding of the product by both parties.

As a result of efforts by the Ship Production Committee (SPC) to implement the NSRP methodology, the ship manufacturing process has moved forward significantly. Applied research has been accomplished in areas having a strong impact on the productivity picture of American shipyards. Under the aegis of the NSRP, projects and publications undertaken by the SPC panels have been reported in NSRP publications and in the Journal of Ship Production of the Society of Naval Architects and Marine Engineers (SNAME).*

The top management of the U.S. shipbuilding industry is just starting to understand the vital link between marketing efforts and technology development as a means of assuring survival by maintaining products throughout their life cycle. Through the dissemination of NSRP results, shipbuilding management is becoming increasingly aware that the shift to a product-oriented work breakdown structure accompanied by a transition to a more product-oriented management and labor organizational structure can pay large dividends in improved cost and schedule performance.

In the context of all of the foregoing, U.S. shipyards, including naval shipyards, are now facing their greatest challenge in finding ways to shift rapidly to product organizations commensurate with the product-oriented methods they are applying in varying degrees. Up to the present, they have ignored or have been slow in conveying the logic and principles of product orientation to first-line supervisors and shop stewards. As a consequence, changes in trade cognizance, which have already started, are slow moving.

Collaborative research should continue to support implementation and further development of integrated product-oriented shipyard operations with some focus on robotics insofar as it contributes to development of the entire manufacturing system as compared to isolated applications. Simultaneously, research should address innovative products, including but not limited to ships, that can be produced with a shipyard manufacturing system. As a matter of higher priority, research should

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*Included in published reports are the following aspects, to name a few, of the manufacturing process: advanced pipe technology; painting of structural steel shapes; design for zone outfitting; design modeling; integrated hull construction, outfitting, and painting; process lanes; line heating; manual on planning and production control for shipyard use; outfit planning; pipe piece family manufacturing; precontract negotiation of technical matters; process analysis via accuracy control; product work breakdown structure; semi-automatic beam line feasibility; ship producibility as it relates to series production; standard structural arrangements; use of scale models as a management tool; zone painting method; product-oriented material management; and flexible production scheduling.

also focus on bottlenecks that retard the transitions to product organizations.

Toward this end, the most likely objectives for improving the technical base are advances in process technology, computer applications, and management and labor cooperation. Through the cooperative efforts of the NSRP, an important beginning has been made toward all three objectives.

The approach should be to let the technical and economic constraints dictate the requirements, which may lead to recommending any mix of:

- Product redesign;
- Redefinition and standardization of processes;
- Increased attention to tolerances;
- An economically rational mix of people, automation, and other machines; and
- Coordinated design, fabrication, information handling, assembly, and inspection.

The goal of this R&D should be a computer-integrated manufacturing (CIM) strategy built upon the foundation of a "common" data base acceptable to the shipbuilding industry and the Navy. Advances in computer applications should proceed with the development of the data base concurrent with increases in the use of computer-aided manufacturing (CAM) from the enhanced computer-aided engineering and design (CAE & CAD).

To make CIM feasible, research should proceed simultaneously in improving process technology; foremost is the need for rationalization--that is, the process of defining designs and methods based on balanced consideration of competing performance and cost requirements. Rationalization of today's naval ships is limited by too much emphasis on detailed design and performance specifications, too little understanding of processes, and too narrow consideration of design alternatives. (It is <u>not</u> limited by lack of basic technology, although there is a lack of specifications for designing appropriate equipment.) As a part of rationalization, group technology principles must be developed for and adopted by the shipbuilding industry. This will, then, lead to rationalized production and the ability of the industry to utilize flexible manufacturing systems that will significantly reduce product cost.

Simultaneously, the top management of industry and labor, with assistance from a number of government agencies, needs to commence research toward applying the principles of decentralized decision making. These should include all levels of manufacturing, including detail design, planning, scheduling, production, quality, and risk/gain sharing.

Ship Operation Research

Collaborative programs are under way to improve worker-management relations on ships in order to create an atmosphere of mutual respect and understanding that will permit far better utilization of the country's available seafaring labor than is experienced today. Principal improvements will be directly coupled with the betterment of the working atmosphere and the increased self-esteem of the individuals involved. The ultimate result, besides reduced manning of ships (see Table 4), will be an average uplifting of the abilities of seamen while simultaneously improving their work life and their importance as members of the management team. This is in the national interest because these status escalations permit the flexibility needed should an emergency arise requiring the manning of greater numbers of vessels to back up the armed forces. The people who have been brought into the effective manning concept will be able to train the newcomers to the profession and will relate to the changing requirements with greater facility.

The parties interested in effective manning projects are the labor unions, the vessel shoreside management, the armed forces, and, of course, the individuals involved. The labor unions are interested because this effort signifies a more secure future made possible through acceptance of obligations that they have been attempting to acquire for years. It further points the way to survival in the face of severe foreign competition.

The ship operators, likewise, are the receivers of a positive return from innovation in this area. It is easy to see that their costs will decrease while reliability will ascend to a higher level simply because the people on the job have a different attitude when they attain a higher degree of self-management.

The armed forces having a specific need for the availability of capable personnel in time of national emergency are naturally interested in the results.

Lastly, the individuals involved have the greatest interest since they are closest to the action, are most able to see the changes in their personal work-life effects, and therefore see that they will reap the most immediate benefits.

The definition of the innovation is worth clarifying. It is primarily sociological research, supported by technical development. In order to proceed, a third party must be accepted as an ombudsman, referee, guiding influence, and arbitrator by all directly interested parties. This role is made all the more important by the fact that existing union contracts on subsidized ships are the major stumbling block to reduced manning levels.

Why must the directly interested parties engage in the project? The main reason is survival. American-flag operators are in an international market. Their capital costs may be the equivalent of the foreign-flag operator if ships have been acquired on the world market, i.e., from foreign shipyards. Their fuel cost may be equal to that of the foreign-flag operator if advanced propulsion plant technology is utilized. The difference in operating cost caused by the human element on the vessels is the gap that must be bridged. It cannot be done by downward adjustment of wages. It must be done by realignment of duties, increased individual efficiencies, and redefinition of work areas. The improvement of on-board management techniques can greatly reduce the cost of ship operation to aid in regaining the competitive edge.

The methods involved in ship operation manning innovation are novel and not easy to assimilate. For this reason, it is vital to the

TABLE 4 Reduced Manning of Ships

Ship Type	Older U.S.	Newer U.S.	European and Asian Advanced
Cargo Vessels			
1950s-era general cargo ship (17,000 dwt)	45		
Modern large container ship (33,000 dwt)	35+	21	14-18
Modern dry bulk (45,000-63,000 dwt)		23-30	18+
Roll on/roll off (21,000 dwt)	34	21+	16-24
Tankers			
T-2	27-35		
37,000 to 50,000 dwt		21-23	18+

mission's success that programs be administered on a level that can comprehend the difficulties.

Industry experience to date has been generally positive, in part because of the Maritime Administration's (MARAD) careful support of industry attempts in this area. Early results have been met with extraordinary enthusiasm by the individuals aboard ship. The resulting operation has shown many areas of required change in methodology both on-ship and onshore. Not every directly involved party was convinced that this new approach was going to improve his circumstances, but this opinion has lessened to some extent. The fact is that under the environment being molded to fit the specific needs, the efficiency of the vessels is at a peak that is unobtainable without employment of the concept on other U.S.-flag vessels.

Government support for ship operation manning innovation has been matched with equal funds and energy from industry. Continued activity will show the soundness and value of more ship operation research and innovation to the entire U.S. maritime industry.

Maritime Safety

The public interest in improving maritime safety stems from opportunities to reduce loss of human life, to improve environmental conditions, and to demonstrate leadership in an area of international concern. There is a private, or corporate, interest in safety as well that includes all of the above plus the potential for improved profits as the result of improved operating efficiency and reduced losses and insurance premiums.

Conventional knowledge of the merchant marine industry suggests that improvements in safety performance might be possible from R&D efforts in the following areas:

- Simulator licensing and training for specific vessel types as a means of reducing human error casualties;
- Techniques and technology for alcohol and drug testing prior to the assuming of deck and engine watches;
- Automated navigation systems for maneuvering in congested channels;
- Improved direct control technology for collision avoidance systems;
- Better resource allocation in regulatory enforcement;
- Improved fail-safe systems to prevent bilge and oil transfer pollution;
- Improved technology for identifying the source of water and air pollution;
- Improved design, work, and habitation facilities to reduce personal injury;
- Improved navigation and weather warning systems that reduce human error resulting from inattention to duty; and
- Advanced fire detection and firefighting systems.

The traditional mechanisms for R&D in maritime safety have been through the U.S. Coast Guard's and MARAD's R&D programs, with the Coast Guard having played a dominant role. Because of its economic implications and the competitive disadvantage it may impose on U.S.-flag ships, maritime safety R&D is of vital interest to MARAD. Objectives of this agency should be determining how merchant marine safety requirements affect the competitive capability of the U.S. Merchant Marine, how safety performance and regulation impact efficiency, and what remedies can be developed.

Safety R&D, like other forms of R&D, does not produce immediate bottom-line results. Accordingly, vessel operators are not motivated to expend large sums of money in maritime safety R&D, particularly in the current business environment.

In the public sector there has historically been jurisdictional friction over which agency should conduct safety R&D. These jurisdictional concerns seem to have limited the amount and scope of safety R&D work that might have otherwise occurred.

The lack of private funding and interagency jurisdictional problems possibly can be overcome by creating a single entity that pools money from a variety of public and private sources.

The first step toward a safety R&D program is to define the level of safety performance of the U.S.-flag fleet and to identify and document costs relating to inefficient safety regulation and poor safety performance. Once this information is known, the potential payoff from improvements can be identified and comprehensive safety R&D strategies and mechanisms can be recommended.

Similar to the potential for safety improvement in the ship-operating industry, there may be opportunities for collaborative efforts to improve safety in the shipbuilding industry and in marine terminals.

Intermodal Cargo Handling

Lowering the cost of the movement of goods in the United States increases the ability to export and the marketability of products. On the import side, reduced transportation costs lower the prices to consumers. In addition to manufacturer and consumer advantages, the railroads, motor carriers, and ports can all benefit from research that improves equipment efficiency and the productivity of operations. Collaborative efforts have particular promise because of the need for integration of the various modes into a single intermodal system.

National research initiatives can develop a dialogue and cooperative agreements between parties involved in the intermodal movement of goods. They can define the problems, develop the advanced technology, advance the projects, and possibly administer the programs. The government should act as a trigger to bring the various entities of the private sector together.

Port Development

Port development will speed cargo flows, and this will result in less costly operation and more efficient use of terminals. The direct beneficiaries of port developments are the ocean carriers, who will be able to experience rapid turnarounds and thus more productive use of their capital investments, and ports (including terminal operators and related port labor) because of the competitive advantage they will receive. Shippers and consignees (and indeed the local community and the general public) are indirect beneficiaries of port developments.

Research in port operations is uniquely suited to collaboration because of the difficulty of maintaining proprietary advantage for long (because of the public nature of the enterprise). A steering committee comprised of representatives of major interested parties should designate the operation or operations that are most likely to benefit from the research.

In recent years, competitive barriers in the industry regarding the sharing of information have eased considerably; however, there is still a limit as to how far an individual operator or carrier will disclose sensitive information to a public forum.

AREAS WHERE GOVERNMENT INTERESTS ARE PARAMOUNT

Government Cargo Preference

Cargo preference has been a long-term instrument of U.S. shipping policy. It has been applied to government as well as various other types of cargoes. Similarly, the United States has been, since 1970, a party to several bilateral cargo reservation agreements such as those with Argentina and Brazil. The United States, on the other hand, has opposed certain international agreements such as the Code of Conduct for Liner Conferences proposed by the United Nations Conference on Trade and Development (UNCTAD), which came into force in October 1983 and incorporates recommendations for cargo sharing. By and large, cargo preference laws have not worked well. They have increased the cost of U.S. international trade and reduced incentives for fleet replacement and productivity improvements, and they have not increased the overall share of U.S. shipping from U.S. foreign trade as well as cross trades.

The Shipping Act of 1984 has curtailed the powers of liner conferences by mandating rights of independent action, including permitting the use of service contracts by conference members. Several conferences have been planned to assess and discuss impacts of the 1984 act.*

*The Federal Maritime Commission and Old Dominion University sponsored a conference in June 1986 (Chadwin, 1986). The Maritime Administration and the Containerization and Intermodal Institute convened one in January 1987. The Federal Maritime Commission plans another in June 1987.

There appear to be many questions on the future use and effectiveness of cargo preference provisions in both bulk and liner shipping. Little research has been performed on the effect of cargo preference on the cost of shipping, participation of national shipping binational and cross trades, and on the expansion or renewal of fleets.

Research is needed on the effect of cargo preference on:

- Investment in liner shipping;
- Cost of shipping operations;
- Structural changes in the liner shipping industry;
- Integration of liner shipping into intermodal operations;
- Joint venturing and novel financing of liner operations;
- Liner service quality;
- Economic cost of liner shipping; and
- Competitiveness in bilateral liner trades.

Similar issues should be studied in bulk shipping. Cargo preference is obviously a highly political factor that affects many economic sectors, such as industry and agriculture, as well as international relations, defense preparedness, and more. The problem is that many of these factors are noted by proponents and opponents of cargo preference without any real backup of information on the impact of cargo preference on these.

Objective research funded by the government is urgently required to determine the direct and indirect effects of cargo preference.

Military Sealift Cargoes

The primary intention of the Merchant Marine Act of 1936 was to develop a U.S.-flag fleet capable of serving the foreign commerce of the United States <u>and</u> contributing to the national defense. Prior to the advent of containerization, this objective was fulfilled by multipurpose liner vessels that were capable of carrying the full range of commercial and military cargoes, thereby making them equally suitable for civilian and military service.

With the commencement of the "container revolution," however, the logistics of the U.S.-flag commercial operations diverged radically from the needs of the military shipper. While modern fully containerized ships are capable of providing service for containerized defense cargoes moving to modern port facilities, the nonself-sustaining container ship is by basic design unsuitable for transporting a large segment of military cargoes, which include palletized general cargo, tanks, trucks, helicopters, and so on. It is, in fact, incapable of delivering even containerized cargo to remote or underdeveloped port facilities in time of national emergency without the assistance of substantial auxiliary cargo-handling equipment. Specialized crane ships are now being provided for this purpose.

Unlike U.S.-flag operators who have focused their efforts almost entirely on container operations and pure container ships, the international market has developed, in addition to container ships, a large fleet of militarily useful multipurpose vessels. These include pure roll-on/roll-off (ro-ro) vessels, combination ro-ro/container vessels, and modern vehicle carriers capable of carrying light and heavy vehicles, containers, and break-bulk cargo.

Had they been able to recognize that the commercial decisions of U.S.-flag operators were resulting in an erosion of U.S. sealift capability, U.S. Department of Transportation (DOT) policymakers responsible for U.S. maritime programs might have initiated the necessary programs that would have led to a reestablishment of a cohesive integration between the commercial and national defense aspects of the Merchant Marine. Unfortunately, these programs have not been developed and responsibility of maintaining an adequate U.S. sealift readiness has, in the interim, fallen on military planners.

The military's concern over this situation was indicated in recent testimony before Congress, and programs such as the SL-7 conversions, T-AKX, and T-5 have been undertaken to provide the U.S. Department of Defense (DOD) with reliable and immediately available logistic capability to complement the Rapid Deployment Force and other DOD readiness programs. Similarly, a buildup of the Ready Reserve Fleet (RRF) has been undertaken to provide initial surge sealift and to perform the secondary mission of resupply. But these programs, as vital as they are, do not effectively address the problem of sustaining U.S. forces in a remote theater. The Falklands crisis provided a modest preview of logistic problems that the United States would face given an emergency in the eastern Mediterranean or Southwest Asia. The aging National Defense Reserve Fleet (NDRF) and dwindling U.S. Merchant Marine are falling increasingly short of the minimum requirement for sealift readiness.

MARAD should consider establishing a research program (in collaboration with DOD) to address this problem. Such a program might eventually lead to placing under the American-flag vessels with a dual purpose: (1) to provide the DOD with a modern sealift capability at a minimal cost, and (2) to strengthen and expand a commercially viable U.S. Merchant Marine. The objectives of such a program might be to develop or to obtain U.S.-owned, U.S.-flag ships of the highest inherent defense utility that are equipped with military sealift enhancement features, operating in the commercial sector during peacetime, and dedicated to DOD sealift in time of emergency.

The implementation of the program through award of appropriate contracts would make a properly structured sealift enhancement program analogous to the Civil Reserve Air Fleet (CRAF) concept for military airlift. It is noted that the Air Force recently entered into a $104 million CRAF contract with Pan American Airways to equip five commercial 747s with defense features allowing rapid conversion to military cargo transports. The contract provides initial payment for conversion of the aircraft and annual payments to the owner to compensate for lost commercial utility. The cost per aircraft year in this CRAF contract is several times higher than the cost would be per ship year to equip them for DOD use.

The dual-use principle underlying this program is the foundation of its cost-effectiveness. Students of modern logistics recognize the dual-use concept as one of the cornerstones of Soviet seapower strategy. It has provided the Soviets with a fleet auxiliary that is integrated into their defense planning and is continually maintained in a status of full operational readiness by the nature of its commercial deployment.

Market Research

At the heart of the maritime industry's economic distress is its inferior competitive position relative to shipyards and steamship lines in other countries (U.S. Congress, 1983; Ladomirak, 1985). As a result, U.S. ship operators (except for liner operators) and shipyards compete primarily for government business. Thus, U.S. shipyards exist primarily to meet Navy requirements, while government and protected cargoes make up an important share of the business of ship-operating companies.

In the other parts of the maritime industry, U.S. ports increasingly compete among themselves for market share of the U.S. foreign trade. Finally, deregulation of rail transportation and falling demand for bulk movements have put the inland waterway segment into a deep depression. Thus, the U.S. maritime industry is very competitive within itself, but much less so with foreign companies.

It is the national policy to have a strong U.S. maritime industry but also to accomplish this at a reduced or minimal level of federal expenditures. The national interest is to assure sufficient maritime capability to meet defense and other international objectives. It is not necessary to quantify precisely what such needs are in order to recognize the value to the country of some maritime activities.

Competitive market forces in each maritime industry sector determine the relative success or failure of individual companies. However, foreign and U.S. government policies and macroeconomic factors impact the overall health and competitiveness of the steamship and shipbuilding sectors. In turn, a healthy U.S. maritime industry can have a profound effect on such vital national interests as:

- Volume and direction of world trade and balance of payments,
- Availability of ships for national defense, and
- Size of direct costs to the government and taxpayers of costs of government-financed cargoes (e.g., food shipments).

Therefore, it is strongly in the national interest to assure that U.S. government policies and expenditures consider the competitive market forces acting on the industry and that the government plan its policies and expenditures to improve the competitive position of the industry.

One of the elements of maintaining national maritime activity is research, development, and innovation. The largest funding for these programs has been by the U.S. Navy and the U.S. Army Corps of Engineers to achieve their own missions. MARAD and the U.S. Coast Guard have smaller R&D programs. However, MARAD's program is particularly important to the maritime industry because it has been conducted in collaboration with the industry and its primary objective is to improve the competitiveness of ship-operating lines, shipbuilders, ports, and waterways.

Organizations with an important stake in the outcome of research into maritime competitiveness and market research include:

- The federal government, which needs such information to formulate and evaluate its policies regarding the Merchant Marine;
- American export industries and American consumers of imports, which rely on U.S. and foreign shipping;
- Railroads and motor carriers, which interchange cargo with ocean carriers;
- State and local governments and authorities, which run seaports and inland waterways; and
- The maritime industry itself.

The objective of competitive maritime research is to develop new or improved knowledge of the economics, operations, and markets for U.S. ships and shipyards. This includes improving knowledge on how shipping via the U.S. maritime industry is affected by world market conditions (exogenous factors), and in turn by prices and conditions in the maritime industry itself (endogenous factors). A portion of such research will be proprietary--conducted by commercial companies for their own competitive advantage and by the government for setting policy. However, there is a great deal of common data that all parties need that can be collected best and most efficiently by the government or collected collaboratively by the industry. Also, research into the competitive impacts of existing policies, foreign actions, barriers to the U.S. industry, and changes in technology can be performed jointly for the benefit of many.

The value of new or improved information is difficult to quantify, and how much information is enough is a judgment call. However, information that can be developed jointly for multiple users is clearly less expensive to the industry and to the government than overlapping or duplicative proprietary research.

Further, with better information, the U.S. government and the maritime industry will be able to anticipate and respond to changes in world markets to better achieve national and commercial goals. These goals include increasing the effectiveness of government expenditures to improve the competitiveness of the maritime industry; to further the larger national interests cited above; and to achieve the business objectives of individual corporations.

Economic models of world markets exist now for the major commodities transported by the U.S. maritime industry. An example of needed research is to supplement these models and their existing data bases with additional historical data on variables describing the maritime industry. This will allow the development of maritime policy-oriented industry models, which can forecast the effects of policy and market changes on the maritime industry. Such research is best done organizationally by private industry responding to government requests for proposal, to the extent the knowledge to develop such models does not exist in-house in MARAD and such agencies as the Department of Commerce. It is possible that some of the major shipping companies and industry trade associations will want to participate in the model development process and share costs and data. They would benefit from having a powerful predictive tool for their own purposes. However, the government may want to keep certain elements of the work in-house in the public and national interest.

In general, as described in the interim report of this committee, maritime industry research can range from corporate proprietary at one extreme, through increasing degrees of collaboration and cost-sharing, to government proprietary at the other extreme. Research involving collaboration between companies and between companies and government are of particular interest here. For example, government-funded and privately performed research is an organizational concept that is in place now. However, the institutional structures for sustained industry collaboration are not in place. Other industries, such as railroads and highways, have established the organizational structures and financial arrangements to accomplish extensive nonproprietary research programs for the joint benefit of their participants. In the maritime industry, on the other hand, the industry-wide institutions are frequently lobbying organizations for corporate members such as the Council of American-flag Ship Operators, the American Institute of Merchant Shipping, the Shipbuilders Council of America, and the American Association of Port Authorities. Such organizations have minimal personnel, funding, or interest to undertake research.

A second type of maritime institution is the technical professional organization for individuals, such as SNAME. SNAME performs some limited research, but does not have the corporate involvement or funding support to accomplish substantial research.

Other organizations such as the American Bureau of Shipping also have strong technical credentials, but do not currently have the funding or the charter to lead a competitive maritime research program. Educational institutions also have the technical resources. They would need corporate endorsement and adequate funding to be effective maritime research institutions.

Cooperative research in the maritime industry will remain meager with or without government funding until an institution evolves or is created that attracts senior corporate involvement and funding, together with the technical and professional resources to manage and carry out the research. Absent such cooperative institutions, collaborative industry research may disappear as MARAD's research and development budget declines.

The barriers and disincentives to collaborative research are formidable. Several have already been mentioned: the proprietary nature of competitive and market information; the lack of effective institutions that combine corporate involvement and funding sources with technical resources; the debilitating financial condition of much of the industry; and the low priority that most maritime industry leaders place on R&D.

However, the costs of not undertaking the maritime industry market analyses described above appear to be quite large. Considerable additional cost will be incurred by all the interested parties by not having timely information for deciding on policies affecting the maritime industry. As made clear above, these additional (opportunity) costs of not having appropriate information are not confined to maritime industry related costs; rather these maritime industry costs are probably dwarfed by the opportunity costs and benefits foregone from not having timely information for decisions on maritime industry policies that affect the major national interests cited above.

Waterway Development

The construction, operation, and maintenance of waterways, despite the prospects of local cost-sharing, and of aids to navigation are essentially federal responsibilities. Therefore, R&D should continue to be primarily federal responsibilities, especially since national and international systems coordination is required.

Research and development is needed to develop and control waterway design and maintenance in a manner that balances transportation safety and efficiency with the cost of the waterway to the government and the benefits of the waterway to the nation. The directly interested parties are the U.S. Army Corps of Engineers, U.S. Coast Guard, MARAD, ship operators, harbor pilots, and port agencies. The Corps of Engineers is responsible for the study, construction, operation, and maintenance of waterways. The Coast Guard is responsible, through aids to navigation and regulations, for navigational safety on such waterways. MARAD is directly concerned with the impact on vessel and port operations.

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5

ANALYSIS OF PROGRAM BENEFITS AND STRATEGIES

While many factors influence the competitive status of industries, a great deal of evidence suggests that attention to the health of an industry's technical base is one of the important factors.* U.S. maritime industrial management spends 1.2 to 1.7 percent of revenues on research and development (R&D) (U.S. Congress, 1985). This figure is small when compared with industries that create and market products, but it is not out of line for the service sector of the economy.

This chapter considers the benefits of R&D in each industrial sector and projects which strategies--private sector action, government action, or collaboration--will be best suited to programs to achieve projected benefits. Table 5 summarizes program benefits and strategies.

SHIPBUILDING

The U.S. Navy remains the only market of consequence for U.S. shipbuilders. This situation will continue for the foreseeable future. The technical base of the shipbuilding industry has been strengthened during the 1980s as the result of large capital investment, including some investment in R&D, made possible by Navy shipbuilding orders, and through technology transfer and R&D undertaken collaboratively under the auspices of the National Shipbuilding Research Program (NSRP).

Through the dissemination of NSRP results, shipbuilding management is becoming increasingly aware that the shift to a product-oriented work breakdown structure accompanied by a transition to a more product-oriented management/labor organizational structure can pay large dividends in improved cost and schedule performance. Toward this end, the most likely objectives for improving the technical base are advances in process technology, computer applications, and management and labor

*Other important factors in the U.S. maritime industries that are not amenable to resolution as the result of R&D are improvements needed in marketing practices, and the results of competitive tactics of trading partners (e.g., foreign subsidization of shipyards and ship buyers) that are not matched by the U.S. government.

TABLE 5 Research and Innovation Benefits and Strategies

Industrial Sector	Program	Benefits	Appropriate Strategies
Shipbuilding	Shipbuilding technology	Advances in computer applications, process technology, management/labor cooperation	Continue/expand government/industry collaboration. Navy participation essential in current market
Ship operating	Ship operation research	Further operating, cost, service improvements	Private-sector strategy appropriate because of possibility of gaining market niche and necessity of meeting world competition Government cost-sharing would be necessary if United States is to become a leader in ship-operating technology, because of difficulty of gaining proprietary advantage
	Maritime safety	Lower costs; reduced loss of life and injury rate; cleaner environment; improved work environment	Some potential for industry collaboration, particularly if cost-shared with government
	Military sealift	Reduced cost to government, enhanced capability of commercial vessels for military missions	Government leadership essential. Some potential for cost-sharing if strategic advantages can be demonstrated
	Government cargo preference	Reduced cost to government	Government leadership essential. Some potential for cost-sharing if strategic advantages can be demonstrated
Ports/terminals	Intermodal cargo handling	Automate terminals, freight documentation; improve use of human resources	Potential for industry collaboration
	Port development	Cost-effective design, construction, maintenance and operations	Government strategy—waterways are a public responsibility
Inland waterways	Waterway development	Reduce construction/maintenance costs, modernize infrastructure	Government strategy—waterways are a public responsibility
All	Market research	Improved responsiveness toward world market conditions	Government leadership essential. Some potential for cost-sharing if strategic advantages can be demonstrated

cooperation. Through the cooperative efforts of the NSRP, an important beginning has been made toward all three objectives.

1. Process technology improvements have resulted from reorganizing shipbuilding and ship repair work in order to rationalize and integrate the ship design, material procurement, and production processes in accordance with the principles of group technology. Further objectives must be to improve component supplier participation in the process and to implement flexible manufacturing where it best fits the needs of the shipbuilding process. Accelerating the development and implementation of effective standards is an important prerequisite to achieving both of the foregoing objectives.

2. Computer applications achievements include fairly significant computer-aided design (CAD) capabilities on the part of most shipbuilders and ship design firms. Many shipbuilders have also established a rudimentary, partial computer-aided manufacturing (CAM) capability. Development of an integrated CAD/CAM system is an important continuing objective. A most important joint Navy and industry initiative has just started to develop a comprehensive digital data exchange capability among shipbuilders, design organizations, and the Navy. This effort should become the driving force toward better integration and coordination of the entire shipbuilding and logistics support process--from preliminary and basic design through material procurement, construction, and operational logistics support.

3. Management/labor cooperation improvements are needed to capitalize on technological improvements in the shipbuilding process. The traditional management and labor barriers and, basically, adversary relationship must evolve into a more rational and flexible relationship that will facilitate the establishment of integrated small work teams consisting of management, planning, design, and production personnel. These personnel would work together to achieve most effectively the individual interim products characteristics of zone-oriented ship construction and repair. Trade and craft cognizance rules must adjust to this new reality, as must management's propensity not to share information flows and the decision-making process fully with production employees. In order to lay the groundwork for change on the part of the individual shipyards and their respective labor forces, the NSRP established a Human Resources Innovation program some years ago. Continuation of this program and its forward-looking industry and labor objectives would appear to be most important to the survival and well-being of the industry.

The private sector R&D strategy is well established in the shipbuilding industry and has been the driving force behind large capital investments. The contribution of the collaborative NSRP is also recognized and appreciated. However, the future of collaboration in this industry is a concern. To be successful, the objectives of the NSRP have to be set by top-level management. Furthermore, in the past, the government has cost-shared projects. Given the market situation in the shipbuilding industry, Navy participation, both in setting objectives and in cost-sharing, is essential.

SHIP OPERATING

Many U.S. ships are fuel inefficient, have high levels of manning, and are not very automated. While technological improvements have been developed in these and other areas of ship operations and management in recent years, the United States appears to be behind other nations in terms of the amount of R&D it supports as well as the degree to which technological advances in these areas have been implemented.

In the area of effective manning, for example, ship machinery automation has enabled many U.S. ships to reduce substantially their manning requirements over the last 10 years. But still lower crew levels have been achieved on Japanese, Scandinavian, and West German ships. U.S. research and development in the area of ship energy efficiency has also taken a back seat to European and Asian efforts. U.S. companies have taken an active role, however, in developing ship management systems that use recent advances in automation to improve ship safety, communications, and living conditions as well assure efficient vessel operations.

The most dramatic U.S. innovation that still continues to evolve and improve cargo handling and transport is containerization. The use of an integrated multimodal system to transport cargo has resulted in significant time and money savings in intermodal point-to-point through movements. Other developments in cargo processing include the practice of changing the form of the cargo to facilitate cargo transfer or transport (for example, the packaging of bananas).

A number of both private and public organizations have conducted R&D on ship and barge operations and have implemented innovations. A wide range of private organizations have developed or implemented innovations including shipping companies, component manufacturers, shipyards, consulting firms, universities, industrial research organizations, classification societies, and architectural and engineering firms. Several maritime technological developments have been fallouts from innovations in other areas, such as space and communications research. Areas of particular opportunity in the future continue to be the range of operating, cost, and service improvements. An area of need is improvement in maritime safety.

The private sector strategy is appropriate for pursuing advances in operating, cost, and service improvements because of the possibility of proprietary advantage. Furthermore, the international competition that exists in the ship-operating industry assures that operators who want to remain competitive will, at a minimum, introduce new technology as soon as it is available. As in the shipbuilding industry, government cost-sharing has been helpful in accelerating technology transfer and in addressing improvements in management and labor practices.

To address improvements in maritime safety there appears to be some potential for collective support by an industry association, particularly when cost-sharing with government is possible. The critical determining factor is the prospect of lower insurance rates. While it is quite clear that the U.S. shipping industry is at a world competitive disadvantage because of its substantially higher premium rates (for personnel accidents), it is not clear why this is so. If the reasons derive from such things as the cost of settlements of injury claims in U.S. courts, then R&D is a futile solution. If, on the other hand, there is an accident incidence differential, then R&D can perhaps be expected to improve the premium differential, and collective industrial support of such R&D is not a vain prospect.

Segments of the ship-operating industry have pleaded in the past for greater collaborative effort (of ship operators) directed to ship operation R&D (Marine Board, 1983).* These efforts have been unsuccessful probably because of the highly competitive nature of the maritime industry.

PORTS/TERMINALS/INTERMODAL ADVANCES

The construction, operation, and maintenance of waterways, despite the prospects of local cost-sharing, are essentially federal responsibilities. Therefore, R&D have been, and should continue to be, federal responsibilities especially since national and international systems coordination is required.

More efficient port operations will increase productivity and reduce costs, both of which are vital to military and commercial objectives. Breakthroughs in material-handling techniques may also aid the domestic equipment manufacturing sector by providing a "leg-up" on the foreign competition. Other less-direct benefits might be a reduction in cargo damage and conservation of energy.

In new terminals, the latest in technology is sought with regard to layout, ease of traffic flow, engineering criteria, and personnel efficiencies. Other ideas are high density, multilevel terminals, buffer systems for increasing crane productivity, and better lighting systems for round-the-clock operations (Marine Board, 1986).

Equipment is a major item of materials handling that receives much attention by the manufacturer, although not necessarily by the user. Improvements needed in this area include equipment that uses less room, is less likely to break down and require maintenance, can be more easily operated with driver comfort, and can lead to greater productivity. Equipment ideas encompass higher, wider transtainers and more flexible lifting devices to accommodate different-sized containers.

Better use of storage space could substantially improve productivity in the marine terminal. More efficient management of the dock space where goods are stripped or stuffed would enable more units of cargo to be handled on a daily basis. Vertical storage of chassis as a space saver is also awaiting improvement.

Better management could relieve some of the challenge marine terminal personnel face when a ship arrives late and the terminal is expected to make up the time. What methods can be used to make more

*This subject was also discussed by the Advisory Board of the Maritime Administration before the board was abolished.

efficient use of what already exists? How can supervisors and field managers be assisted in becoming strategic thinkers?

The standardization and transmission of documents comprise a major area of marine terminal operations awaiting consensus and solution. Coordination of documents from all of the parties in an international transaction occurs at the terminal. Shippers, consignees, forwarders, brokers, carriers, Customs authorities, statistical collection agencies, carriers by sea, rail, truck, and barge, and public safety and environmental authorities all need information on a timely basis.

Systems also need to be developed that improve the safe handling of containers and equipment. The securing of containers onto rail cars or trucks could be improved.

Many consider the current use of computers in marine terminals to be at an early stage of development. Future applications can include automating documentation, invoicing, and location of containers, improving chassis and related cargo equipment as well as facility equipment, maintaining historical records, and forecasting.

Computers can also be used for simulation and modeling. The high costs of testing and developing full-scale models can be avoided by computer simulation, which aids management decision making. Computer-aided design allows draftsmen to be designers, and for marine terminal development, CAD can create complete models and simulations before a penny is spent on the site.

The true integration of intermodal movement of goods is just in its infancy. The load center concept, which calls for the concentration of cargo volume for ocean transportation and handling efficiencies, creates the need for new methods and transportation systems to move containers quickly between the ocean, rail, and truck modes to or from origins or destinations. It is in the national interest to design and develop marine inland satellite, rail, and truck terminals to handle large flows of cargo with minimal delays.

The study of the movement of goods is not limited to the physical handling of the container but must include the paperwork necessary to move the shipment, the inspection requirements of government bodies, i.e., Customs and Agriculture, and the proper equipment that could handle light and heavy loads for safety on highways and roads. Studies must combine the new technologies of the rail double stacks and motor carrier, 102-inch-wide, double bottom trailers into the design of future transportation systems.

Lowering the cost of the movement of goods in the United States increases the nation's ability to export as well as the marketability of its products. Reduced transportation costs also help lower the price of imports to the consumer. Besides the manufacturer and consumer advantages, the railroads, motor carriers, and ports can all benefit from research that improves equipment efficiency and operational productivity and reduces overhead costs.

As in the shipbuilding industry, the private sector strategy is well established among ports (as landlords) and terminals as evidenced by the large capital investments that have been made and that are planned. The ultimate beneficiaries of port and terminal improvements, however, are the shippers and consignees. In many cases these are federal entities.

There are also many parties whose interests are similar to those of the port and terminal operators. These include the freight carriers (ship, truck, rail), labor, and equipment manufacturers. As a result of the multiplicity of congruent interests, this sector would benefit from collaborative R&D. A trade association, such as the American Association of Port Authorities (AAPA), would appear to be in the most central position to bring potentially interested parties together to address questions of standardization, automation (of both material and document handling), and management and labor improvements.* Government cost-sharing could be instrumental in bringing interested parties together, as it has been in the shipbuilding industry. The seeds for this have already been sown in the Cargo Handling Cooperative Program of the Maritime Administration (MARAD).[§] U.S. Customs is leading some demonstration efforts with ports to computerize freight documentation.

INLAND WATERWAYS

Technology developments in the inland waterways sector of the maritime industry have resulted in dramatic increases in transportation productivity through improvements in vessel and barge design and operating systems. However, the current depression and overcapacity in the industry have dried up incentives and investment for further improvements. Consequently, R&D is now limited to MARAD-funded study projects and U.S. Army Corps of Engineers and Coast Guard projects aimed at improving the physical infrastructure. The development needs of the industry include improved management, information, and communications systems. Also, the industry needs a technical capacity for participating in developing intermodal systems.

Previous comments about waterways as a public responsibility and the relevance of private sector and collaborative strategies to ship operation apply equally to the inland waterways, even though the nature of objectives set by management will differ somewhat. In the case of the waterways, the American Waterways Operators is in a position to foster collaborative R&D.

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*A more comprehensive listing of needs that could be addressed collaboratively appears in Improving Productivity in U.S. Marine Container Terminals (Marine Board, 1986).

[§]The Cargo Handling Cooperative Program is a joint venture of five U.S. general cargo ship operators supported by the Maritime Administration. The overall objective of the program is to improve cargo-handling productivity and thus improve the competitive position of the U.S.-flag carriers.

NEEDED--NEW INSTITUTIONS FOR TECHNICAL ADVANCEMENT

There are many institutions in the United States with some capability to conduct R&D in support of the U.S. maritime industries. The institutions include universities, maritime academies, nonprofit research centers, government laboratories and research programs, consulting companies, technical departments of maritime companies, and entrepreneurs. In this, the maritime industries are no different from counterpart industries, and the contributions of these institutions are legion. In fact, the technical resources of these U.S. institutions are the envy of the world.

Yet, despite past accomplishment and current capability, with several very specific and narrow exceptions, there does not seem to be any mechanism for setting priorities, planning programs, or pooling funds to address shared objectives. Nor are there mechanisms for integrating the interests of Congress, the executive branch, industry, and academia in an effective way.

Other countries seem to have gone to greater lengths to create shared institutions to promote and achieve commercial technical advancement that is in the national interest. In Japan, for example, technical advancement is promoted through nationally chartered R&D organizations that include industries, suppliers, and users in their membership. Support flows to the organizations from both the public and private sectors. A planning committee, composed of representatives of member organizations and academics, develops the R&D program. Committees are then organized to implement the program.

Variations of this institution occur in a number of other countries. The essential elements of the institution are: government participation (especially seed money), top-level industry direction and oversight, program planning by the technical community, pooling and allocation of R&D resources (money, people, facilities). The U.S. maritime industries have nothing of this sort.

Earlier it was shown that some U.S. industries, e.g., electric utilities, steel, electronics, and railroads, are working toward these kinds of arrangements. In other words, much can be done under current rules and conditions. But what does it take to make it happen? In every instance of accomplishment in this arena, there has been an external push--usually either losing ground to stiff competition or the threat of government intervention. There has also been a catalytic agent, either an industry association or the government in one way or another.

While the maritime industries certainly seem to be burdened with competition sufficient to spark interest in new approaches in advancing the technical base, it is doubtful whether there is a prime mover. Certainly the federal government has backed away from any such role.

What about the organizations that serve the industry? The trade associations, such as the American Institute of Merchant Shipping, the Council of American-flag Ship Operators, the Lake Carriers Association, the American Waterways Operators, and others, are organized along parochial lines. Furthermore, they have historically concentrated their efforts on policy versus technical issues. No single association promotes the national interest in the maritime industries. The professional associations and societies, such as the Society of Naval Architects and Marine Engineers (SNAME), have never been chartered nor funded by their members or sponsors to exercise the kind of leadership that is needed. Despite the current state of affairs, there are some prospects. The SNAME Ship Production Committee does attempt to follow the Japanese model to an extent.

Progress in the ports industries will depend on the participation of all involved interests--ship, port, cargo, terminal, truck, rail management, and labor and government. All of these interests already participate actively in the technical activities of the AAPA. It would seem that the AAPA faces a real opportunity. It could form a strong technical program within the organization, as was done by the Association of American Railroads and the American Petroleum Institute, or it could cause an independent entity such as the Electrical Power Research Institute to be established. The public port authorities of the United States would have much to gain and very little to lose from such developments. However, the catalytic ingredient of top-level management commitment is still missing.

The inland waterways industry is in some respects similar (in its readiness for the creation of an industry R&D institution) to the ports industry in that the majority of interested parties participate in the industry trade association, the American Waterways Operators.

The ship-operating sector does not have the extent of preemergent conditions of the other sectors. Evidence of this lies in the near total inaction of this industry in response to a major effort in 1983 to develop an R&D program for industry implementation and to describe alternative organizations for implementation (Marine Board, 1983). Operators' severe economic problems probably eclipsed the call for a cooperative industry R&D effort at that time.

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CONCLUSIONS

The committee has sought to identify how research and development (R&D) can contribute to increased competitiveness of the maritime industries in the international marketplace. And, it has tried to determine how R&D can contribute to enhancing the availability of the commercial maritime industries and their assets to potential military needs in the future. Numerous specific areas have been identified where R&D might make a contribution to both of these goals.

In those instances where U.S. maritime industries have become more competitive or enhanced national security, it has been for one of two reasons. Either they have increasingly integrated their maritime activities into an overall system (manufacturing system in the case of shipbuilding, integrated transportation system in the case of shipping and ship operating), or they have reaped maximum benefits of technology transfer, or both.

Keeping up the momentum for systems integration and technology transfer will continue to be important. Such efforts should be directed to those parts of the maritime transportation systems where there will be greatest benefit. Technical areas identified in the report include ship operation management including manning, port improvements, and intermodal cargo-handling improvements.

So far as military sealift capabilities are concerned, there is a real need for developing technology and strategies to better utilize the increasingly dominant container ship to support the nation's sealift needs. Particular emphasis should be placed on the development of capabilities for mobile off-loading and on-loading capabilities where it may be necessary to move military goods into ports that do not have container capabilities.

The top priority for maritime R&D should be systemic investigations, especially those addressing management, labor, and information management activities that might facilitate linking the various maritime segments together more effectively. However, given the fragmented nature of the maritime industries, a comprehensive approach is likely to come only with government initiative and support.

APPENDIXES

APPENDIX A: BIOGRAPHIES OF COMMITTEE MEMBERS

GEORGE F. MECHLIN, JR., chairman, has spent most of his business career working in advanced technology areas. He has been with Westinghouse Electric Corporation since 1949 and is currently vice-president of research and development and general manager of research laboratories. Dr. Mechlin is a member of the National Academy of Engineering, a member of the Commission on Engineering and Technical Systems, past member and chairman of the Marine Board, and past member and chairman of several Marine Board committees concerned with engineering safety in the marine environment. He holds master's and doctor's degrees in physics from the University of Pittsburgh. Dr. Mechlin is a member of a number of professional societies and is the recipient of the U.S. Navy Meritorious Public Service Award, the Westinghouse Order of Merit, and the John J. Montgomery Award.

DANIEL BRAND is an expert in transportation engineering and research. He has been vice-president of Charles River Associates, Inc., since 1977. Mr. Brand has been chairman of several committees of the Transportation Research Board. He also was vice-chairman of the American Public Transit Association's (APTA) Policy and Planning Committee. Author, editor, and co-author of numerous publications, he has been active in other professional activities in the transportation field. He was undersecretary, Executive Office of Transportation and Construction, Commonwealth of Massachusetts, from 1975-1977. He was associate professor at Harvard University, 1970-1975, and lecturer at the Massachusetts Institute of Technology, 1969-1970. Mr. Brand has a master's degree in civil engineering from the Massachusetts Institute of Technology; he also attended the University of Vienna and the Swiss Federal Institute of Technology.

JOSE FEMENIA is a maritime engineering educator and an expert on marine fuels and operations. Since 1974, he has been chairman of the Engineering Department at the State University of New York (SUNY) Maritime College, Fort Schuyler, New York. He is also a visiting professor at the World Maritime University in Malmo, Sweden. His research interests include marine power plant evaluation, ship vibration, pollution control, and marine fuels. From 1979 to 1980, he served on the National Research Council Committee on Alternate Fuels for Maritime Use. He is a life member and past member of the executive council of the Society of Naval Architects and Marine Engineers. Mr. Femenia holds an M.S. degree in mechanical engineering from the City University of New York (1967) and a B.E. in marine engineering from the SUNY Maritime College (1964).

ERNST G. FRANKEL is professor of ocean systems at the Massachusetts Institute of Technology (MIT) and also ports, shipping, and aviation adviser to the World Bank. Author of over 100 papers on shipbuilding, ship operations, port development, and other aspects of ocean systems, Dr. Frankel has worked and consulted for numerous shipbuilders, ship operators, government agencies, port administrations, and manufacturing companies. He has authored texts on both shipbuilding and shipping. His research and consulting interests include ship production and fabrication, naval ship design and operation, system reliability and maintainability, transport system analysis, port planning and design, transportation economics, port and coastal engineering, international shipping and shipbuilding, shipyard management, and naval ship procurement. At MIT, he teaches graduate courses in these areas as well as special courses to industry and government executives. Dr. Frankel received a B.S. degree from London University, a mechanical engineering certificate from MIT, an M.B.A. degree from Boston University, and a Ph.D. from London University. Dr. Frankel is a member of numerous professional societies including the Society of Naval Architects and Marine Engineers and the Royal Institute of Naval Architects.

ANDREW E. GIBSON is a shipping company executive, with policy-level government experience. Since 1983, he has been chairman of American Automar, Inc., an American ship owning and chartering company. From 1979-1982, he was president of Delta Steamship Lines, Inc., a leading American shipping company operating 24 vessels in trade from the United States to Latin America. He has also been president of Maher Terminals, Inc. (1975-1977) and Interstate Oil Transport Co. (1973-1974). From 1969-1972, Mr. Gibson served in the Nixon administration as assistant secretary of commerce for maritime affairs and then as assistant secretary of commerce for domestic and international business. He has also served as an ambassador-level international trade negotiator. Mr. Gibson is a member of the board of directors of the Panama Canal Commission and the Industrial Policy Advisory Committee of the Department of Commerce. He is also a director of the American Bureau of Shipping. Mr. Gibson holds a B.A. degree in economics from Brown University (1951) and an M.B.A. degree from New York University (1959).

WILLIAM J. HARRIS has been involved in materials science and industrial research and development for many years. He founded the Research and Test Department of the Association of American Railroads and built this department into a focal point of planning and coordination of technical development for the railroad industry. Earlier in his career, Dr. Harris worked on materials science problems and issues while on the staff of Battelle Memorial Institute and also during his service with the Materials Advisory Board of the National Research Council. His professional activities have included membership and service with the Engineers Joint Council, the American Institute of Mining, Metallurgical, and Petroleum Engineers, the Metallurgical Society, and other organizations. He is a member of the National Academy of Engineering, and has served on many National Research Council study groups. Dr. Harris received a B.S. degree in chemical engineering and an M.S. degree in engineering from Purdue University in 1940, and an Sc.D. in metallurgy from the Massachusetts Institute of Technology in 1948. Dr. Harris retired from the Associa- tion of American Railroads in 1985 and is currently distinguished professor of transportation engineering at Texas A&M University.

JOHN H. LEEPER is concerned with technology development and economic feasibility of maritime projects. He is president of the engineering consulting firm of Phillips, Cartner & Co., which he joined in 1985. Before that he was with Simat International, Ltd., where he directed projects on port and carrier marketing, intermodal transportation, foreign-trade zones, and port and carrier financing. He regularly validates economic and market analyses on new transportation and maritime ventures. Prior to joining Simat International, Mr. Leeper was for several years a senior project manager with the Maritime Transportation Research Board of the National Research Council. Mr. Leeper is past chairman of the Panel on Economic Analysis of Marine Transportation Systems of the Society of Naval Architects and Marine Engineers, and is a member of a number of other professional societies. He holds a B.S. degree in transportation economics from the University of Colorado (1960) and an M.B.A. degree from the American University (1967).

FRANK W. NOLAN, JR. is an expert in marine terminal design and operation. He spent 38 years with the International Terminal Operating Company, retiring in 1984 as vice-president of engineering and purchasing. He is currently an associate of Container Transport Technology Co., which provides engineering services and technical management support in the areas of terminal development, container handling and logistics, terminal management, and container and related transport equipment design. Mr. Nolan is past chairman of the Cargo Handling Panel of the Society of Naval Architects and Marine Engineers. He is currently vice-chairman of the International Cargo Handling Coordination Association. Past service with the National Research Council includes membership on the Committee on Ship Operation R&D and the Committee on Intermodal Terminal Design. Mr. Nolan has a B.S. degree in marine transportation from the Massachusetts Institute of Technology.

EDWIN J. PETERSEN has 23 years' experience in ship construction, repair, design, and research and development management, and 14 years' active service with the U.S. Navy. Currently vice-president and general manager, Naval Technology Division, Todd Pacific Shipyards Corporation, he established and manages this new organizational element which was founded to develop and promote conceptually advanced naval ship designs with emphasis on highly efficient design and construction methods. He also develops and manages the corporation's research and development program. His previous experience at Todd includes service as vice-president of programs and resources, assistant general manager, and program manager for frigate construction. Earlier in his career, Mr. Petersen was associated with Designers and Planners, Inc., and Defoe Shipbuilding Co. In the Navy, Mr. Petersen held a number of engineering duty assignments, including project management and waterfront supervision of construction and repair at naval and private shipyards. Mr. Petersen is a member of the American Society of Naval Engineers as well as the Society of Naval Architects and Marine Engineers. He recently stepped down from the chairmanship of the Ship Production Committee of that society. Mr. Petersen holds a B.S. degree in engineering from the U.S. Naval

Academy and an M.S. degree in naval architecture and marine engineering from the Massachusetts Institute of Technology.

MILTON PIKARSKY is an engineer and manager with broad experience in transportation system research and operations. Currently a distinguished professor at City College of New York, other academic appointments he has held include director of transportation research and research professor, Illinois Institute of Technology Research Institute, and adjunct professor at the University of Illinois at Chicago. Professor Pikarsky has worked as a public works civil engineer, and has been commissioner of public works for the City of Chicago. He has also been chairman of the Chicago Transit Authority. Professor Pikarsky served on the Transportation Advisory Committee of the Federal Energy Administration. He was elected a member of the National Academy of Engineering (NAE) in 1973, has served on the NAE Committee on Public Engineering Policy, and currently serves on the Governing Board of the National Research Council. He has also been chairman of the Transportation Research Board and chairman of the NAE Bay Area Rapid Transit Committee. Professor Pikarsky was elected Chicago's Engineer of the Year (1968) and Civil Engineer of 1970, Illinois Section of American Society of Civil Engineers. He has authored two books and a number of technical papers on the subjects of public works and urban transportation policy and management.

ROBERT N. STEINER is an expert in marine terminals and ports. He has served with the Port Authority of New York since 1967. He is currently deputy director of the port department, where he directs the planning, maintenance, operation, promotion, and development of marine terminal facilities. Early in his career, he sailed as a deck officer in the U.S. Merchant Marine and was employed by Sea-Land Service in the marine operations and marine terminals departments. Mr. Steiner is a member of a number of professional and trade organizations. He graduated in 1962 from the U.S. Merchant Marine Academy at Kings Point with a B.S. degree in marine transportation.

JOHN F. WING has extensive experience in transportation systems and operations. He is senior vice-president, Booz, Allen & Hamilton, and is manager of the firm's Transportation Consulting Division. His personal consulting practice is in the maritime field, where he directs studies of economic analysis and new technology evaluation for liner and bulk fleets, market research for marine equipment, manning, development and feasibility for seaports, evaluation of barge versus rail movement, marine safety and risk analysis, and other marine-related policy, technical, and economic evaluations. Mr. Wing's early professional experience included engineering assignments with Alcoa Steamship Company and ship design with Bethlehem Steel's Shipbuilding Division. Mr. Wing has lectured on transportation economics at the University of Michigan and at Clemson University, and has presented papers for the Society of Naval Architects and Marine Engineers and the Society of Automotive Engineers. He is a past chairman of the Marine Board of the National Research Council. Mr. Wing received his B.S. degree in naval architecture and marine engineering from the Massachusetts Institute of Technology and his M.B.A. degree from Harvard University.

H. PETER YOUNG is vice-president of marine operations for American President Lines, Ltd. (APL). He is an expert on ship operation and fleet management. Mr. Young is currently responsible for all fleet operations, maintenance and repair, fuel purchasing, vessel design, acquisition, and construction. Since joining APL in 1979, he has served as director of vessel maintenance and repair, managing director of breakbulk services, and managing director of the Taiwan region. Prior to 1979, Mr. Young spent 3 years with Seaworthy Systems as manager of marine systems. He additionally held technical positions for 5 years in the marine application of gas turbines and related fuel research and development with United Technologies Corporation after a 2-year stint as a licensed seagoing marine engineer. He is an engineering graduate of the U.S. Merchant Marine Academy, class of 1969. In 1972, he obtained an M.S. degree in management from Rensselaer Polytechnic Institute.

APPENDIX B

EXCERPTS FROM "THE ROLES OF GOVERNMENT AND INDUSTRY IN RESEARCH AND DEVELOPMENT FOR THE MARITIME INDUSTRIES: AN INTERIM REPORT"

3

U.S. MARITIME INDUSTRIES: STATUS, TRENDS, AND NEEDS

STATUS

The U.S. maritime industries (i.e., shipbuilding, ship operating, marine terminals, and coastal and inland waterways shipping and shipbuilding) are in the midst of rapid change as the result of an eroding U.S. competitive position in world shipping and trade, deregulation of the freight transportation industries, and increasing competition for scarce government funds. One consequence of these changes is the oversupply and overcapacity of capital assets, including ships and barges, shipbuilding capacity, and in some cases underutilized marine terminals. Some of the oversupply/overcapacity is nominal--too many or too much. In other instances the oversupply/overcapacity is structural--the surplus facilities are too old or poorly sited for modern conditions. The problem of oversupply/overcapacity adversely affects the business climate in the maritime industries.

The business climate for U.S.-flag shipping is both depressed and intensely competitive, with excess capacity high on the list of causes. Any time any segment shows signs of profitability, as did the U.S. cruise business several years ago, foreign shipbuilders and the governments that support them produce additional tonnage for virtually any owner. The result once again is oversupply. Given the long list of failures that such a shipbuilding policy has generated, many of the developed countries are reassessing the wisdom of continued support of shipbuilders, with the result that closings are taking place at an accelerated rate.

The mounting losses incurred by the shipowners has hit the international lending institutions particularly hard. Recent difficulties of several major shipowners have sent shock waves through the banking industry. It will be increasingly difficult for even the soundest shipping companies to obtain financing in the future. This will lead to further diversification out of the industry.

As a defensive move, many European ship operators are "flagging out" existing tonnage or selling off their fleets and chartering in cheaper third-flag vessels. This indicates that time has run out on their efforts at cost reduction for their national flag ships. Given the existing overtonnaging, freight rates have plummeted to a point where any tax or regulatory burden or crew cost differential cannot be absorbed. Many owners have concluded that neither the available systems nor the technologies exist that can produce sufficient increases in productivity in the short run to offset the cost differential enjoyed by the third-flag carriers.

A new generation of 4,000 twenty-foot equivalent unit (TEU) container ships is now servicing the United States. This additional low-unit-cost transportation capacity virtually guarantees that 1986 will be another year of depressed freight rates. The demise of well-established shipping companies is likely to continue.

Although the dollar has begun to weaken against the major currencies, the lag time built into foreign trade transactions precludes any substantial change in U.S. trading patterns in the short-to-mid term. For example, there is no recognized forecast indicating any major improvement in the U.S. grain and coal export picture that is essential for a substantial increase in traffic on the rivers. Existing overcapacity also will continue to depress freight rates in this area as will the reduction in the world price of petroleum. The drop in oil prices has also dampened activity in the oil service and supply sectors, and the shipbuilders and repairers that serve that industry. No improvement is in sight.

TRENDS

The U.S. maritime industries are faced with a continuation of trends already well begun. The most competitive shipbuilding and ship operating companies will certainly survive. The surviving ship operators, in particular, will become part of a highly competitive international industry, but much of their expansionary efforts will be in the intermodal land transportation systems so that the ship itself will continue to be deemphasized.

The domestic fleet will continue to shrink and some changes may take place in the cabotage laws, particularly as they pertain to the requirement that all vessels be U.S. built. Because of increasingly competitive land transport alternatives, the higher cost of some Jones Act services can no longer be passed along to the consumer. At present, the cheaper tug-barge systems are taking over, but some provision for foreign building is inevitable in the future.

Many state governments appear to be willing to continue to stimulate port improvement and expansion through the use of state-backed industrial bonds, tax incentives, and subsidies. This will sustain a competitive environment that puts pressure on port costs and at the same time will result in excess port capacity nationwide.

There is a growing concentration of cargoes at a smaller number of ports. This concentration is caused by the necessity of improving the utilization of capital-intensive ships, double-stack trains, and modern marine terminals. To increase the number of vessel voyages and unit train round-trips, carriers must limit the number of port and terminal stops. Load centers have developed around high capacity, high service-frequency ports that offer throughput efficiencies. The growing number of container double-stacked unit-trains has benefited the U.S. carriers that introduced them by substantially reducing inland costs.

The concentration of ship operating activities is hardly good news for some shipbuilders. The largest shipbuilders are sustained with Navy work; the smaller shipbuilders must develop new markets or go out of business.

NEEDS AND OPPORTUNITIES

Even in this depressed climate, there are a number of opportunities for improvement that could add to the overall profitability of segments of the U.S. maritime industries.

Shipbuilding

Given the lack of any significant commercial market, the principal beneficiary of increased efficiency or improved shipbuilding and ship repair techniques is the U.S. Navy. A number of worthwhile projects are being undertaken to accomplish this. These projects constitute a collaborative effort within the industry, with government sponsorship. Despite such efforts in process technology (where benefits accrue to the government in the form of reduced costs for building and overhauling naval vessels), U.S. shipbuilders have just begun to scratch the surface of opportunities that could be created through market research, development of new products, and entry into new markets. An example of this is the industrial plant and floating plant market, which is already creating employment for some U.S. shipyards. Private collaborative opportunities to exploit the foreign market for these units are available through the use of export trading companies and foreign trade zones.

Without government support it will be difficult for the U.S. shipbuilders to be internationally competitive within the foreseeable future. U.S. government assistance in international marketing and in low interest financing of foreign sales is appropriate and necessary. The absence of any international demand for American-built ships, together with high U.S. labor costs, greatly restricts the available market and guarantees an insurmountable price differential.

Ship Operating

Improved utilization of the seagoing work force leading to more effective manning and possibly crew reduction offers a real opportunity for future savings and is being undertaken with the cooperation of some of the U.S. labor unions and the U.S. Coast Guard. A number of the European maritime nations and Japan are well ahead in this effort. Several major U.S. shipping companies are transferring the effective manning technology of Europeans and others into their operations. A MARAD-sponsored R&D program with industry and labor has facilitated advances in this area. The technical basis still needs to be developed for revising maritime education and training curricula and for making manning and licensing changes in the context of U.S. maritime safety regulations.

Long-term efforts relating to energy efficiency are being successfully undertaken by European diesel engine manufacturers and their Asian licensees. Given the limited U.S. market, there is little incentive to undertake independent research in this country; however, U.S. ship operators (and shipbuilders) are monitoring overseas developments and should consider participating in future developments.

Marine Terminals

No significant technological limitations impede marine terminal operations. Most modern container terminal operators are aware of and use the latest technologies when their use is cost-effective. The two most promising areas for productivity improvement in the next five years are advances in automation of information flow within marine terminals, and improvements directed to the performance of the human element, including management and labor.

As in other sectors of the maritime industries, technology development and application in marine terminals is healthiest in certain Asian and European countries. Any shortcomings in performance in U.S. terminal operations compared to foreign operations of similar capability is due more to the performance of the human element--management, dockside labor, organization, and work practices--than it is to a need for new technological development.

Generally speaking, labor has not impeded the technical development and application of most competitive technology in U.S. marine terminals. However, in East and Gulf Coast ports, long standing labor/management agreements have denied much of the cost-saving benefits of new technologies to the terminal operator; this has impeded full utilization. Manning levels of longshore gangs in these areas are two to three times the size of those in most areas of the world, and crane productivity in U.S. terminals is less than that of the most productive terminals in the world. In spite of this disadvantage, terminal operators have continued to innovate, albeit with a resultant squeeze on profitability. In contrast to other economic sectors of the maritime industries, there is healthy competition in the marine terminals industry between ports, between terminals, and between labor unions. As a result of relocation of ports and creation of new marine terminals, the traditional labor union alignments are being challenged by newcomers to the longshore industry. High labor costs are creating an opportunity for new approaches and organizations and its growth is bound to continue.

Inland Waterways

Since all basic waterway improvements are government sponsored, the lack of funds and time-consuming procedures for approval of waterway projects are major barriers to improvements in operating conditions and business opportunities. Nevertheless, incremental operational improvements that modestly reduce cost and increase service can reasonably be expected, based on past performance. Opportunities for improving the productivity of vessel operations are to be found in advances in the engine room, hull design and materials, improved maneuvering, personnel safety and health, training of personnel, better communications, and eliminating burdensome regulations.

OTHER CONSIDERATIONS

Given the depressed earnings in the maritime industries, any real interest in technology development and application on the part of the industry will only be to identify short-term opportunities for cost saving or market segment enhancement. Additionally, with continued government emphasis on the eventual elimination of all direct subsidies for the maritime industry and reduced federal investment in ports, only projects that further these short-term goals can be expected to have federal support unless they can be presented as essential to national security.

4

TECHNOLOGY DEVELOPMENT AND APPLICATION IN THE MARITIME INDUSTRIES

This chapter presents an overview of technology development and application in the maritime industries in recent years and identifies the roles of industry and government in these endeavors. It addresses the forces that are driving developments, the key developments, the organizational infrastructure that produced the developments, and additional needs of the industry.

The sources of information for this overview were background papers on the state of technology development and application in each of the four economic sectors being addressed--(1) shipbuilding, (2) ship operating, (3) marine terminal operations, and (4) inland waterway operations.

The papers were developed by experts from each of the industry sectors [the members of the work groups are listed at the end of this excerpt]. The definition of technology development and application in those papers and in this interim report is broad, as has been explained. It encompasses development and commercial application of changes in hardware, operating methods, information systems, and management systems. This broad definition was adopted because it encompasses the types of engineering and operating advances that appear to be important in the maritime industries.

The framework for this chapter is to examine, for each of the four industry sectors, the economic issues and driving forces in the sector, then to identify key technology accomplishments and their benefits, the infrastructure for accomplishment (i.e., how and by whom the work was conducted and implemented), and finally to assess remaining needs and opportunities.

U.S. SHIPBUILDING INDUSTRY

A paucity of merchant shipbuilding and ship repair work is hastening a contraction of the U.S. shipbuilding industry. Even expanded Navy ship acquisition programs require less than the industry's capacity. Shipyard employment, with several exceptions, is down, and several yards have closed.

Intense competition for a limited market has resulted. On a global scale, an increasing number of shipbuilders are chasing a decreasing volume of commercial shipbuilding work. In many instances, foreign governments are making available varied forms of direct and indirect subsidies, as well as liberal credit terms, which enable their shipbuilders to offer favorable prices. The United States is not of the same disposition.

U.S. shipbuilders have not, in modern times, competed in the world market for many reasons. These reasons include disparities of costs of labor, lower productivity, unfavorable foreign exchange rates, stricter laws affecting employment and ship design, separation of design and production segments of the industry, and a lack of support by the U.S. government to the extent that other governments support their shipbuilding industries. Furthermore, the federal government has not provided direct subsidies for commercial ship construction since 1981.

The scarcity of merchant ship work has made shipbuilding, conversion, and repair for the U.S. Navy increasingly important to American shipyards. To this end, a 600-ship Navy that includes 15 carrier battle groups, nuclear submarines, and greater amphibious assault capabilities will be reached by 1990. Most of the ship construction contracts to achieve that objective have been placed. The majority of this work is being undertaken in a handful of shipyards. Four shipbuilders employ approximately 70 percent of the total new construction work force.

The industry has made significant advances in shipbuilding productivity through technology advancements and better management in the design, planning, and production processes, in part as a result of the competitive award of naval shipbuilding contracts with incentives to minimize cost. The MARAD R&D program facilitated the introduction and application of technology advances in U.S. shipyards.

A Navy survey found that many defense contractors will modernize their facilities when contractual incentives and long-term market stability provide a viable base for business investment. Absent these conditions, naval shipbuilders will seek direct government funding for plant modernization.

Since 1983, as a consequence of improved shipyard productivity and lower-than-estimated inflation, some shipyards have been able to deliver ships ahead of schedule and under budget. The costs of some naval ship construction programs have dropped by as much as 34 percent. These savings have been achieved through combinations of facilities improvements, changes in labor/management attitudes, production management systems, advances in construction techniques, and wider use of computer systems in design and production. The shipbuilders themselves have identified and created these opportunities for improved productivity; the necessary investments have come from the shipbuilders with contractual incentives from the Navy.

During 1981, the Navy funded six top-down self-assessment surveys with leading shipbuilders to identify what technologies would improve naval shipbuilding productivity. Shipbuilders submitted technology proposals directed toward improved manufacturing techniques, processes, or machinery. The outcome of the survey revealed that the shipbuilders were extremely conservative in their approach to technology development because barely 6 percent of the 160 technology proposals required production technologies whose feasibility had been proven only under laboratory conditions. The remaining 94 percent of technology proposals mainly called for technology transfer from other shipyards or industries, which could be implemented with minimum risk and delay.

While conservatism with respect to introducing new production technologies in a shipyard environment was evident, considerable production gains have been achieved by the shipbuilders. Some have acted independently, responding to the incentives created by the naval ship acquisition programs; some have obtained direct government funding of advances under the Manufacturing Technology Program of the U.S. Department of Defense; all have benefited from the collaborative National Shipbuilding Research Program.

The National Shipbuilding Research Program is a cooperative venture between the shipbuilding industry and MARAD. It provides financing and management of research projects to improve the productivity of U.S. shipyards and their competitiveness in the world shipbuilding market. The program, initiated in 1971, is financed by both industry and government and provides for industry involvement in technical management and execution through involvement of the Society of Naval Architects and Marine Engineers' Ship Production Committee (SPC). The SPC collaborates with MARAD in the management of the program, especially to set program priorities, assign responsibilities for projects, provide technical direction, and assist in demonstrating program results. Panels of the SPC work to exchange technical information, identify new problems and recommend opportunities for R&D, oversee ongoing projects, and demonstrate completed work. The costs of research projects are shared by the lead shipyard and the government, often on a fifty-fifty basis.

Two developments in shipbuilding technology have great potential and should be advanced by the Navy, shipbuilders, and suppliers. They are integration of engineering and production to support zone-oriented, modular ship construction and the use of computers in shipbuilding.

Shipbuilders, suppliers, and the Navy are introducing computers in the three fundamental areas of their operations: design, manufacture, and production management. Yet, shipbuilders' systems are, in general, considerably behind the state of the art. Because the Navy is the major shipbuilding customer in the United States, it has the obligation to initiate industry-wide innovations that will lead to significant communication and productivity improvements, leaving selection and implementation of computer systems to the shipbuilders and suppliers themselves.

The traditional, adversary relationship between management and labor hinders technology development and application in the shipbuilding industry. Personnel are the most important resource in the ship development and production process, yet until quite recently management and organized labor have shown little interest in working together as an integrated team. Important issues to be resolved in order to maximize efficiency of the shipbuilding process include: work rule flexibility, cross-craft training and assignment, automation of the shipbuilding process, and employee involvement. The National Shipbuilding Research Program has recently initiated a Human Resources Innovation Program to address these important issues.

In summary, technology developments in the shipbuilding industry focus on manufacturing and production improvements aimed at productivity gains and reduced costs. Considerable progress has been made in the last 5 years in reducing the labor hours in shipbuilding. Navy shipbuilding programs have been the primary drivers for these advances, which have been accomplished by the shipyards. The collaborative industry-government National Shipbuilding Research Program, administered by the MARAD, has served as a principal driving force to plan, organize, and manage this R&D. The program has facilitated technology transfer in this arena, and has funded supporting research and development.

In view of its current role as the most direct beneficiary of improvements to the shipbuilding process, the U.S. Navy would benefit from having within its organization a central focus for collaborating with the shipbuilding industry and with the MARAD on developing and implementing process technology. A shipbuilding technology division was recently established at DTNSRDC, which could fill this role.

U.S. SHIP OPERATING INDUSTRY

As the largest international trading nation, the U.S. presents an immense market for U.S. and foreign ship operating companies. Most U.S.-flag operators have not been cost competitive, but this has not prevented vigorous participation by U.S. operators in the liner trades. This participation was made possible in the 1950s, 1960s, and 1970s by the government's subsidy programs but increasingly in recent years by application of U.S.-developed container technology and intermodal systems.

The U.S. shipping industry includes general cargo and bulk cargo segments. The general cargo sector includes several aggressive containership operators competing successfully for international cargo.

The major East/West liner trade routes are served by modern, large to ultra-large container ships supported by foreign-flag feeder ships and an expanding U.S. and worldwide intermodal network operating under increasingly sophisticated control systems.

The general cargo trade protected by the Jones Act is served mostly by older container ships operating in coastwise trade and to Puerto Rico, Hawaii, and Alaska. The trade also supports a few highly competitive, modern coastwise integrated tug barge systems also operating to both Alaska and Puerto Rico.

The U.S.-flag bulk carrier segment comprises mainly older vessels carrying petroleum, grain, and dry bulk cargoes in the cabotage and Jones Act restricted trades. Few U.S.-flag vessels are operating competitively in the international bulk trades. Most of the vessels operating in foreign trade are subsisting on government-aid cargoes. They are generally old by world standards and require freight rates more than double the world scale, even after subsidy, because of high labor and other costs.

Technology developments in the ship operating industry will be discussed in three areas: (1) containerization, (2) effective manning, and (3) management and control.

Containerization

The transition to containers in liner shipping has transformed ship and port design and operations as well as the economics of ocean shipping. Rapid growth in containerization and intermodalism in the 1970s and 1980s was made possible by several key technology innovations. These included changes in ship configuration, cargo handling equipment, terminals, and rail cars as well as new marketing, operating, and management systems.

The most modern containerships can carry in excess of 4,000 20-foot containers. They are powered by fuel-efficient, slow-speed diesel engines, and have hull forms that minimize resistance and reduce construction costs. Increasing use of automation and restructuring of shipboard work is allowing crew sizes to be reduced.

Both rail and ocean carriers have caused the development and implementation of innovations such as:

- Lightweight, articulated rail cars designed to carry double-stacked containers.
- Automated information systems for processing and shipping data between carriers, shippers, terminals, and third parties.

At ports and terminals, developments have been directed toward more rapid and efficient transfer of larger unit loads between ocean carriers and land carriers.

The container revolution and the evolving intermodal transportation systems are the result not only of technology development; as, or more, important have been the creativity and willingness of managers to take major capital investment risks to gain a competitive advantage. Thus, developments were driven by commercial incentives to increase productivity of physical assets and human resources and to be able to offer better service than competitors.

There has been only modest industry-wide or cooperative research and development in this arena, nor has there been an infrastructure to lead such work. This is hardly surprising considering the highly competitive nature of the U.S. industry and the minimal history of cooperative research in the maritime industry. However, some collaboration motivated by necessity has occurred; examples include the standardization of container sizes and lift points. More recently, MARAD has sponsored a Cargo-Handling Cooperative Program (CHCP) modeled after the National Shipbuilding Research Program. Under the CHCP, U.S. liner operators, which also operate marine terminals, are investigating technologies needed by all, such as systems for automatic identification of containers. Significant advances are being achieved through this cooperative industry-government program.

Effective Manning

At the present time, manning levels for new large oceangoing container ships and single-product tankers are generally in the 18- to

22-person range. Ten to fifteen years ago the manning levels for comparable vessels were in the 30 to 35 range. In some instances, the reductions have been achieved without significant planning; in other cases, there has been considerable joint experimentation and negotiation by management, labor, ship, and shore personnel.

Manning changes require innovations in operating practices and hardware--engine, deck, bridge, food service, and other equipment--as well as fleet management practices. In reducing manning, it is also necessary to address human factors elements, such as the effects of isolation on worker performance and safety. Most of the effective manning advances to date were developed and applied first by foreign ship operators, often as the result of collaborative national programs.

In addition to the technology development required for more effective manning, organizational changes are required based on work redesign. Work redesign refers to deliberate efforts to modify the organization of shipboard work. This might include structural changes such as new billets, new management practices, and revised union work rules. Research to identify the educational and training needs of present-day and future seafarers is needed.

One important work organization change has been that of intradepartmental flexibility in which individuals take on more responsibilities within their own departments, e.g., steward/cook, cook/baker, and electrician/reefer/junior engineer.

Crew continuity, a potentially important manning innovation, is very difficult to achieve in the U.S. merchant marine because of the current surplus of labor. Unions attempt to spread diminishing job opportunities among their members.

Hardware innovations enabling further manning reductions have largely proceeded from foreign shipyards, frequently in association with nationally funded R&D efforts. Shipyards and governments wishing to continue the export of merchant ships are quite aware of customer interest in smallest-crew vessels. As the level of manning drops into the mid-teens, a need develops for significant further technology innovation in hull and machinery maintenance.

In the U.S. ship operating industry, the advances in effective manning are being achieved primarily within individual steamship companies working with their unions. Engineering design organizations have provided guidance on the availability of supporting hardware. Also, MARAD has performed an important catalyst role through sponsoring technology transfer, and facilitating joint labor- management approaches to problem solving.

Ship Management and Handling

A number of ship management functions have been partially or fully automated through use of computers and satellite communication systems with a resulting positive effect on ship management methods and organization.

Ship routing systems were introduced based on satellite weather information, accurate position measures, and onboard and shore-based computer systems that could determine the optimum course and speed for a ship to minimize its fuel consumption while achieving its desired arrival time within acceptable levels of probability. Ship routing systems used various weather and ship progress forecasting techniques. The U.S. Navy has been the principal sponsor of this technology development.

Other important technological developments have been in the area of ship condition management. This refers to implementation of an optimum strategy for fuel and water consumption as a result of monitoring the tanks, stores, and positions of cargo; and computing ship stability, trim, draft, list, bending moment, and shear in near-real time.

Further reductions in manning and auto-pilots controlled by a computer routing/collision avoidance system are expected applications. Other technological changes will probably include remote cargo and ship condition management whereby preprogrammed cargo loading/discharge and ship condition changes are performed without shipboard crew involvement.

Research and development in ship management systems has been performed by commercial equipment suppliers and research firms. MARAD has been a principal sponsor of research in this area through its Fleet Management Technology Program, which has funded research, testing, and implementation work on weather routing, collision avoidance, and other management systems. Many technological advances are fallouts from developments in other areas such as space research, satellite systems, communications research, and automated data base systems.

Interest developed in the early 1970s in the interaction between safety in ship operations and ship handling. This was the result of a number of collisions, rammings, and groundings involving tankers and also vessels striking bridges.

The primary sponsors of research on the safety of ship handling were the U.S. Coast Guard and MARAD with guidance from the Society of Naval Architects and Marine Engineers (SNAME). There has been a continuing R&D effort directed at prediction and improvement in ship handling and controllability. This effort is at a very low funding level after a peak in the mid-1970s. For commercial transportation application MARAD was the major source of funds although these now are minimal. In selected cases, the U.S. Coast Guard and U.S. Army Corps of Engineers have also funded work. The Navy has also supported some basic work in ship controllability which can be applied to commercial vessels. Industrial funding has been very limited.

Ship/waterway interface technology concerns the prediction of ship performance in a particular harbor, channel, or waterway, and the determination of the effects of changes in the waterway on safety or operating efficiency. The driving force behind R&D in this area is harbor/waterway development and maintenance projects. Small changes in channel and turning basin dimensions can have very major cost and environmental impacts. The primary sponsors of research have been MARAD, the Corps of Engineers, and the Coast Guard. SNAME Panel H-10 has continued to provide guidance.

The major tool in this research is the real time, man in the loop, ship handling simulator, of which MARAD's Computer-aided Operations Research Facility is the most advanced in the U.S. Implementation of research in this area has been quite rapid. It has become a standard procedure to use simulators to evaluate alternatives in port and waterway design. Decisions affecting the expenditure of hundreds of millions of dollars for port and waterway construction have been made on the basis of simulator studies.

The shipbuilding and operating side of the industry with few exceptions has made little investment in ship handling research. The most notable exception has been oil company sponsorship of research associated with tanker maneuvering in shallow water in the late 1970s. Fleet management is another area of opportunity. However, the barriers to more effective technology development for the ship operating industry include lack of economic incentives and a weak R&D infrastructure.

In summary, technology developments in the ship operating industry focus on implementation of containerization and intermodal systems, effective manning, and ship management and handling. Containerization, which revolutionized the liner segment of the industry, was developed primarily by operators investing in capital intensive ships and cargo handling equipment spurred by market and profit potential. The next revolution may be in effective manning, with operators and labor trying to catch up with a competitive advantage already achieved by foreign operators. MARAD has played an important supporting role in effective manning technology transfer and facilitation, and in ship management computer systems development.

U.S. MARINE TERMINAL INDUSTRY

Every coastal metropolitan region of the United States centers on a commercial port. The hubs of ports are marine terminals, which are complex networks of receiving, storing, and transporting facilities for cargo carried by ships. At marine terminals, cargo is transferred between deep sea vessels, feeder vessels, and inland transportation modes.

Deregulation on both the land and ocean side has changed the competitive balance substantially. Each element in the transport chain--ocean carriers, inland carriers, and seaport marine terminals--must now stand alone in the shipper's evaluation of least system cost. Furthermore, under the rapidly growing intermodal systems that are developing in the deregulated operating environment, a single carrier may be responsible for the entire routing from origin to destination. Consequently, where past port routing decisions were made on the basis of tradition and legal precedent (under outdated shipping laws), current routings are made on the basis of cost and service performance.

In summary, only marine terminals in those ports that recognize the need to improve productivity will survive the competition heightened by deregulation. Advances in seaport marine terminal technology as well as channel depth, labor-management relations, equipment and facilities, management techniques and computer systems can improve terminal productivity. These areas are discussed next for general cargo terminals as well as bulk cargo terminals.

Channel Depth

The 40- to 45-foot deep channels at the major ports are adequate for virtually all of the largest ships in service or being constructed for the transport of general cargo. The extensive need for landside container storage space, however, has led to relocation of container terminals away from traditional "downtown" shipping centers to outlying areas of ports, necessitating either development of new access channels or deepening of relatively shallow secondary channels. The advantages inherent in the use of large vessels will probably impose pressures for further improvement of the main channels at major ports including the widening of channels for wide-beamed ships.

Channel improvements under today's regulatory environment require resolution of technical problems associated with dredging. Better methods for dredging and removal of dredged materials with minimal adverse environmental impacts need to be developed. The technical basis needs to be developed to increase the utilization of dredged materials and to view them as a resource, as opposed to their current status as a waste material that needs to be disposed of. At estuarial ports, where significant salinity intrusion may result from deepening of a channel, methods have to be developed to prevent contamination of water supply systems that have intakes in the estuary. A means for protecting timber piles exposed by dredging to attack by marine borers must also be devised. Solutions to such technical problems are being sought by the dredging industry and port development organizations.

A major physical constraint to increasing the depth and width of many ships is the limitation of navigation locks in the Panama Canal, the St. Lawrence Seaway, and on inland rivers. The construction of a sea-level canal across the Isthmus of Panama or, alternatively, new locks for accommodating large bulk carriers will, even if adopted, require over a decade to complete.

Alternatives to waterway deepening include the offshore construction of terminals either of man-made platforms or islands in deep water. Another alternative is to serve exceptionally deep-draft vessels at a limited number of ports, each within a major region of the nation.

The use of wide-beamed ships and draft-assistance devices also would avoid the need for channel deepening. Both of these concepts could, however, still necessitate some dredging work.

The principal federal organizations concerned with marine transport and channel works are MARAD, the Coast Guard, the U.S. Army Corps of Engineers, and the Environmental Protection Agency. Several of these organizations sponsor R&D in advancing marine transport and port development. MARAD issues planning criteria for U.S. port development and funds studies on port siting, operating, and financing. It also aids the planning of port facilities and shipping operations by compiling statistics of the nation's waterborne commerce, and updating inventories of port facilities and vessel fleets. One of MARAD's thrusts in technology is its computer-aided operations research facility (CAORF). Located at the U.S. Merchant Marine Academy at King's Point, New York, CAORF simulates navigation operations for the planning of waterways.

The U.S. Army Corps of Engineers conducts a major part of the research on the technical and environmental issues involved in channels, bank protection, and flood control works. The Corps' Waterways Experiment Station at Vicksburg, Mississippi including its Coastal Engineering Research Center is among the few laboratories engaged in the study of hydraulic and sediment regimes, and other phenomena affecting channel development and shore protection. The Corps also conducts research on improvement of dredging equipment and operations.

The EPA and other government agencies have compiled a significant body of knowledge on ways to mitigate the adverse impacts of port and channel projects on the environment. State and municipal agencies, port authorities, and consulting engineers conduct studies oriented primarily to solving technical problems for specific port projects. University researchers also make valuable contributions to understanding the physical phenomena affecting coastal, port, and offshore works.

The main barriers to waterway improvements are a lack of funds and the complicated and time-consuming procedures for approval of waterway projects.

Labor-Management Relations

The application of technology to the operations of the marine terminal industry has had and continues to have a profound impact on the use of longshore labor as well as on labor-management relations within the industry. The use of containers for packaging ship cargo, for example, has prompted significant productivity gains by reducing labor costs and more efficiently using capital assets such as oceangoing liner vessels. To a lesser extent, the introduction of bulk self-unloading vessels, the mechanization of special product carriers such as banana-carrying ships, and the development of other labor-saving technology have all improved the labor productivity of the marine terminal industry. The application of computer technology to terminal management and information processing is also affecting the use and productivity of the work force.

It is apparent that a major labor management challenge facing the marine terminal industry on the Atlantic and Gulf coasts arises from the lack of flexibility in the traditional work rules. The high costs of redundant workers in marine terminals makes this particularly inefficient. It is possible that increased application of technology in marine terminals on the Atlantic and Gulf coasts will be accompanied by the use of a nontraditional waterfront work force.

Equipment and Facilities

Land within ports is in increasing demand. More efficient use of this scarce commodity will be an important area for development in the future.

In the area of marine container equipment and facilities, the major technological developments implemented since 1975 have been improvements in the efficiency of containerized transportation systems. With a few exceptions, notably intermodal operations and technology, there have been no major breakthroughs similar to those seen in the previous two decades.

Some of the technological advancements in the area of containers include designs which are lighter, allow for safer and more trouble-free/maintenance-free operation, and prevent cargo damage. Most of these designs were developed in response to operating feedback of 10 to 15 years of operations with containers prior to 1975.

A particularly beneficial development are containers designed to fit cargo and intermodal transportation requirements more efficiently. High cube containers, 45-foot containers, 24-ton/20-foot containers, and other designs provide economy of scale in the handling of specific cargo for certain trade routes.

Many container terminals do not operate at anywhere near optimum capacity. This is because ports often have caused the development of new terminal facilities for other than economically rational reasons, such as the desire to promote civic image. The only rationalization of terminal usage occurs indirectly through the choice by ship operating companies of the public terminals that they will call at.

The infrastructure supporting technological developments in marine terminal facilities and equipment is varied. Successful projects typically include a combination of government and private sector involvement. Projects completed most quickly and with the greatest impact, however, are sponsored and developed by a single company.

A formidable barrier to innovation in marine terminal equipment and facilities is high R&D costs. These costs are typically too large for one company, port authority, or manufacturer to bear on its own. Millions of dollars of theoretical research, prototype work, evaluation, and analysis may be required to develop an automated piece of handling equipment, for example. Similarly, computer systems development includes major operational impact analyses, hardware and software development, and careful implementation prior to use. Although the system may be cost-effective on paper over a period of time, the resource allocation may be too large for an individual terminal operator or carrier to reasonably undertake on his own. The sophistication and complexity of some projects also often surpass the technological capabilities of any one group. Without sufficient return on investment, engineering developments that originate in the United States are likely to be applied initially overseas.

Attempts to pool resources to surmount these problems have not been successful in the past. There are inherent difficulties in coordinating common or associated entities, such as port authorities, carriers, and manufacturers. Varying profit motives, proprietary notions, and difficulties in focusing a number of individuals on a common goal are typical stumbling blocks.

Another barrier to innovation is the assumed resistance of labor to such change. Some organizations do not implement labor-saving improvements for this reason. In addition, many third-world nations have lobbied in international forums against change, particularly in the area of container development. They fear that once they enter into the fray of intermodal container operations with standard equipment and fixed port facilities, development of more efficient containers and automated ports will make their investments obsolete.

The cost of buying, maintaining, and controlling ocean containers has resulted in renewed interest in break-bulk cargo handling. Highly automated systems for handling break-bulk cargoes have been developed in Europe and will be introduced into the U.S. in the near future.

Computer Systems

Great strides have been made over the last 20 years by using the computer as a management tool. Recently, for example, terminal operators have developed the capability to simulate alternative engineering operations to discern optimum operating configurations. On another front computer systems are being developed to facilitate the movement of freight documentation between brokers, customs officials, and the port authority.

Management systems technology is available to accomplish major gains in terminal productivity, but the major elements--information networking on a grand scale and an electronic identification system for cargo containers--are outside the control of the terminal operator. Standardization and transmission of documents constitute a major area of marine terminal operations awaiting consensus and development.

The majority of companies involved in the operation of marine terminals do not perform R&D. Marine terminal operations frequently rely on external sources for ideas as well as input.

A limited amount of cooperative development and testing is undertaken under the Cargo Handling Cooperative Program established by MARAD in partnership with liner companies.

Bulk Terminals

Technical developments in bulk marine terminals have emphasized increases in speed, capacity, and automation. Considerable improvements have been made in speed and capacity of ship-based, self-unloading cargo handling systems; less dramatic advances have been seen in shore-based systems. Aided by advances in computer technology, bulk handling is increasingly automated. With the aid of programmable controllers, an operator not only can run an entire bulk handling plant but also diagnose malfunctions of any component and prescribe remedies without leaving his control room.

The current profit squeeze in the marine terminals industry has limited application of new technology developments in the United States. Occasionally, new concepts and improvements of existing systems have been developed by engineering companies. The Technical University of Hanover in Germany as well as various manufacturing companies in Japan and Europe have been the main source of recent R&D achievements.

A prime motivation for innovation during the past 5 years has been the growing need for improvement in efficiency and profit in the face of high interest rates and capital shortages. Historically, cargo handling equipment manufacturers undertook a large share of this responsibility, but with severely depressed margins these corporations have not been able to contribute as they had in the past. Much of the recent development work, consequently, has resulted from partnerships between users (such as steel and power companies and operators of facilities) and engineers.

In summary, technology developments in the marine terminal industry focus on channel improvements, labor-management relations, equipment and facilities productivity improvements, and computer systems. Terminal developments have paralleled the container revolution in the liner industry. In the bulk industry, advances in speed and capacity of cargo handling have outstripped the ability of inland cargo systems to accommodate them. Only in the area of channel improvements is there a substantial, established R&D program because, historically, harbor development has been the responsibility of a federal agency--the Corps of Engineers, which has sponsored its own research for its own needs.

U.S. INLAND WATERWAYS INDUSTRY

The Mississippi River and its navigable tributaries are the heart of the commercial inland waterways system of the United States. Intracoastal waterways extend along the Gulf and Atlantic coasts. In the West, the Columbia-Snake Waterway provides shallow draft navigation above Portland, Oregon to Lewiston, Idaho. The Great Lakes and the Tenn-Tom waterway round out the U.S. inland waterways. Nearly 35,000 vessels, primarily barges and towing vessels, operate in the domestic coastal and inland water transportation system of the United States.

The barge and towing industry carry more than 12 percent of the nation's total freight at 2 percent of the total freight bill. The major commodities carried, petroleum and petroleum products, coal, grains, and sand and gravel, can accept the slow delivery of barge movement because of the low cost.

Historically, the U.S. government did not charge water carriers for the use of navigation facilities provided by the government. These facilities include locks, dams, and other improvements on the rivers, locks on the Great Lakes, and harbor improvements on the Great Lakes and on the coast. This policy has been changed. P.L. 95-502 established a fuel tax on inland river carriers beginning at 4 cents a gallon in 1980 and increasing incrementally to 10 cents a gallon in 1985.

Domestic water transportation was a growth industry for the quarter century preceding the decade of the 1970s. During that decade many national and global changes occurred to turn this industry into a mature one due to the construction of excess equipment in certain trades and due to a decrease in the demand for bulk commodities in other trades.

The euphoria of the 1970s has turned into the depression of the 1980s. It is estimated that excess equipment amounts to about 30 percent over what is required and freight rates have plummeted to the levels of the early and mid-1970s. Other problems involve the infrastructure. Locks and dams on the rivers and the St. Lawrence Seaway are in need of replacement and repair.

The industry has until recent years steadily improved its productivity. An important development in towboat design was the adoption of the Kort nozzle, which increases towing ability by directing the flow of water around the propeller. Most importantly, towboats operating on the Mississippi River have increased dramatically in size and power, and tow-handling capability has been improved by the installation of flanking rudders.

Barges have also undergone a similar evolution resulting from early experiments. Steel barges, with streamlined rakes, lessened resistance so that horsepower requirements are from 45 to 60 percent below those of their more cumbersome predecessors. Barge types have been improved; weather-proof covered barges now protect cargoes and tank barges carry all manner of liquids. The barges are designed for minimum resistance in fleet operation.

Breakthroughs in technology or inventions that would revolutionize the operation of river vessels are not expected in the near term. Most of the future advancements will probably be developed by other industries rather than through original development by the maritime industry.

What can be realistically achieved lies in the area of incremental improvements, innovations, and refinements to what already exists. The major areas for opportunities for improving the operation of the vessel are the engine room, hull design, and materials; improved maneuvering; personnel safety and health; training of personnel; and communications.

Hull design and materials improvements result in small increases in speed and fuel savings. Variable pitch propellers and increased use of bowboats and bow thrusters enhance fuel efficiency. More emphasis on training of personnel adds to efficiency and safety.

Telemetry systems, which improve communications between the vessel and the home office, enable the office and vessel to be in constant contact, allowing the office to monitor the vessel's performance, location of equipment, and loading and discharging of cargo and to evaluate planned performance so that greater efficiencies can be achieved.

The invention of a universal barge coupling, which could be retrofitted at reasonable cost and be simple and safe to operate, would be a breakthrough in speeding fleet make-up and turnaround time.

Opportunities for increasing lock capacity exist. Lock controls could be centralized and automated. Closed circuit television cameras could expedite lockages because a person would not have to walk from one end of the lock to the other to make sure everything was in order. Separate facilities could be constructed to take care of recreational boat traffic. Impact barriers could be installed to protect gates. Double gate systems could be installed as an alternative to having two chambers. If one gate is damaged, the other would be operable without having to shut the chamber down. Replaceable fenders, energy absorbers, or rolling fenders could be installed on lock walls to prevent damage. Waiting areas could be provided near lock gates. More responsive and flexible scheduling procedures could be established and priority given to faster locking tows.

The cost of locks and dams may be reduced as new construction techniques are developed such as precasting various elements of a lock structure and/or precasting entire segments of locks and assembling them by using post tensioning and prestressing methods. Technological advances in the design of locks and dams over the past several decades have improved safety, service time, and maintenance requirements. Additional savings in this area as a result of research and development should result in improvements which will offset any increase in construction costs.

Physical modeling for waterway systems is an expensive undertaking. More effort needs to be directed at developing mathematical models for portions of the system.

Finally, ongoing research needs to be continued to extend the navigation season in the colder areas. New technologies include lock-wall heating elements, especially for locks being rehabilitated, air curtains at lock entrances, ice control by booms and other structures, coating for lock walls and gates, and protection for floating mooring bitts.

The inland waterways industry lacks organized information on which to base management decisions. During the last 10 years MARAD, through its Cooperative Industry Research Program, has funded most of the research studies conducted in the industry. Since the projects usually have the participation of industry, MARAD's programs have been guided toward commercially viable goals.

Major areas of research include maintenance and repair, advanced ship systems, market analysis, ship board automation, navigation and communications, cargo handling, energy conservation, and fleet management.

Maintenance and repair projects evaluated underwater cleaning and inspection techniques as a method of extending the period between dry dockings. Research on marine coatings and preventive maintenance has produced better rust inhibitors and anti-fouling bottom paints.

Example projects included the Vessel Vital Signs Monitoring System study which evaluated the need to obtain, transmit, and analyze vessel equipment performance data to produce decision-oriented management information to aid the maintenance department.

Another project is for better communications for the western rivers and the Gulf Intercoastal Waterway. A prototype system tested in 1985 resulted in a successful vessel to shore communication. The entire system will be capable of handling voice and data communications.

The foregoing areas of technology development and application represent a high risk if a single company attempted the work alone. However, with initial funding by MARAD and cost sharing by the private companies involved, this research was possible.

In summary, technology developments in the inland waterways sector of the maritime industry have resulted in dramatic increases in transportation productivity through vessel and barge design and operating systems. However, the current depression and overcapacity in the industry have dried up incentives and investment for further improvements. Consequently, research and development is now limited to MARAD-funded study projects and Corps of Engineers and Coast Guard projects aimed at improving the physical infrastructure. The development needs of the industry include improved management, information, and communications systems. Also, the industry needs a technical capacity for participating in developing intermodal systems.

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Cambridge, Massachusetts

Daniel Brand
Charles River Associates, Inc.
Boston, Massachusetts

Charles R. Cushing
C. R. Cushing & Company
New York, New York

Jose Femenia
SUNY Maritime College
Bronx, New York

Andrew E. Gibson
American Automar, Inc.
Washington, D.C.

John H. Leeper
Phillips Cartner & Co.
Alexandria, Virginia

Eugene R. Miller, Jr.
Hydronautics
Laurel, Maryland

Milton Pikarsky
City College of New York
New York, New York

John F. Wing
Booz, Allen & Hamilton, Inc.
Bethesda, Maryland

H. Peter Young
American President Lines, Ltd.
Oakland, California

MARINE TERMINALS

Frank W. Nolan, Jr., Leader
ITO Inc., Retired
New York, New York

Leo Donovan
Booz, Allen & Hamilton, Inc.
Bethesda, Maryland

Lee Lane
Bradley Gewehr
Association of American Railroads
Washington, D.C.

Eugene K. Pentimonti
American President Lines, Ltd.
Oakland, California

Milton H. Pikarsky
City College of New York
New York, New York

Christopher Redlich, Jr.
Marine Terminals, Inc.
Long Beach, California

Albert Rosselli
Harry Ekizian
T.A.M.S.
New York, New York

Robert N. Steiner
Michael Morrow
William Cronin
Port Authority of New York/New Jersey
New York, New York

David Tolan
Sea-Land Services, Inc.
Iselin, New Jersey

A. Yobey Yu
ORBA Corporation
Mt. Lakes, New Jersey

INLAND WATERWAYS*

William A. Creelman
Marine Consultant
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Robert Meyer
National Marine Service
Houston, Texas

*Reviewed working paper.