Ship Operation Research and Development: A Program for Industry (1983)

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Ship Operation Research and Development

A Program for Industry

Committee on Requirements for a Ship Operation Research Program
Marine Board
Commission on Engineering and Technical Systems
National Research Council

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PREFACE

ORIGIN OF THE STUDY

Like the merchant fleets of other industrialized nations, that of the United States now faces severe economic pressures. While protective legislation may still be afforded the U.S. merchant marine, both the market and the government require more efficient performance and less public support.

The U.S. Maritime Administration (MarAd) is charged with subsidizing the U.S. maritime industry and fostering its development and economic health. Among other MarAd programs directed to these objectives is that of Research and Development (R&D), addressing shipbuilding, ship operations, cargo handling, and port and terminal operation. In 1981, the U.S. Congress pared MarAd's research budget by about half. Prior to the action of the House committee, MarAd had considered reordering its research and development program on the evidence of its varying success. Ship operation research had not attracted the same favorable attention as the National Shipbuilding Research Program, which had been judged successful by an independently conducted comparison of nondefense R&D funded by the government (BAER 1976).

In 1982, MarAd requested that the National Research Council (NRC) review its ship operation R&D program and make recommendations for its improvement. The NRC appointed the Committee on Ship Operations Research to conduct the assessment under the direction of the Maritime Transportation Research Board.* Members of the committee were drawn from the ship-operating industry as well as the ship operation research community.

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*In the spring of 1982, the Maritime Transportation Research Board merged with the Marine Board.

SCOPE OF THE STUDY

The charge to the committee was to examine the structure and content of cooperative government-industry R&D in ship operation. The committee was asked to review the MarAd program, and relevant similar programs that might suggest guidelines for a successful program--maritime R&D in other countries; domestic non-maritime R&D; and the National Shipbuilding Research Program.

The committee interpreted the scope of inquiry to include mechanisms for program initiation, funding, management, review, and technology transfer--and the extent and nature of government and industry collaboration in each of these. The committee also addressed generic program content, specifying categories of research attention and providing as an illustration a list of potential project areas.

The committee defined the goal of ship operations R&D as furthering the productivity and safe operating practices of the ship operating industry. The committee recognized, however, that, due to the severe economic difficulties of the industry, improved operating efficiency will be the principal research objective for the near term. In this, the safety objective will not be neglected, since safety is coincident with operating efficiency in many ways.

The committee stopped short of making specific recommendations for research because it considers the identification of specific program content as a function best performed within the new structure of research it recommends.

STUDY SOURCES AND METHODS

Information about MarAd's research and development program in ship operation was acquired from agency documents, discussions with program officers, and a meeting with former MarAd R&D administrators and industry managers experienced in MarAd-sponsored projects.

R&D within U.S. shipping companies was investigated through questionnaire and interviews with the senior executives of 13 vessel-operating firms.* The companies in the survey are representative of the subsidized and unsubsidized segments of the industry; deep sea, Great Lakes, and inland waterways; and operators specializing in container, breakbulk, dry bulk, and tanker operation.

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*Alcoa Steamship Co., Inc., Central Gulf Lines, Inc., Delta Steamship Lines, Inc., Exxon International Co., Farrell Lines, Inc., Matson Navigation Company, Mobil Shipping and Transportation Co., Sea-Land Service, Inc., United States Lines, Inc., American Commercial Barge, Inc., American President Lines, Inc., Ashland Oil, Inc., Dravo Mechling, Inc.

**American Institute of Merchant Shipping (AIMS), Council of American-Flag Ship Operators (CASO), Joint Maritime Congress (JMC), Lake Carriers Association (LCA), Maritime Institute for Research and Industrial Developmente (MIRAID), and Transportation Institute (TI).

Interviews and requests for written responses were designed to encourage interest and candid responses, rather than to elicit exhaustive detail. (Questionnaire is reproduced in Appendix A.)

Review of the National Shipbuilding Research Program is based on previous studies of the program and interview of its director.

The staffs of industry trade associations** were interviewed to determine the following: (1) what types of ship operation research they conduct, (2) whether their organizations might host an industry advisory group, and (3) to what degree their organizations might influence ship operation research, regardless of whether they do it.

Information about the Technical and Research Program of the Society of Naval Architects and Marine Engineers (SNAME) was gained initially from the program's annual report and developed in discussions with the president of SNAME and vice president for the Technical and Research program.

Information about ship operation research overseas was supplied by the committee's overseas member, and supplemented by review of the literature as well as responses to a questionnaire distributed at the ERGOSEA conference in Plymouth, England, October 1981.

This report presents research and analysis by individual committee members as modified and approved by the committee as a whole in several meetings, and committee deliberations.

ORGANIZATION OF REPORT

An executive summary gives the principal findings of the committee's review, followed by conclusions and recommendations. Succeeding chapters treat in detail ship operation research and development now conducted in the United States, and other models of research and development programs. Consideration of these other models--for example, of ship operation R&D abroad, collaborative R&D in transportation and energy, MarAd's shipbuilding R&D--was material to the committee's deliberations, and they may warrant further attention in the development of a new domestic program of ship operation research and development.

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SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

At the request of the U.S. Maritime Administration (MarAd), the Committee on Requirements for a Ship Operation Research Program of the Marine Board reviewed the status of, and options for, the future of ship operation research and development in the United States. Of particular concern to the agency in the review were the considerations, guidelines, and models it might use in restructuring this program.

Ship operation R&D, as defined by the committee, is the systematic pursuit and innovative application of scientific knowledge to effectively use resources (men, money, material) in the waterborne transport of goods and passengers. MarAd now spends about $11 million annually to support 70 R&D projects in ship operation.

The committee's review of ship operation research and development now conducted in the United States encompassed the MarAd program, R&D conducted by ship operators, and the programs of trade associations and professional organizations. Other models of R&D reviewed by the committee included ship operation R&D overseas, MarAd's National Shipbuilding Research Program, and R&D conducted by other industries in the United States. In these reviews, the committee focused on mechanisms for 1) initiating, funding, managing, and evaluating R&D programs; 2) communicating results; and 3) effecting government and industry collaboration. The content of such programs was not of direct interest; it was considered by the committee only as it related to the three focal areas of review.

The committee's review led to the following findings of fact.

- The United States is unique among maritime nations in the number and fragmentation of organizations representing ship operators, and trade unions.
- In Japan, Norway, Sweden, Denmark, Germany, Netherlands, United Kingdom, and Canada -- a single organization represents ship operating companies and one or two national maritime unions represents labor. A collaborative maritime research program is part of a national strategy to enhance the country's competitive posture in international markets.

- Research and development programs in other countries having well-developed ship-operating industries differ from those of the United States in the R&D conducted as an integral activity of ship operating companies.
- All the shipowners' associations in the countries studied undertake and collectively fund research in research facilities or institutes partly or wholly funded by government. The research is overseen by industry advisory groups.
- Ship operation R&D in the United States suffers four major disadvantages in comparison to that of other nations: 1) the construction and operations of ships has greater economic importance in the countries reviewed; 2) antitrust laws (or the perception of them), domestic competition among companies, and related concerns inhibit collaborative undertakings in the United States; 3) a single national organization represents the ship operators of each foreign country studied; the United States has several; 4) ship operation R&D has high-level participation and support from ship-operating management abroad, but this was not found to be the case in the United States.

The committee concluded that:

- The ship operations R&D program of the Maritime Administration has not achieved wide acceptance of its project results, principally because of insufficient industry participation in the direction and management of research.
- A cooperative R&D program on ship operation could be of value in this country, but should be reoriented in both structure and content.
- Cooperative ship operation R&D should be coordinated and managed not by a government agency but by the private sector. This can best be achieved through an industry-owned, industry-managed research center.
- The program should be directed through high-level industry initiation and sanction rather than through the "bottom-up" style that has characterized research management in the past.
- No significant improvement can be made in cooperative ship operation research until a research management infrastructure is developed within the industry itself. Any cooperative research organization should encourage and rely on, not replace, this internal capability to manage research. For this reason, to the degree that responsibility and management are linked to ownership (and the connection is clear), industry itself should fund research, especially short-term research.
- Government and industry cooperation should continue, but should be achieved principally through the industry's research center. Government funding of ship operation research has been significant overseas, especially in long-term, high-risk projects. Such projects could also be funded by the government in the United States. Research contracts between single companies and government, however, should become the exception rather than the rule.

- The program should foster the development and strengthening of companies' internal capability for R&D. This does not mean that companies need to establish separate R&D departments, but it does mean a research network should be created within industry and between industry and government. Otherwise, no improvement in ship operation research is likely, whether in initiating appropriate projects or in implementing successful innovations.
- Consultants should play a supportive, technical role in research, rather than one of promotion and management.
- Although ship operation research should continue to pursue engineering innovations, especially those related to fuel conservation and economics, it should move substantially toward projects involving manpower utilization and economics.

Based upon these findings of fact and conclusions, the committee offers the following recommendation:

- Steps should be taken to form an industry-managed Ship Operation Research Center. In this structure, ship operating companies will not rely solely on government agencies for cooperative research. The recommended center would not necessarily be a research laboratory in the sense of sizeable equipment and staff requirements, but rather an administrative entity to coordinate the collaborative research activities of multiple companies and multiple contract researchers. This center will be sponsored and managed by industry, and will facilitate cooperation in research among member companies between industry and government. Individual firms would gain (or an additional) R&D capability through their continuing association as would the role of industry in managing research through the direction of high-level executives on the research center's board.

The objectives of the center would be to further the productivity and safe operating practices of the industry through cooperative selection, management, and evaluation of R&D programs and projects. Management of the R&D program would encompass gathering and disbursing funds for the intramural and extramural conduct of research, including the transfer of information and technology.

Neither the committee nor MarAd can determine whether the program here outlined can be established. As the subtitle of this report indicates, the proposed program is one for industry, and industry alone can evaluate and act on the present recommendations. Because there does not now exist a central, all-inclusive body or organization which can bring representatives of industry together to discuss the implications of these recommendations, the committee considers it appropriate that the Maritime Administration take the lead in convening a gathering of high-level executives of the industry for that purpose. Once afforded that opportunity, further actions leading to organization of a ship operation research center are clearly the option and responsibility of those industry leaders.

2

INTRODUCTION

DEFINITIONS

To clarify the objectives and boundaries of the committee's study, certain key terms had to be defined--notably, "research," "development," and "ship operation." This exercise proved more than preliminary: defining the limits of ship operation research (particularly project content and industry scope) became a central issue of the committee's review.

The National Science Foundation's definition of "research" was judged appropriate for the present study:

> . . . systematic study directed toward fuller scientific knowledge or understanding of the subject studied (National Science Foundation 1981).

"Development" was defined in the following way:

> . . . the activity directed toward the creative application to practical affairs of that knowledge gained from research and that frequently in itself involves the discovery of new knowledge.

This definition of "development" was devised for the present study, rather than adopting another, because this study concerns a service industry. Whereas most industrial R&D is conducted to develop a product or manufacturing process, "ship operation" is a different sort of enterprise, which may be defined as follows:

> . . . the means by which vessel-operating organizations perform their functions. Those functions entail the effective use of three organizational resources (human, financial, and material) in the waterborne transport of goods and passengers.

Combining this definition of "ship operation" with those of "research" and development," "ship operation R&D" is then the following:

> . . . the systematic pursuit and innovative application of scientific knowledge to effectively use resources (human, financial, and material) in the waterborne transport of goods and passengers.

Another term added to the project lexicon was "action research," a term implying simultaneous research, development, and implementation used to describe workplace experiments undertaken to gain knowledge of groups of people in working environments to test technological and organizational innovations, and to institute the innovations that show promise. Maritime action research has been carried out by European nations and Japan to develop, evaluate, and implement new shipboard technologies and crew organizations.

The term "structure of research programs" was defined as "the manner and mechanisms through which research is initiated, funded, managed, reviewed, and disseminated," and distinguished from the content of research programs.

VALUE OF SHIP OPERATION R&D

MarAd supports about 70 projects in ship operation research at an approximate cost of $11 million. Total funding for all ship operation R&D in the United States, including that of the private sector, is not known.

The return on this investment is more difficult to measure in terms of dollars, and in any event, beyond the scope of this study. Nevertheless, the value of this research and development is an important issue, and the qualitative evidence is of interest.

Booz-Allen and Hamilton (1981) compared maritime R&D programs in Norway, West Germany, and the United States, demonstrating that the resources allocated to these programs varied significantly by country. This study included military R&D expenditures; thus, direct comparisons of commercial ship operation research are imprecise. Nevertheless, it is clear that Norway and the Norwegian ship operating industry support a research program superior to that of the United States, in funding (in proportion to such indexes as the gross domestic product, imports, exports, and industry revenues), and in "coincidence with goals," "program direction," and "program balance" (Booz-Allen 1981: 13-17). Moreover, the Norwegian maritime industry is generally considered one of the healthiest of the industrialized democracies. The leadership of this industry is sufficiently clever to retain its competitive position; it probably does not spend its resources unprofitably.

More specifically, the Norwegian fleet's comparative resilience in the current shipping depression has been influenced to a large extent by innovative use of crews. The review of ship operation research overseas indicates that shipboard organizational innovations such as "general purpose ratings," "shipboard management teams," and "shipboard work planning" did not naturally evolve. They are the product of deliberate experimentation and analysis.

Finally, and most generally, the costs of manning and fuel account for approximately 70 percent of the expense of large-tonnage deep-sea operation. Since ship operation research can address both of these subjects, its potential impact on operational performance is clear.

3

SHIP OPERATION RESEARCH AND DEVELOPMENT IN THE UNITED STATES

Ship operation research in the United States is conducted by individual companies, by industry-government collaboration, by professional organizations (principally the Society of Naval Architects and Marine Engineers or SNAME), by trade associations, and by the federal government. These are briefly described in this chapter, and analyzed and compared with other programs in Chapter 4.

RESEARCH AND DEVELOPMENT BY INDIVIDUAL COMPANIES

Figure 1 shows the content of research undertaken by the vessel operators in the committee's sample. Few of the companies engaged in R&D sustain it as a continuing activity distinct from operating functions. Of the thirteen companies and the Lake Carriers Association, only two companies have formal R&D departments. In both these companies, research groups are engaged in both short-term and long-term projects.

The Marine Transportation Department of another company does not have an R&D division, but does support a Marine Planning Group that performs economic research and analyses. Like other companies that support research projects but not permanent research divisions (six of the firms), this operator relies on its technical and operating divisions to conduct the research felt to be needed. Its Marine Transportation Department has the assistance of the company's Research and Engineering Department for specific projects. The results of corporate research are available to all vessels of this company, regardless of the flag they carry.

Another operator, lacking a research division and large engineering department, relies primarily on consultants for research and engineering. Like the other two carriers of dry cargo that do not specialize in containerization, and the Great Lakes and river operators, the company does not conduct continuing research. All these operators differ from the specialized container lines and the tanker firms in this respect.

Concerning the content of research, Table 1 indicates that fuel technology is given considerable attention by nearly all companies and

TABLE 1

R & D Program Activity of Sample U.S. Flag Vessel Operating Companies

	Dry Cargo Carriers								Petroleum Carriers		River Barge Operators			Great Lakes Operators: Lake Carrier Association
	●	●	●	●	●	●	●	●	●	●	●	●	●	
Fuel Technology									X	X		X	X	X
Hull Coatings		X							X	X		X		
Vessel Communications	X	X			X						X	X	X	X
Shipboard Computers								X	X	X	X	X	X	
Auxiliary Machinery		X			X		X							X
Behavioral Sciences					X				X	X				
Container/Cargo Securing	X	X			X			X						
Main Engine		X									X		X	X
Refrigerated Cargo		P			X			X						
Manning		X			X				X	X				X
Shiphandling									X	X				X
Vessel Design									X	X				
Pollution Control									X	X				X
Mooring Systems									X	X				
Terminal Technology									X	X				

modes of transportation. Other engineering topics addressed by several companies are hull coatings, vessel communications, and the use of shipboard computers.

The survey also revealed research topics particular to the transportation mode in which firms specialize. Tanker companies, for example, research single-point mooring, and container operators container-securing devices. Because of the greater environmental consequences inherent to potential tanker casualties, operators of these vessels engage in more research in vessel safety than in efficient operation. Their safety-related research includes ship-handling performance, mooring operation, cargo transfer, and pollution abatement. Similarly, operators of river barges are concerned more than other operators with vessel communications, owing to traffic density.

A contrast in research emphasis between tanker and dry cargo carriers can be seen in the subject of habitability, which is an increasingly important research area in manning. This distinction may reflect institutional, rather than technological differences between the two categories of operators. Tanker firms in the study's sample do not rely on a hiring hall for crews, but retain their seagoing employees. Investments in behavioral science research, such as habitability, may provide substantial dividends through crew continuity. Dry cargo carriers in the survey conduct relatively little behavioral science research in habitability, manning, or shipboard working practices. Such research likely predominates when the investment may be returned in greater retention of employees; additionally, the management of some firms may consider the topics sensitive because of their contracts with the national seamen's unions.

COOPERATIVE RESEARCH AND DEVELOPMENT

Various types of cooperative R&D supplement the research and development of individual firms. Particularly those companies with limited internal capability report that they rely on research results published by MarAd's Office of Research and Development, SNAME, the American Petroleum Institute, and (on the Great Lakes) the Lake Carriers Association.

Government-Sponsored Research (MARAD)

History

Although the MarAd R&D Program may be traced back to 1960 when it was brought into being at the recommendation of a National Research Council study, it was not until the Merchant Marine Act of 1970 that it became fully funded and fully staffed. Previous to this, projects were largely internal, and annual funding did not exceed 2 million dollars. After 1970, annual budgets rose to the level of 25 million dollars.

The program has concentrated on the five broad areas of shipbuilding, ship operation, maritime technology, market analysis, and the use of ports and terminals. As of October 1981, the agency had 157 projects under way, representing a government obligation of more than $27 million, being executed by more than 100 contractors. (Maritime Administration 1981).

Content

Projects in other MarAd R&D categories (e.g., "Maritime Technology") can also be classified as ship operation research by the committee's definition. Based on the agency's summary sheets, (Maritime Administration, 1981), more than 40 percent of R&D funds support ship operation projects. The government's direct financial contribution to 72 projects amounts to more than $11 million (an average cost per contract of approximately $150,000).

Selected examples of projects listed in MarAd's 1981 summary illustrate the scope of its ship operation R&D:

- Atomization of residual fuels for marine boilers
- Nondestructive testing of pipes
- Replacement of steam plants by diesels in T-2 tankers
- Substituting coated steel for bronze in propellers
- Increased speed in handling bulk cargoes
- Management of spare parts inventory
- Fleet logistics management techniques
- Data processing and distribution for operation and financial matters
- Fleet management under wartime conditions
- Improved transfer of technology in the U.S.-flag fleet
- Improved air distribution in reefer boxes
- Reducing port costs for liners
- Human factors in ship safety
- A computer-assisted system to avoid collisions
- Applying copper-nickel sheathing to ship hulls
- Skill requirements for licensed personnel
- The economic impact of charges to waterway users
- A twenty-five-year forecast of demand for vessels and international trade
- An atlas of arctic ice
- Market planning for the liner trades.

Structure

The program has consisted of a Deputy Administrator for R&D in charge of three principal offices (Office of Maritime Technology, Office of Advanced Ship Development, Office of Advance Ship Operation). Each office is staffed by a number of program managers with specific topical responsibility. In the case of the Office of Advanced Ship Operations, the specialities are ship machinery, cargo systems, fleet management technology, ship performance and safety.

MarAd also operates the Computer-Aided Operations Research Facility (CAORF) and the National Maritime Research Center (NMRC) at the U.S. Merchant Marine Academy in Kings Point, New York. CAORF is a ship-handling simulator for use in maritime research, such as bridge design, or port and channel risk analysis. CAORF has operated since 1975. NMRC was originally intended as a maritime research center that would make use of CAORF, but NMRC has never been funded to operate in this mode.

Program/Project Selection

Since 1969, when introduced by the Maritime Administrator Andrew Gibson, it has been MarAd policy to engage almost solely in industry cost-shared research. In every project, the participating company (or companies) was expected to contribute from 1/3 to 1/2 of project costs. Such contribution could be in kind or cash. The bulk of such cost-sharing has been in kind. Nearly 90 percent of MarAd research has been cost-shared in this fashion.

In the beginning, MarAd had to promote its R&D programs to foster industry involvement. The Office of Advanced Ship Development chose to approach its industry (shipbuilders) through the Ship Production Committee of the Society of Naval Architects and Marine Engineers (SNAME). The other two offices, including that of Advanced Ship Operations, relied on individual contact between program managers and industrial personnel for generation of ideas, research proposals, and proposed industrial participation. Also some industry direction has been gained through occasional symposia. There has never been a formal or informal industry advisory mechanism for the advanced ship operations and maritime technology offices. Based on the contacts of the program managers, program plans are prepared which identify projects, budgets, and industry partners. These are updated every six months. About 75 percent of MarAd R&D is funded sole source with the company that has agreed to cost-share the project.

Project Management

Once a contract is awarded to a company, that organization is responsible for project management (subject to MarAd oversight). The companies have the option to do this themselves, to make a new hire, or to employ a consultant. Since few ship operating companies have extensive experience in preparing R&D proposals or managing R&D projects, MarAd encourages ship operators to make use of consultants or external research organizations. This arrangement has encouraged some consultants and external researchers to come directly to MarAd with project ideas and then to hunt for a company that would agree to cost-share with the government. External consultants have played a larger role in ship operation research than they have in shipbuilding research.

The final reports of ship operations R&D projects are sent to every U.S. shipping company, the National Technical Information Service, and (formerly) the Maritime Research Information Service. Abstracts of research reports are also publicized in newsletters and trade journals.

Cooperative Research and Development Within Industry

Ship Technical Operation Committee

The collaboration of companies in research has taken a number of forms, perhaps the most extensive of which (in communication if not dollars) is the Ship Technical Operation Committee of SNAME.

SNAME is the principal professional society in the United States for maritime technology. Its members are individuals concerned with engineering, and they represent all maritime organizations and cognate disciplines--commercial vessel-operating companies, design firms, academia, government agencies (the U.S. Coast Guard, Navy, and Army Corps of Engineers, MarAd, the National Oceanic and Atmospheric Administration), shipbuilders, ship repairers, equipment manufacturers, suppliers of technical products, and independent professionals.

SNAME was organized to advance the art, science, and practice of naval architecture and marine engineering in all applied forms, including the construction and operation of ships and other marine vehicles and structures. It provides a forum for 13,000 members, and for an even larger audience worldwide through publications and symposia.

The Technical and Research Program has been a major society activity for the last 41 years. It now involves nearly 1,000 experts in many disciplines from maritime and associated industries (including governmental and regulatory bodies) who voluntarily serve on 65 committees, panels, and task groups. Through its T&R program, SNAME encourages and sponsors maritime research with particular emphasis on marine vehicles and offshore structures. This work encompasses structures, hydrodynamics, machinery, production, operation, and systems development. The T&R program is funded at approximately $60,000 per year. (SNAME also participates through its Ship Production Committee in the National Shipbuilding Research Program (NSRP), which is separately sponsored by MarAd and the Naval Sea Systems Command through cost-sharing contracts with individual shipyards.)

The SNAME T&R program, directed by the vice president who is chairman of the T&R Steering Committee, is responsible for the detailed planning and execution of the program. Two other related committees support the T&R program: the T&R Advance Planning Committee, which establishes research priorities, projects needs for technology, and develops research programs to meet them; and the T&R Finance and Administration Committee, which raises funds for the program and administers them.

Working under the T&R Steering Committee are six principal technical committees, several task-oriented ad hoc committees, and these committees' panels and task groups. Staff assistance is provided by society headquarters.

Results of the T&R program are disseminated in T&R bulletins, reports, data sheets and symposia proceedings, articles for SNAME's quarterly journals Marine Technology and Journal of Ship Research.

One of the principal T&R committees, the Ship Technical Operation Committee (STOC), is that most closely associated with ship operation research. STOC is concerned with the efficient and economic operation of the ships, one of its major objectives being to provide designers and builders feedback on operating experience so that they can make engineering improvements. These improvements can affect major elements of operating cost, such as fuel, labor, and hull maintenance. The committee's panels are:

- Measurement of Ship Operating Efficiency (0-21)
- Ships' Paints (0-23)
- Coatings for Offshore Structures (0-23-2)
- Life Support Systems (0-25)
- Cargo Handling (0-31)
- Computers (0-34)
- Economic Analysis of Marine Transportation Systems (0-36)
- Heating, Ventilation, and Air-Conditioning (HVAC) Design (0-37)
- Human Factors (0-38)
- Fleet Management Technology (0-39)

Fuel and hull maintenance are of primary concern to STOC and to the Hull Structure and Ship's Machinery Committees. The topic of labor costs is more problematic for STOC, in that institutional factors are involved. The charter of the Human Factors panel mentions manning issues and applications of the behavioral sciences, but the panel consists principally of designers, and their work has concentrated on habitability. Another panel with a non-engineering focus is Economic Analysis of Marine Transportation Systems.

Trade Associations

Trade associations also undertake collaborative research in varying degrees. Among their other functions, overseas ship operator associations conduct and sponsor research. The closest equivalents in the United States are several operator associations and a number of labor-oriented trade promotion organizations. The former are defined by industry segment--Great Lakes, inland waterways, and deep-sea industries-- and the deep-sea industries by whether their members are subsidized by the federal government. This distinction of deep-sea operators largely coincides with that of liner and bulk carriers. The labor-oriented associations are identified by their links to the unions that established them through collective bargaining with contracted operators.

The operator associations engage primarily in lobbying and for this reason are based in Washington, D.C. (Lake Carriers Association, which has its headquarters in Cleveland, is one exception.) Both the American Institute of Merchant Shipping (AIMS) and the Council of American-Flag Ship Operators (CASO) have undertaken technical research not directly related to policy issues: AIMS in tanker and tug maneuvering tests, with the U.S. Coast Guard and MarAd; CASO in communications and data transmission, with MarAd and the Military Sealift Command. Technical research is an exceptional rather than regular activity of these organizations. They sustain technical committees on operation, but with the objective of articulating policies on technical issues that will be the subject of national or international regulation. An AIMS official explained, "R&D is not our field, but if we have a clear need for some research, we have a committee structure that allows us to do it."

Research and development sponsored by the Lake Carriers Association (LCA) is conducted by staff members who sometimes rely on consultants and outside specialists, and LCA has participated in various MarAd programs that it judged helpful in advancing its research objectives. LCA has no continuous or long-term research and development program, nor budget for these activities. Rather, the association serves to centralize and coordinate the collective needs of its members.

In structure and function, labor-oriented trade promotion organizations follow a pattern first established in this country by the construction industries. Although the term "research" may appear in their titles, these organizations conduct and sponsor very little research and development as defined by the committee. Their principal purpose is to represent, promote, and defend their industry's interests, and their research always concerns policy.

The labor-related associations have boards of directors, trustees, or advisory committees, which consist of high-level executives and labor leaders of steamship companies. The Transportation Institute (TI) is an exception, as its Board of Trustees has no labor representation.

Many of their functions are similar, but some distinctions can be observed: the Maritime Institute for Research and Industrial Development (MIRAID) focuses on congressional and regulatory affairs; while the Joint Maritime Congress (JMC) undertakes technical economic studies. An informal division of labor among these associations is occasionally made in decisions about which will take the lead on a particular legislative or regulatory issue.

4

RESEARCH AND DEVELOPMENT MODELS

Research and development programs selected for this review are conducted by industries or organizations that share important features with the ship operating industries and organizations of the United States, or by collaborative arrangements that could be of interest as models. They are the ship operation R&D conducted overseas; the National Shipbuilding Research Program administered by MarAd; and programs conducted by other service industries. Summaries of the committee's reviews of each are given in succeeding sections, and the committee's analysis concludes the chapter.

SHIP OPERATION RESEARCH AND DEVELOPMENT OVERSEAS

Some research organizations overseas conduct or monitor projects and others advise appropriate government departments. The Netherlands Marine Research Institute MARIN conducts research and development, for example, the U.K. Ship and Marine Technology Requirements Board advises.

Some ship operating companies overseas carry out R&D with their own funds, and they also participate in collaborative R&D projects. Shipping and shipping services (banking, brokering, and insurance) also provide so significant a contribution to the gross domestic product of these countries (especially in Norway and the United Kingdom) that government aid supports shipping R&D programs as part of a national strategy to enhance the nation's competitive position in shipping.

Some overseas ship operation R&D is highly centralized (at MARIN in the Netherlands, for example), some is less so (Trondheim, Bergen, and Oslo, Norway), while some is fragmented (Germany and the United Kingdom).

Most major shipping companies in northwest Europe and Japan employ R&D personnel. Very little ship operation R&D is done by contract, and in such cases, is performed by universities or government-funded research institutes. In all the countries examined, managers of all levels help select and monitor the progress of R&D programs. This is true of industrial research (in all countries), of research laboratories (in Japan), and advisory organizations in the United Kingdom and Norway).

The existence of a single and active shipowners association in each of the countries examined (and of only one or two national maritime labor unions) allows the R&D results of any one company to be conveyed to all associated members. The collaborative research of shipping companies in these countries, it should be noted, is not threatened by antitrust legislation.

Dissemination and application of research findings is achieved throughout northwest Europe and in Japan in a number of other ways as well. Informal and very active networks exist among the people engaged in R&D in the various companies, in research centers, and in universities and institutes, especially in Norway where the institutional relationships overlap. In all the overseas programs reviewed, managers and seafarers are actively involved in the research itself or in evaluating and monitoring research proposals. Some national institutions (e.g., the Ship Support Unit of the U.K. National Maritime Institute) are specifically directed to publish and to hold seminars on their R&D results.

Norway has developed a particularly effective mechanism for disseminating R&D results. When a project with widespread implications is initiated (e.g., on the causes of collisions and groundings), a heirarchy of committees is established. At the working level, a project committee is formed of leading researchers and primary sponsors. The project committee reports to a steering committee representing the organizations most immediately affected by the results (e.g., the government department of marine safety, labor unions, and the shipowners' association). In turn, the steering committee reports to a hearing committee, the membership of which is open to any institution that may have an interest in the R&D topic (the Navy, the Department of Education, pilots associations, harbor authorities, welfare organizations for seafarers). The long-term benefits of such hearing committees is that the problems facing ship operators and proposed solutions are heard by a wider community, and one whose support may be needed in making changes.

Succeeding sections review the content and structure of ship operation R&D overseas.

Program Content

Much of the ship operation research conducted overseas is multidisciplinary, combining engineering, behavioral science and economic analysis. For convenience of comparison, engineering and behavioral science research are summarized separately.

Engineering

Since 1970, research and development in all the countries of the committee's sample concerned bridge design and bridge operational procedures. Since 1975, R&D has increasingly focused on fuel quality, fuel efficiency, and energy conservation.

Engineering attention has also been directed to ship handling in heavy weather; lifeboats, survival craft, and launching methods; ship boarding and access systems; hazards of shifting cargoes; machinery failures; technical requirements for ships of the future; engine control and surveillance systems; marine traffic control and routing; monitoring of ship performance; shipboard computers; cargo operation; and berthing.

Behavioral Sciences

The main topic of behavioral science R&D, especially in Scandinavia and the Netherlands, has been organizational change aboard ship: reduced manning and new working practices. The earliest experiments of this kind were conducted on the ships of Leif Hoegh of Oslo, followed by further experiments in other Norwegian companies by the staff of the Norwegian Work Research Institute and monitored by the Norwegian Shipowners Association. In Sweden, Denmark, the Netherlands, West Germany, and Japan, reduced manning projects are mainly conducted in-house, but in close cooperation with labor unions, shipowners associations, and government departments responsible for ship safety.

Other behavioral science programs study the attitudes of seafarers to their employment; the seafaring career; manpower supply and demand; training for service in technologically advanced ships; health and medical aspects of seafaring; and the management content of seafarers' jobs. The comprehensive "Sealife" project in the United Kingdom simultaneously investigated organizational change, recruitment, career development, wages and rewards, and the involvement of seafarers in ship design. In addition, many bridge simulators in Europe and Japan are now also used in behavioral science research.

As noted, a number of overseas projects in ship operation combine engineering and behavioral science R&D; examples are those aimed at designing, building, and operating technologically advanced ships manned by nontraditionally organized crews--the Baff Project in Sweden, the Netherlands' Ship '80 Project, Japan's Super Rationalized Ship Project, and Norway's Ship Operation of the Future. In many cases, these so-called sociotechnical projects use experimental ships in action research.

Other sociotechnical R&D projects treat the causes of collisions and groundings, the safety of advanced ships, human factors in ship accidents, marine rescue, and maintenance.

In summary, the content of ship operation R&D overseas has focused on the following:

- Fuel technology and energy conservation
- Effective manning, that is, developing the technical and organizational requirements of ships of the future, especially through action research.

Program Structure

Funding

A substantial amount of ship operation R&D overseas is funded in whole or part by government. Funding arrangements can be grouped in three broad categories by source--government, industry, and joint industry and government.

Government Funding

Government Marine Research Facilities Norway, Sweden, the Netherlands, and the United Kingdom have test tanks and cavitation tunnels (used primarily for research on hull forms and propeller design). Additional facilities are clustered around these base research facilities--in Norway at Trondheim, in the United Kingdom at the National Maritime Institute, and in the Netherlands at the Netherlands Organization for Applied Scientific Research, Toegepast Naturweenschappelijk Onderzoek (TNO). TNO is the largest government-sponsored research organization in the Netherlands. The principal research facility is at Wageningen. Facilities are at or near universities in Norway (Norges Technikse Hogeskole, or NTH, in Trondheim) and Sweden (Chalmers University, Gothenburg). Fundamental hydrodynamic research at these facilities is entirely funded by government.

Government Funding of R&D Projects at Other Institutions Governments occasionally sponsor R&D pertinent to safety or to the exports of their shipyards and equipment manufacturers. These projects are carried out by contractors or universities with complete government funding. Examples are:

- Bridge design and development of a bridge design code of practice (United Kingdom)
- Lifeboats, survival craft, and launching methods (Norway)
- Hazards of shifting cargo (United Kingdom)
- Ship boarding and access systems (United Kingdom)
- Safety of the sociotechnically advanced ship (West Germany)
- Attitudes of seafarers to their employment (United Kingdom)
- Human factors in ship accidents (United Kingdom)

The German Research Foundation (Deutshe Forschungsgemeinshaft, or DFG) funds and directs basic maritime research. Applied maritime projects are funded by the Department of Research and Technology (der Bundesminister fur Forschung und Technologie, or (BMFT). According to the federal constitution, individual states (lands) may also finance marine research through the state departments of education and science.

Germany recently established the Project Council for the Ship of the Future (Schiff der Zukanft) formed of members drawn from shipping companies, shipyards, equipment manufacturers, and government and attached to the BMFT. Fifty R&D projects are now in progress under the aegis of the council. A separate government-funded council, hosted by Bremen University, will investigate manpower issues for the ship of the future.

Government and Industry Funding

Commercial Contracts at Government Marine Facilities All the government marine facilities carry out research for their own and foreign shipyards, shipping companies, and equipment manufacturers. The Netherlands Organization for Applied Scientific Research in Wageningen, for example, is testing the extended hull forms designed by Matson Navigation Company of San Francisco. Most commercial contracts are for testing vessel designs, but some concern ship operation. For example:

- Ship maneuvering (United Kingdom and Norway)
- Simulators for ship handling (Netherlands)
- Instrument displays (United Kingdom)

Government and Industry Funding of R&D Projects at Other Institutions This form of R&D funding is by far the most common overseas. In the Netherlands such projects are centralized at the Netherlands Marine Research Institute MARIN, which is a separate company funded by shipowners, shipbuilders, and government (through TNO), with representatives of all three parties on the Board of Directors. The research staff is on MARIN's full-time payroll. This arrangement has the advantage of enabling continuous exchanges of ideas among researchers in different fields, and multidisciplinary efforts to solve problems of ship operation. This advantage might be enhanced if MARIN were close to a university. Although the Dutch government may provide initial funds, no project is continued unless 50 percent of needed funds are obtained from industry within 18 months.

The Swedish Ship Research Foundation was established in 1955 by Swedish shipbuilders who then provided complete funding. In 1970, Swedish shipowners began providing half the funding, and the government later joined as a third partner. Most of the foundation's research, which centered on technical and engineering problems, was carried out at the Chalmers University research facility. The foundation was disbanded in 1979, but some fundamental research is still conducted at Chalmers, funded entirely by the government.

In Norway, ship operation R&D is centralized by subject: technical projects are undertaken at Trondheim (NTH), economic projects at Bergen Commercial University, and social projects at the Work Research Institute in Oslo. Industry support consists more of in-kind services than funds.

Examples of joint R&D projects in ship operation include:

- Bridge design (West Germany and Sweden)
- Ship handling in heavy weather and hull surveillance systems (Norway)
- Causes of collisions and groundings (Norway)
- The ship of the future (West Germany)
- The "Ship '80" project (Netherlands)
- Engine monitoring and fuel efficiency (Norway)
- Bridge and engine simulators (United Kingdom)

Industry Funding

In reviewing the R&D funded by industry, it should be remembered that in addition to operating ships, all the countries in this survey build ships and marine equipment for export. A significant proportion of marine R&D in these countries is concerned with these exports. Thus, "industry" includes ship operators, shipyards, equipment manufacturers, and the classification societies, especially in Norway, where the four types of enterprises are closely linked.

Central R&D Facility Funded by Industry In the United Kingdom, the British Ship Research Association (BSRA) was completely financed by the shipyards and shipping companies before British shipbuilding was nationalized. BSRA still conducts R&D projects in design and operation on behalf of its members and under contracts for others.

The Swedish Ship Research Foundation has been described. The best example of an existing research facility completely funded by industry is the databank on machinery failures and repair times maintained by the Swedish Shipowners Association. All member companies submit reports of machinery failures and repair times, and in return receive such information from other members. They can thus determine how their experience varies from the norm or that of other shipowners. The databank also allows them to approach a manufacturer together when an item appears to be defective in many ships.

Another example is Det norske Veritas' central laboratory, established at the behest of Norwegian shipowners, to monitor the quality of bunker fuel.

Collaborative R&D Projects Undertaken and Funded by Industry Shipowners associations in the countries considered by the committee have undertaken research from time to time on issues of universal concern to members; for example:

- Manning the technically advanced ships of the future (the BAFF project conducted and financed by the Swedish Shipowners' Association)
- The seafaring career, with particular reference to wastage (funded by the British Shipping Federation, now the General Council of British Shipping, the GCBS)

- The "Sealife" project (funded by the GCBS)
- The management content of the jobs of ships' officers (funded by the GCBS)
- Manning and organizational changes in Norwegian ships (originally the experiments of Leif Hoegh, previously noted, and later of the Norwegian Shipowners Association).

Projects of Individual Companies Projects that originated as in-house research by individual shipping companies and that later affected other national carriers include the Leif Hoegh experiments, and in addition, projects addressing:

- Organizational change. The important experiment of Jebsens in the United Kingdom resulted in more effective manning and organizational change both aboard ship and ashore. It stemmed from the work of its parent company in Norway and from the United Kingdom's "Sealife" project. This experiment also affected a U.K. seafarers union (Dawson, 1978).
- Decentralizing operation. This project of DFDS in Denmark fundamentally changed the allocation of duties between sea and shore staff, drastically reducing the latter. Although it originated as an in-house project, it had important consequences for all companies (both Danish and foreign) attempting to reduce labor costs. DFDS is now offering a consulting service, Danaconsult, to help other companies decentralize shipping operation (Dawson, 1978).
- In the Netherlands, Shell Tankers BV has embarked on the long-term project PLA (Project With the Long Breath) aimed at more effective manning.
- Also in the Netherlands, van Nievelt Goudriaan has embarked on project PROVO in collaboration with MARIN. Both the Shell PLA project and PROVO have long-term consequences for Netherlands shipping, labor unions, and educational systems.
- In Sweden, Brostroms of Gothenburg has studied more effective manning by reallocating tasks in engine maintenance between ships staff and engine manufacturers. The experiment will affect Swedish shipping companies and shipyards and engine manufacturers both in Sweden and abroad.

Projects of Labor Unions The only union-funded project the committee found was one initiated by the National Union of Seamen for unlicensed seafarers in the United Kingdom. Conducted by the staff of the Tavistock Institute of Human Relations, the project studied how the union should be organized in response to future changes in shipping.

Industry R&D Advisory Boards

The committee's review of industry advisory groups for foreign maritime R&D was limited to cooperative R&D programs in which government is the sole sponsor or a partner with industry. (Cooperative research programs involving shipping companies only, or initiated by individual shipping companies, is discussed in the preceding section.)

In the absence of government participation, cooperative R&D is conducted within (or sponsored by) shipping councils or trade associations and overseen by ad hoc or standing panels drawn from their member companies. No case is known of intraindustry cooperative R&D that was overseen by any group or individual outside the host trade association.

"Industry advisory groups," then, provide advice on R&D programs in which the government participates as the sole sponsor or as a partner with industry, and for which industry oversight is provided by a group that has members representing interests other than those of the organization performing the R&D.

The committee reviewed the structure and function of a number of maritime industry advisory groups that fit this description in Canada, West Germany, Norway, the United Kingdom, the Netherlands, and Japan. A brief summary is provided in succeeding sections.

Industry Advisory Groups, by Country

The Marine Advisory Board advises Transport Canada, which acts as the lead agency for a number of government research contributors (much as the Committee on Marine Structures of the National Research Council supports the Interagency Ship Structures Committee of the United States). In Norway the Ship Research Committee of the Royal Norwegian Council for Scientific and Industrial Research (Norges Teknisk Naturvitenskapelige Forskningrad, NTNF) advises several sponsors of government and industry maritime research. In the United Kingdom the Ship and Marine Technology Requirements Board advises the Department of Industry. In Japan the Japanese Ship Research Association (sponsored by industry and government) is directed by a board of industrialists. The Japanese group is unusual in that industry advice is given by the same people who are responsible for the operation of the intramural research facility itself. In this respect they are 'external' only with respect to government involvement in partial funding of the research center. A similar arrangement was tried for the Netherlands Organization for Applied Scientific Research (TNO), the largest government-sponsored research organization in the Netherlands and the principal ship operation research capability in that country. Through the organizational structure of institute boards, TNO attempted to combine responsibility for oversight of research projects (responsibility for the operation and continuity of TNO's intramural research program) with the function of bringing new ideas and industry guidance to the organization. The attempt resulted in some conflict for the institutes' boards in ensuring that the needs of the industry and those of the institutes are met. TNO is now in the process of establishing industry advisory committees that will have no responsibility for the operation and continuity of the institutes they advise.

Scope

The foreign maritime advisory groups are not oriented exclusively to ship operation. The Canadian board considers the research needs of three primary components of the "maritime industry" (ship operation, shipbuilding, and ports and terminals operation). Norway's Shipping Advisory Committee, on the other hand, is concerned only with ship operation and ports and terminals operation. Under Norway's NTNF structure of advisory committees, shipbuilding is the responsibility of another group. A similar situation exists in Japan, where the board of the Japanese Ship Research Center advises on topics of ship operation and ports and terminals, while the shipbuilding industry is the concern of another research institution that has its own industry advisory group. In the United Kingdom, shipbuilding and ship operation are covered by the Ship and Marine Technology Requirements Board.

Functions

For their continuing program of ship operation research, Germany's Department of Research and Technology has no intermediary or external advisory group. Although the department occasionally uses committees of outside experts to act in an advisory capacity to the agency staff (such as the Project Council for the Ship of the Future), most research management and decision making is handled directly by the sponsors and the contracting researchers or research organizations. This sort of arrangement seems to be unique to the United States and Germany.

All the industry advisory groups reviewed by the committee recommend research in engineering, and some also advise and oversee research in the behavioral sciences or economics. Their latitude in making recommendations is usually limited to the sort of projects that the research institutions or sponsoring organizations are chartered to support. In Canada, for example, the Marine Advisory Board's scope clearly excludes research on general marine policy, tariffs, subsidy, and planning, unless the proposed project has significant technical content. The Ship and Marine Technology Requirements Board of the United Kingdom recommends no research in economics and comparatively little in the behavioral sciences. The board has recently become an executive committee of the Mechanical and Electrical Engineering Requirements Board, and its engineering focus has been sharpened by the Department of Industry's concern with the development of exportable products.

All the industry advisory boards considered by the committee are concerned with safety in ship operation and environmental protection, and productivity. Only in the recent reorganization of the United Kingdom's Ship and Marine Technology Requirements Board has the concern for safety been relegated to another group--safety is now a function of the Department of Transportation, which is not a sponsor of the board.

The most general function of the maritime research industry advisory groups is to provide an external source of direction and evaluation for research programs funded by government or by government and industry. A common function of such boards is the periodic definition of critical issues within the maritime industry, which guides the development of long-term research plans or programs. Only the United Kingdom's Ship and Marine Technology Requirements Board does not perform this function, as it is a specific responsibility of its parent organization, The Mechanical and Engineering Requirements Board. The groups all draw up short-term research plans and corresponding budgets. They all initiate requests for research proposals and evaluate responses; some monitor research and disseminate results.

Structure

The membership of the foreign advisory groups generally includes industry representatives (labor and management), researchers, and government representatives, with the industry participants most numerous. The chairmen are usually from industry.

With one exception--Norway's Ship Research Committee--the foreign maritime research industry advisory groups are hosted in some fashion by the government agencies or the research institutes they advise. The agencies or facilities provide a staff and budget to support the advisory groups. Only Canada's Marine Advisory Board seems to be without a supporting staff. Norway's Ship Research Committee is not hosted by a government agency or research institute, but is a unit of the Royal Norwegian Council for Scientific and Industrial Research (Norges Teknis Naturvitenskelige Forskingrad -- NTNF).

NTNF is Norway's principal organization for determining research needs, collecting funds, and directing research, with the goal of advancing and implementing technical, industrial, and related research in Norway. NTNF and the National Research Council are both chartered by their governments as independent institutions established to further science and technology, and both accomplish their advisory role through standing and ad hoc committees. The differences between the two organizations are in their involvement in research activities. The National Research Council reports the status and prospects of scientific knowledge on technology pertinent to policy decisions, and the NTNF provides both technical and scientific advice and research services.

Other Structural Features of Ship Operation Research Overseas

Most of the large shipping companies overseas have R&D personnel in their employ. In some cases, these employees have other duties; in others, they make up an R&D department, or operate as a self-supporting subsidiary that conducts R&D for the parent company and other clients. Irrespective of how they are organized, shipping company employees engaged in R&D interact with one another in the course of their work, and with researchers in government facilities, institutes, and universities. In Norway, the network of communication is particularly strong owing to the close relations and exchange among shipping company managers and researchers in the shipping research institutes. In the U.K., this network extends to practicing seafarers. The National Maritime Institute has a Ship Support Unit staffed by seafarers who guide research applications through appropriate funding arrangements, and monitor research progress.

Governments play an active role in stimulating R&D in all the countries examined. Again, a significant part of marine R&D is stimulated by the prospects of exporting ships and equipment.

THE NATIONAL SHIPBUILDING RESEARCH PROGRAM (U.S.)

The Merchant Marine Act of 1970 created a research program in which industry and government collaborate to improve the productivity of the shipbuilding industry. The National Shipbuilding Research Program (NSRP) has been rated one of the best governmental efforts to foster innovation through joint participation of government and industry (BAER, 1976). For this reason, and because the program has generally received high marks from the industry, it might serve as a model in restructuring the current program for ship operation research. The following sections describe important characteristics of the NSRP in this regard. The chapter, "Analysis" considers the applicability to ship operation of those aspects that seem most salient to this program's success.

Program Content

The NSRP attempts to improve the shipbuilding industry's productivity by investigating and initiating more economical and efficient ship design and construction. The NSRP's activities in its early years were directed to organizing the program, defining its scope, and conducting low-risk projects with a single application (for example, in welding). The program has recently emphasized large-scale projects (for example, product-oriented work-breakdown structure).

Program Structure

The premise for forming the NSRP was that the shipbuilding industry's methods could be best improved by joint participation of the interested parties. Government would provide the initial funds for projects carried out by co-sponsoring shipyards, while the industry would select most of the projects based on its own needs. The cost of the NSRP is shared by MarAd and the shipbuilding industry. Such cost-sharing of research by government and industry was not new when it was proposed, but had not been employed so extensively by commercial shipyards.

The Ship Production Committee of the Society of Naval Architects and Marine Engineers (SNAME), formed in 1969, was tapped to serve as the forum for exchange of information among the communities interested in the NSRP, to coordinate and plan research programs, and to ensure a solid technical base for direction of the research program.

The Ship Production Committee plans and selects shipbuilding projects through both full committees and subcommittees or panels, while the program's sponsors evaluate funding priorities. The sponsors are MarAd's Shipbuilding Research Program Office (part of its Office of Research and Development), the Naval Sea Systems Command (since 1982), and senior representatives from the larger domestic shipyards. Shipyard project personnel carry out the studies, tests, demonstrations, analyses, and dissemination of results.

The specific technical panels of the NSRP and their sponsoring yards are shown in Figure 2. The panels are composed of technically qualified personnel from each sponsoring shipyard and range from a few to as many as forty members. Representatives from MarAd and certain classification and regulatory agencies also serve as panel members when deemed appropriate. The panels meet at least quarterly, reviewing industry needs for new and ongoing research. New projects are recommended and approved by an annual budgetary process in which the panels, the Ship Production Committee, and the sponsors participate.

MarAd's Shipbuilding Research Program Office, composed of a director and assistant, funds and monitors projects that the Ship Production Committee submits. Project funds are budgeted to panel areas: facilities, manpower, motivation, ship productivity, and shipyard automation. The Shipbuilding Research Program Office functions primarily through jointly funded shipyard program and project managers who serve the panels and carry out some of the research.

Approximately 150 projects, about 75 percent of those recommended by the Ship Production Committee, have been funded through the NSRP in the past 10 years. The government's share of the costs has been approximately $25 million. The cost share of the shipyards in these projects, however, totals only 0.02 percent of shipyard revenues, which is far below R&D expenditures of other industries.

Dissemination of information by the project has taken the form of on-site demonstrations to other industry representatives (judged the most effective), briefings, and written reports (judged the least effective). From 100 to 200 industry representatives have participated at their own expense in the demonstrations of successful projects. This is an important indication of the NSRP's industry following. It is also an indicator that government and industry can collaborate successfully in such industry research.

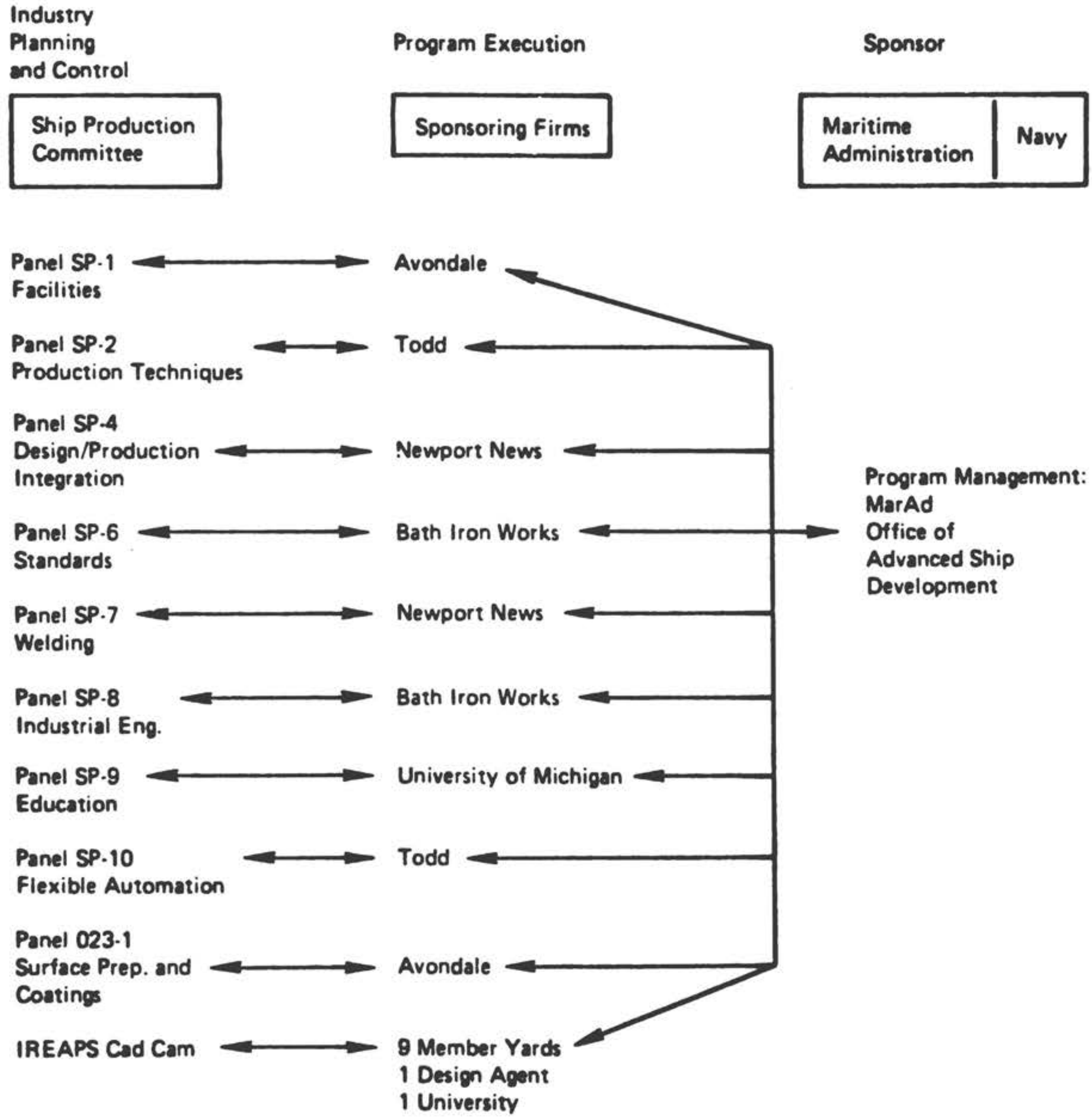

FIGURE 1. National Shipbuilding Research Program

Shipyard managers were concerned when the program was initiated that the federal government would use it to influence or dominate the shipbuilding sector. As the program got under way, the role of the industry in defining and carrying out projects, while sharing their management with the Shipbuilding Research Program Office, allayed this concern. The involvement of top levels of management ensures that the projects of greater interest are pursued, and that the results are expeditiously applied.

Competition among the shipyards was an important issue in the early stages of the program that was decided by the yards' agreeing not to discuss pricing or costs. The gains realized through collaborative research and development eventually eased reservations respecting the proprietary information companies are concerned to protect.

The Program's Growth

As the NSRP has evolved, it has grown to encompass two other technical groups: the Shipbuilding Standards Program and the group on computer use (CAD/CAM)* of the Institute for Research and Engineering for Automated Production of Ships (IREAPS).

The Shipbuilding Standards Program helps develop shipbuilding standards for the American Society for Testing and Materials (ASTM). Such standards include those for industrial engineering methods and practices in shipbuilding, including computerization, advanced production methods (especially outfitting, dimensional control, and production planning), improved welding techniques, improved methods for surface preparation and coating, and improved standards for facilities.

The IREAPS group is linked to a project panel of the NSRP, but functions somewhat differently. It requires a 50 percent direct share of costs by participating yards, and its projects are jointly controlled by the sponsoring yards and MarAd. Now incorporated (April 1981) as the Institute for Research and Engineering for Automation and Productivity in Shipbuilding, IREAPS can enter into contracts directly. It is headquartered at the Illinois Institute of Technology.

OTHER INDUSTRY RESEARCH PROGRAMS (U.S.)

In reviewing other programs of research and development, the committee examined those of non-maritime transportation and public utilities. These industries share with the ship-operating industry provision of a service rather than a product. The industries selected by the committee are the air cargo, motor carrier, and railroad

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* Computer-Aided Design/Computer-Aided Manufacturing

transportation, and public utilities. The R&D programs of these industries that the committee judged to provide useful analogues are those of the Air Transport Association; Air Cargo, Incorporated (ACI); Aeronautical Radio, Incorporated (ARINC); the American Trucking Association; the Association of American Railroads (AAR); and Electric Power Research Institute (EPRI).

In addition to the preliminary criteria for selection, the committee developed a list of critical distinctions to guide comparison and contrast of these industries' R&D programs, and to guide judgment about the applicability of any of their features to an R&D program for ship operation in the United States. Keeping these distinctions in mind also helped the committee wade through a great deal of information without losing sight of its objectives in the vast sea of fascinating particulars. These distinctions are:

- The degree of interdependence within the industry, that is, the degree to which the actions of one company affect other members of the industry (for example, through exchange of rail cars among railroads and through regional grids among utilities).
- The competition within the industry, that is, the degree to which an individual company could gain a competitive advantage through proprietary research and development. (There is almost no competition within the utility industry, for example, while there is heavy competition within the motor carrier industry.)
- The extent of fragmentation within the industry, that is, the extent to which the industry specializes by identifiable groups. (For example, the AAR is almost alone in representing the railroad industry; in the electric utilities industry, three major associations represent private, municipal, and user-owned utilities; while a great number of groups represent the motor carriers and their owners and operators within and without the American Trucking Association.)
- The number and size of the companies in the industry. (For example, the motor carrier industry is composed of a large number of relatively small companies, the utility industry of a large number of relatively large companies.)
- The amount of R&D support that vendors provide for an industry and the average life of an industry's physical assets. (For example, airframe manufacturers develop successive generations of aircraft for airline operators, and truck manufacturers continually improve trucks for motor carriers.)

As in the review of ship operation research overseas, the review of research in the nonmaritime U.S. industries will be presented in some detail. A summary of the review is therefore provided.

The nature of these organizations and the support they receive for R&D varies: EPRI and ARINC Research Corporation are independent organizations that receive millions of dollars annually for research. The Research and Test Department of the AAR is a well-funded, permanent unit of a national assiciation; the committees of the American

Trucking Associations and Air Transport Association are funded informally, and ACI receives almost no support for R&D. The amount of funding provided by the federal government ranges from none (Air Transport Association, ACI, American Trucking Association, and EPRI) through an appreciable amount (AAR) to the greatest part of the R&D budget (ARINC Research).

The percentage of research conducted by the organizations themselves also varies--about 16 percent by EPRI, 50 percent by AAR, and 100 percent by ARINC Research.

A striking similarity in the centralized R&D programs of these organizations is their criterion of industry-wide importance for the projects they undertake. Individual companies in the industries they serve conduct R&D in their own interests. Another similarity interesting to observe among so many differences is that the industry-wide R&D of all these organizations indicates a recent and pronounced shift to shorter term projects that will lead to immediate applications. Industry sponsors and research managers frequently stated that centralized R&D can and must be turned to immediate problems as well as to long-term, high-risk projects that promise high returns.

Program Structure

Organization

In each of the transportation industries examined, centralized research is conducted by a unit of a national organization. The research organization for the electric utilities is an independent entity.

EPRI and three of the national organizations for the transportation industry -- Air Transport Association, ARINC, and AAR -- are highly centralized. ACI is somewhat decentralized, with 11 geographically determined directorates, but has strong central guidance. The American Trucking Association is highly decentralized, with several separate and nearly independent organizations: 8 professional councils, 13 functional conferences, and 51 state associations.

None of the organizations has direct government or labor participation on the board or in management, through either funding or representation (distinguishing *ex officio* direction from research sponsorship and official contributions to policy from informal contributions to program content). All function with the active participation of senior management and professional staff from their supporting industries.

The organizations also vary regarding research staff and standing research committees. Air Transport Association and ACI have neither formal research staff nor such committees. The first is governed by five councils, each conducting research *ad hoc* as required. ACI conducts little research, and what it does conduct is funnelled through corporate management.

The American Trucking Association has a research staff of 18, but no specific research committee. The research staff is responsible to the association's management. In addition, the association's councils, conferences, and state associations sponsor some research independently of the national organization. At least one of the conferences and one of the state associations have had their own research committees and full-time research staffs.

ARINC and AAR have full-time, well-staffed research activities and formal organizations for industry oversight of research. ARINC established ARINC Research Corporation as a division in 1946, and incorporated it as a subsidiary in 1958. The board of directors, which represents the industry stockholders, is actively involved in both ARINC and ARINC Research. The AAR has seven departments, and conducts most of its research through the Research and Test Department. The Economic and Finance Department, the Management Systems Department, and the Executive Department also conduct some research. A formal Research Committee of the Board of Directors oversees the research program. All major railroads are represented on it, as are small railroads, suppliers, and government (represented by the associate administrator for research and development of the Federal Railroad Administration). As an organization devoted solely to research, EPRI has both a large research staff and a formal structure for managing research.

Industry Participation

Industry participation is a key element in the R&D of all six organizations. Senior management and senior staff from the client industry are represented at various levels in the organizations (except in ACI, which is a cooperative operating venture).

The Board of Directors of Air Transport Association consists of the chief executive officers of twenty airlines. Other senior management representatives are on each of the five councils, and representatives of the carriers serve as chairmen. AAR is organized similarly: its board of directors is composed of chief executive officers of the member railroads. A member of the board serves as chairman of each of the board's committees, and these are staffed by senior management from the member railroads. The Research Committee establishes a five-year research program and provides support to individual railroads for specific projects. Members include representatives of marketing, operation, and finance, as well as technical fields.

ACI is a corporation whose stockholders include most of the scheduled airlines in the United States (29 airlines). Representing the stockholders, the board of directors elects officers at annual meetings. Thereafter, the board monitors management's performance through monthly meetings.

ARINC is a nonprofit corporation whose stockholders must be aircraft operators. (Foreign, helicopter, and commuter operators may not purchase more than 10 shares; scheduled and corporate business operators may purchase any number of shares up to but less than one third of those issued.) The 17 board members represent 55 stockholders. As in the case of ACI, industry participation is funnelled largely through the board.

As noted, the American Trucking Association is highly decentralized, as is industry participation, but it is also complete. Industry is represented on the board of directors, the councils (corresponding to professions within the industry), the conferences (corresponding to various motor carrier divisions in the national association), and the state associations.

Of the six organizations, EPRI has the greatest participation of industry. Representing the utility sponsors is a fifteen-member board of directors supplemented by two large advisory groups: the Research Advisory Committee, drawn from utility research, engineering, and operating departments; and the Advisory Council, drawn from education, business, government, science, and from other organizations outside the industry. The Research Advisory Committee provides technical counsel, while the Advisory Council determines the emphasis and direction of the research program. In addition, EPRI has formed division review committees and task force review committees. The chairman of each task force committee participates in division review, and chairmen of division review committees serve on the Research Advisory Committee. Altogether, about 600 members of the industry contribute to EPRI research during the course of a year.

Program Planning

In all six organizations, the content of research is determined or strongly influenced by industry representatives. Senior management and technical personnel from the sponsoring companies review, recommend, and sometimes decide which projects will be funded, usually through participation on standing committees or advisory councils. The origin of the candidate projects for research, however, varies widely.

Both AAR and EPRI have formal multiyear research and development plans. In both, plans are developed by permanent staff in close cooperation with industry advisors. Input to the AAR plan and suggestions for individual projects not covered by the plan are generated throughout the AAR organization: the board, the Research Committee, the Federal Railroad Administration, the suppliers, and the permanent staffs in the various departments. The EPRI process is as formal and broad. One-year and five-year plans are established by the staff, and reviewed and revised by various levels of committees, whose endorsement is required.

The source of research projects in the Air Transport Association is diverse, but the process of developing new projects is informal. The need for research (which may originate from a member of the board, the staff, government, or someone in the private sector) is made known to the president or executive vice president, who turns the matter over to the appropriate council for assignment to a committee. Studies are conducted by committee members (and the additional expertise of their companies' staffs), staff members, and outside sources when particular expertise is not found in the association. ARINC operates in much the same way. Suggestions for research come from stockholders, industry members, and representatives of government. ARINC management reviews these, and decides which R&D projects will be conducted in house and which by ARINC Research.

Most of the research conducted by the American Trucking Association's research group originates from its national level leadership or from one of the councils. The association's research is not centrally coordinated; the councils and other participating organizations are free to originate, sponsor, or conduct research as they see fit at any time.

Little research is undertaken by ACI, and in these occasional instances, solely on the initiative of corporate management (topics may be identified through suggestions from stockholders).

Program Content

As would be expected, the areas of research vary considerably from organization to organization. What little research is undertaken by ACI primarily concerns containerization, handling of materials, and road equipment. This research is usually done in conjunction with vendors and ACI's contract cartage agents. AAR and EPRI research programs on the other hand, cover a broad range of subjects.

The AAR Research and Testing Department not only has a large staff in Washington, but also a Technical Test Center in Chicago that performs technical analyses to support the certification testing of new designs of cars and components, the quality control checks on components and new materials, the analysis of field components, and lubricant testing. The department recently acquired the High-Speed Test Track at Pueblo, Colorado, from the Federal Railroad Administration. This will be used to test new concepts in car design and configuration of components. Four subject areas claim more than 70 percent of the department's budget (excluding the new Pueblo facility): train track dynamics, track, mechanics, and operation (including freight-car management). AAR also uses its R&D program to support its legislative functions, which are carried out by other departments.

The distribution of EPRI's budget by subject area is: power generation, 43 percent; environmental problems, 19 percent; delivery problems, 14 percent; fuels, 13 percent; energy management and conversion, 8 percent; and energy analysis, 3 percent. Increasing emphasis on short-term projects has resulted in a greater number of research projects directed to financial, environmental, and production problems, and fewer in the development and improvement of hardware (however, the 10 hardware development projects remaining require a greater financial commitment, and several expensive ones will run many years).

About 90 percent of ARINC Research's budget reflects its military contracts, and the remaining 10 percent contracts with other agencies (most governmental) and funding from the parent organization for research. The principal subjects of R&D are high-technology system design and development (a microwave landing system, for example), development and demonstration of automated management systems (a prototype marine terminal system), and development of standards for automating information exchange (in one project, between insurance agents and insurance companies). Major defense projects are undertaken in avionics, electronic warfare test equipment, command and control and communications systems, and aircraft and vehicle design.

The Air Transport Association's research budget is small, but the scope of its R&D is broad. Projects have recently been initiated or completed in aircraft control and guidance, navigation methods, air traffic control, aircraft certification, maintenance and airworthiness, fuel consumption, engine noise levels, flight schedules, airport facilities design, market forecasts, cargo containerization, road feeder services, handling of hazardous material, and statistical analysis of operation. Extensive use through committees of its members' expertise enables the association to support an ambitious program.

Almost all research conducted by the American Trucking Association addresses policy issues. About 40 percent of the budget goes to data collection and analysis, the balance to research supporting the association's state and national legislative programs. The ATA's Operations Council occasionally undertakes research in dock design, the use of drag lines, or a like subject of interest to members. In cooperation with vehicle manufacturers, the association's Engineering Department has studied topics such as flap design and brake systems.

As noted, the R&D organizations or departments serving these selected industries are moving to short-term research projects (one to three years). An estimated 20 percent of AAR's current research budget is devoted to very short-term projects (less than one year), and 30 percent to short-term projects. Increasingly frequent requests for short-term research have shifted the allocation of AAR's budget to in-house research for quick response. The association aimed to accomplish 50 percent of its R&D program through consultants, but the share is less than 40 percent.

Five years ago, only 40 percent of EPRI's R&D budget went to consultants, and the five-year plan specified 69 percent. The part of EPRI's budget devoted to long-term research has shifted from 20 percent 5 years ago to 10 percent today and 3 percent in the new five-year plan. The change in emphasis to short-term projects results from industry pressure through EPRI's committees for help with immediate problems--maintenance, land management, and energy conservation in addition to those mentioned in finance, environmental protection, and production. Industry is not as interested as it was in high-risk, long-term projects, such as fusion and magnetohydrodynamics, no matter how great their distant promise.

Program Structure

Funding

The annual budget for the Air Transport Association in 1981 was approximately $10.8 million. The first 7.5 percent of actual expenses incurred each year is apportioned equally among all members. The balance of actual expenses is apportioned to all members according to the cumulative revenue-ton miles of passenger, mail, and cargo each carries during that period. A small part of the association's budget is allocated to R&D, about 5 percent.

ARINC is a self-supporting organization. Profits go to the stockholders in the form of increased services. ARINC Research paid dividends of $400,000 to ARINC in 1979 and of $600,000 in 1980. Its 1982 sales are estimated at $128 million. More than 98 percent of sales are to government agencies, of which 90 percent are military.

The American Trucking Association's R&D budget for headquarters' staff is in the high six figures -- approximately five percent of the association's total budget. Each member firm is asked to contribute one-tenth of one percent of its gross revenues to the association, but these contributions are voluntary, and many members contribute less than the suggested amount. Additional funds are provided by affiliated organizations.

The AAR is funded by a percentage of the gross revenues of its member railroads. Historically, the amount has been about one-tenth of one percent. In 1980, about 30 percent ($10.5 million) of AAR's total budget was spent for R&D. Of that sum, approximately $8.1 million went to the Research and Test Department (research was also conducted by the Economics and Finance Department, the Executive Department, and the Management Systems Department). Additional funds are expended for R&D by the railroad supply industry, by the railroads themselves, and by the Federal Railroad Administration (FRA). In 1980, the suppliers contributed $4.2 million, the railroads contributed $4.8 million, and FRA spent $19.2 million. The AAR participated in most of the FRA program through joint projects, as a contractor to the administration, and as an adviser to its research program.

Since 1972, EPRI has started more than 1,700 research projects; 1,300 are now active (reflecting earlier emphasis on long-term projects). EPRI will contribute 63 percent of the total cost of all these projects (about $2.5 billion) and cosponsoring organizations the remainder. After a period of rapid growth, the EPRI budget has been relatively constant since 1979 (most of the dollar growth since that year reflects inflation). Each utility member contributes according to the amount of electricity it generates. EPRI's annual budget is about $265 million.

EPRI works closely with the federal government and large corporations, and will jointly fund contracts undertaken by outside organizations, but will not accept outside funds for its research.

Dissemination of Results

Even with the participation of several hundred industry representatives, EPRI's management considers the transfer of technology its greatest problem. For several years, the institute took what it now considers too simple a view: "If we produced good research results and wrote clear technical reports, the individual utilities would pick up the results and implement them." The concerns of management and the board for more effective methods of communicating the results of its R&D program led to a reorganization of the institute and creation of the Information Services Group in 1981. Transfer of results is now planned as part of each project -- as seminars, video tapes, special demonstrations, or in some other form. The results of each project are reviewed by the responsible task force committee at two-day meetings three times a year, and research applications program documents how the utilities use the results of EPRI's research. With the increased emphasis on short-term projects treating the industry's immediate problems, the institute considers its new emphasis on the transfer of results as important as the research itself.

AAR has had some problems in transferring research results, but they are comparatively few because of its size and the ties among industry members. AAR is also finding that its industry sponsors have increasing interest in the rigorous review and evaluation of its Research and Test Department's program.

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ANALYSIS AND DISCUSSION

A recurring question is why U.S.-flag carriers have conducted so little research compared with ship operators of other industrialized nations. R&D in the United Kingdom, Germany, and Japan has often been prompted by the vendors' and shipowners' concern to export marine equipment and ships. In Norway, R&D is driven largely by owners' and operators' concern to sell vessels on the secondhand market. In Denmark and Sweden, R&D is required for survival in the face of severe international competition.

None of these spurs for R&D has been operative in the maritime community of the United States. We do not build large vessels for export (although we export offshore service craft and marine electronics). We do not normally sell used ships (except to the government), and we have not, until recently, been concerned with positive initial balance of payments. A possible answer to the question is that operation differential subsidy and construction differential subsidy have cushioned U.S. operators from international competition, indirectly impeding R&D.

Recent government actions to discontinue subsidy programs may now stimulate industry -- both labor and management -- to reconsider the value of technological and organizational innovation. The following analysis and recommendations about ship operation research are offered in that light.

IMPLICATIONS OF THE STUDY FOR THE CONTENT OF U.S. SHIP OPERATION RESEARCH

A striking finding of the committee's informal survey of ship operators is the keen interest in research that addresses common industry problems (for example, increasing fuel costs and decreasing fuel quality.) An expected finding is the emphasis on engineering (as opposed to the ship operation research conducted by individual companies in the behavioral sciences or economics). This reflects the view of operators that the content of R&D is technology. But interviews with U.S. ship operators indicated that the industry's problems are not strictly or even principally technological. The prevailing view that R&D has only limited potential to help companies compete may result from the identification of R&D with engineering.

The committee's review of the R&D programs in other industries indicated a broadening of research interests to include economic as well as engineering topics, but review of overseas ship operation research revealed even greater scope of research and development interests. Other industrialized maritime nations concentrate on relatively large projects or programs to enhance the competitive position of their national-flag commercial fleets. The term "sociotechnical" is frequently used to describe the content of these projects that develop and experiment with innovative combinations of new technologies and nontraditional crew organizations. Ship operators in the United States have conducted comparatively little research of this kind.

It might be argued that the behavioral science research of the ship-operating industry in other countries is occasioned by unique apects of culture or politics, but it is also true that the unique characteristics of the industry itself--common to fleets of all nationalities--bring considerations of human resources to the fore. One such characteristic is the unusual working and living conditions of the industry's employees, and another is the high percentage of vessel accidents attributed to human factors. Finally, the cost of labor is very significant in ship operation. It is the variable that largely determines the competitiveness of a national or company fleet.

The reasons prompting sociotechnical maritime research in the industrialized countries of Europe and Asia are equally applicable to research in the United States. To remain internationally competitive, nations with highly paid, highly skilled mariners must develop new ways to capitalize on this characteristic of their maritime industries. Rather than viewing their high-priced manpower as a liability, these nations must consider new shipboard and shoreside organizations and management practices that capitalize on the comparatively greater skills of their crews and convert them to assets.

This strategy and research agenda are not unique to the ship operation industry, but apply for the same reasons to any industry that has high labor costs and that faces strong international competition. A six-year development project in Norwegian shipbuilding, one that involved nine yards and whose cost was shared by industry and government, was justified in the following way (Westhagen and Hotvedt, 1980, p. 18):

> If we presume that Norwegian shipyards will continue to build and equip ships and other steel constructions for maritime use, which of these factors [products, production technology, organization of human resources, or administrative systems] should be our prime objective in the endeavour to increase our competitive ability? Our answer is this: organization of human resources. Technology as such is international in character and easily transferred among countries. Not so with human resources. The possibilities of releasing the productivity potential of human resources depend much more on national conditions. Consequently, our relative competitive ability will primarily depend on how well we succeed in doing this. In our opinion, we have a good basis for this in Norway.

The general level of education is high, and relations between the main parties in economic life are comparatively good. Therefore, we should direct our efforts towards making the most of these advantages.

The technical component of needed ship operation research (as indicated by the committee's survey) remains important. This was emphasized for the committee in review of other industries' R&D programs addressing industry-wide problems, and the National Shipbuilding Research Program.

As a preliminary exercise in identifying R&D subjects of industry-wide interest that individual ship-operating companies could not likely undertake on their own, and that would likely be of equal benefit to the partners collaborating in them, the committee developed the listing shown in Figure 3. The listing is illustrative only: the committee's review of various R&D programs has repeatedly brought to light the importance of development and direction of the research and development program by the industries that will use the results.

COMPARISON AND CONTRAST OF R&D PROGRAMS: IMPLICATIONS FOR STRUCTURE OF SHIP OPERATION R&D

The committee found that U.S. ship operation research suffers four major disadvantages compared with its counterparts in northwest Europe and Japan.

1. The foreign countries examined export ships and marine equipment or are countries in which shipping and shipping services make significant contributions to the gross national product; thus, their governments readily support ship operation R&D.
2. These other countries do not appear to forbid ship operators from collaborating in research. In the United States, the fear of contravening antitrust laws may discourage ship operators from collaborating as do their competitors abroad.
3. There is just one shipowners association in all countries considered, but a number of such associations exist in the United States.
4. All other countries considered conduct ship operation R&D with the active participation of industry, including the participation of high-level industry executives.

The critical distinctions among industries that the committee took into account in review of the R&D programs of non-maritime industries in the United States can also be applied to the ship operation industry. Is there enough interdependence of the maritime industry for a given structure of R&D to offset the industry's current competition and fragmentation? Are the number and size of the companies in the maritime industry sufficient to support a large, centralized organization or arrangement for R&D? Is the maritime industry a

Table 2 Sample R&D Program for Ship Operations*

Areas of Investigation:	Use and Management of Fuel	Human Resources	Industry Response to Changed Statutes and Regulations	Performance and Standards Data
Research Projects:	Adaptation to fuels of decreasing quality Optimal use of fuels for given design and operating features Hull design Hull roughness Hull coatings Propeller roughness The power factor of main and auxiliary machinery Propeller design (retrofit) Slow steaming Purifying and clarifying various grades of fuel Alternative fuels	Analysis of reduced manning and organizational changes aboard ship Shipboard organization with redefinition of work assignments (inter-departmental flexibility) Implications of transferring tasks from ship to shore Psychological factors such as "habitability" and "quality of working life" aboard vessels Redefinition and reassignment of work in shoreside operation to complement shipboard changes	Hull and machinery design (e.g., efficiency of double-hulled barges) Management of emissions	Machinery failures (or successes) Data banks for maintenance and repair
	Standardization and Interchangeability of Equipment	**Human Factors Analysis**	**Vessel Movement**	**Cargo Systems**
	Lifesaving gear Hose connections Electric standards, especially for portable electric devices Bridge electronic devices Radio frequency assignments for communication and navigation Fire detection and firefighting gear	Design of control displays Crew performance under conditions of extreme motion, heat, noise, etc.	Coastal routing (traffic systems, routing around or through offshore drill rig areas, etc. Scheduling barges through locks and canals Approach and staging methods at berths, anchorages, locks, and canals Control of port traffic with and without the aid of vessel traffic systems Economics of tug-barge exchange systems (i.e., "drop, swap, stay") Updating regulations for entering and clearing (quarantine, etc.) Simplifying the documentation for entering and clearing	Devices and Systems for securing cargoes Refrigeration, ventilation, heating, and other arrangements for special-care cargoes Systems for hazardous cargoes Management of cargo space for carriers of petroleum and chemicals Vehicular exhaust sciences applied to ships Efficiency of discharging cargoes Measurement of liquid cargoes

Navigation

- Weather routing shoreside and aboard ship
- Restudy of navigation lights -- their characteristics, location, and potential simplification
- A common international language for pilots, towboat captains, and other vessel operators
- Ship discipline and management in channels

Training

- Analysis of the concept of sea-time equivalency
- Evaluation of training systems
  - Technology used in training (simulators, etc.)
  - Traditional training systems (schools and shipboard training)
- Advanced standards for shipboard medicine and emergency treatments
- Calculating and planning for trim and stability
- Control of damage and emergencies resulting from casualties

Communications

- Use of computers aboard ship and ashore
- Satellite communications and remote control

Measurement Technologies

- Discharge of oily water
- Steam flow
- Machinery power (main and auxiliary)
- Oil and liquid cargoes
- Hull stress
- Integrated use of the metric system

Mooring Systems

- Dockside, at anchor, through locks, and offshore

Marine Insurance

- Sensitivity of policies to technological improvements
- Cargo pilferage and injury of personnel

Security, Piracy, and Fraud

- Precautions against terrorists
- Precautions against piracy in congested waterways and anchorage sites
- Pilferage of cargo and documentary fraud

*SOURCE: Committee on Requirements for a Ship Operations Research Program market large enough to stimulate vendor research and development? Given the average life of its physical assets, can the maritime industry's problems be solved by vendor research and development?

The U.S. maritime industry is more fragmented than are those of the other U.S. transportation modes and public utilities and that of ship operators overseas. The U.S. maritime industry is divided by service (liner and nonliner operation, domestic and foreign trade), by offering (common, contract, and proprietary carriers), by vessel type (container, breakbulk, and dry-bulk types, tugs and barges, and tankers), by degree of government aid (subsidized and non-subsidized), and by other distinctions. More importantly, each of the other industries and the ship operators overseas have active core trade associations that represent most of their industry's revenue.

Of all countries reviewed, only the United States has multiple shipowner associations. This multiplicity impedes the coordination of an industry-wide program. The same problem results from the existence of multiple, rather than single, trade unions in the United States. Whether or not this fragmentation would prevent companies from collaborating in research is a question that cannot be answered in advance of the actual effort.

A feature shared by the ship operation and shipbuilding industry of the United States is their size and influence with their sup- pliers. The U.S. shipbuilding industry depends on a large framework of supplier industries, but has relatively little purchasing power. Shipbuilders spend more for steel than for any other material, yet their purchases total less than 2 percent of the total output of steel mills. Thus, shipyards lack economic leverage sufficient to drive research in steel production. Ship operators similarly lack leverage with their supplier industries. The major purchase for ship operation is fuel, but it is clear that ship operators have little control over the quality of fuel they buy. Other industries that have similar relations of economy and influence with their suppliers compensate for them by collaborating in R&D (as, for example, the use of the collaborative databank by the Swedish Shipowners Association to make representations on behalf of the group to manufacturers of defective equipment, and the independent tests of lubricants conducted by the Associaion of American Railroads).

Directing and Conducting Research

Need for Involvement of Industry Management

The review of research programs overseas suggests that their success depends critically on the degree to which companies -- both individually and jointly -- initiate, manage, and review them. All countries reviewed at minimum have industry advisory boards to direct multicompany and industry-government programs.

Review of other U.S. research programs also indicates that to be successful, a centralized R&D program must have the active support and personal participation of senior management from a large fraction of the industry (representing, for example, 97 percent of the industry's revenues at AAR, 70 percent at EPRI). Regardless of the impetus for a centralized R&D program, industry must be represented on the board of directors and committees. The success of the NSRP is frequently attributed to the oversight and direction of high-level shipbuilding executives on the Ship Production Committee. The commitment of top management is particularly important for large, multiyear efforts that have long-term returns. Participation by technical and line personnel in R&D projects may be a necessary but not sufficient condition for the program's success.

The only collaborative ship operation R&D program in the United States, that of MarAd, lacks an industry advisory panel and active participation of high-level management. MarAd has sought industry-wide evaluation of the program in occasional program-planning conferences or seminars on specific projects, but project initiation has been left to the agency's program managers, third-party consultants, and technical-staff representatives of the companies. Projects are often initiated by one or more of these parties, who then seek agreement from the others.

The government then provides funds to the contracting company for the project. The company helps manage the project and subcontracts the work to a consultant or consulting firm. Because the company generally has no large financial or manpower commitment, the project may be undertaken without the evaluation and continuing review of top management. The lack of direction from top management in U.S. ship operation research may have led to undertaking fewer multidisciplinary projects and fewer projects that focus on broad issues. This may explain, in part, why manning issues have not been successfully addressed in ship-automation research carried out in this country. Generally, this arrangement reduces the probability that the research topics of greatest importance to the larger community of ship operators will be selected, and that the results will be applied (even by the contracting firm). It may also explain why some projects undertaken by single companies with MarAd seem to be useful only to specific companies, and are difficult to transfer to others.

In short, based on our investigations and discussion, we feel that ship operation research in the United States has suffered principally for one reason--industry has not participated sufficiently in directing and managing research.

Dissemination of Results

To the degree that U.S. shipping companies share research results, they do so principally after the fact through professional society and trade meetings and the National Technical Information Service. The great majority of projects from which this information proceeds are carried out by companies on their own or in cooperation with MarAd's Office of Research and Development. The Ship Technical Operation Committee of SNAME is the closest equivalent in the United States to a collaborative (multicompany) program for ship operation research, but it serves principally as a forum for exchange of information about externally conducted research, and the society's budget for its Technical and Research Program is much too small to support substantial research at its own instigation.

For dissemination of results, several promising approaches were explored in the committee's review of other R&D programs: demonstrations, for example (as in the NSRP and sponsoring shipyards), or the integrated planning of the projects and dissemination of results practiced at the Electric Power Research Institute (EPRI).

Related Considerations

The lack of management involvement may be due in some measure to the structures of mature U.S. industries: chief executive officers are frequently trained in fields other than engineering, and financial and legal skills predominate in the boardrooms. This is especially true of management in shipping, markedly so in the subsidized sector. Since research is perceived to contribute only marginally to success, and its returns to be realized only in the long term, it is thought to have little value for a steadily declining industry in an increasingly political environment.

These characteristics of the U.S. ship-operating industry have led government and organizations peripheral to the industry (princi- pally consulting firms) to play well-intentioned but solitary roles, in the management of ship operation research. Because the public has a stake in the subsidized sector of the industry (and less directly in other sectors), MarAd has for many years sponsored research and development to improve the industry's efficiency and reduce the tax- payers' burden. In trying to help U.S. ship operators MarAd may have inadvertently discouraged them from doing more R&D on their own.

Legal Considerations

Although a collaborative program in ship operation research could be viewed as contrary to the provisions or interpretation of antitrust laws, the Section 15 Agreement of the Shipping Act of 1916 may provide a mechanism to overcome any obstacles. By means of Section 15 agreements, the Federal Maritime Commission recently allowed an exception to antitrust laws for a number of companies jointly exploring rationalization of Pacific routes (FMC Agreement No. 10,050-3). The character of this cooperative activity is much more sensitive to antitrust provisions than would be cooperative ship operation R&D. In addition to this shipping-specific provision, a number of government programs are directed at fostering cooperative industrial R&D.*

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*Bruce Merrifield, Department of Commerce, August, 1983. Personal communication.

Funding, Feasibility, and Value

The collaborative research organizations reviewed by the committee universally encourage and rely upon the internal capability of their industries to manage research. To the degree that responsibility and management are tied to ownership (and the connection is clear), industry funds the research. The contributions in funding by national governments are similarly proportionate with the industry's importance to the country's economy.

The results of the committee's review indicate that the U.S. ship operation industry holds a view of the limited utility of R&D. This attitude of industry reflects its concern with issues that it considers will not be solved by research. Nevertheless, the evolution of R&D programs overseas, of the National Shipbuilding Research Program, and the R&D programs of non-maritime industries briefly recapitulated in this report all indicate that such programs can be structured (and oriented in content) to provide significant help with the immediate problems shared by an industry; the first two mentioned give ample evidence that such a program can be developed for ship operation.

Over time, the focus of research may alter (e.g., from navigational safety, to fuel efficiency, to manning). Yet the efforts of others have demonstrated that collaborating parties have grown more competitive in international deep-sea shipping. Owners in Northwest Europe and Japan have demonstrated that they can collaborate in R&D to achieve results they could not realize individually (e.g., through shipowners' associations and the General Council of British Shipping projects on "Sealife," manning, and organizational change.)

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CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS

The over-all conclusion reached by the committee after its review, analysis and deliberation is that collaboration to address industry-wide problems can be effective, and that such a program can be instituted and sustained in the United States for ship operation. The value of collaborative R&D is recognized even in the high-technology industries where there might be greatest concern over a potential diminishment of competitive drive or innovative spirit. Witness the growing number of joint ventures in R&D within the electronics and aerospace industries (Behr, 1983). Collaboration in R&D is further indicated when the results of R&D challenge conventional wisdom as codified in legislation, regulation, or collective bargaining agreement. Individual companies and unions are less likely to successfully implement such findings than would a number of organizations jointly planning, sponsoring, monitoring and evaluating research. (The committee's key recommendation is described under "Proposal for a Ship Operation Research Center.")

The specific bases of the committee's over-all conclusion are:

- Common interest Some problems of ship operation are widely shared both by members of the industry and by industry and government (e.g., fuel and manning). The diversity of the U.S. vessel-operating community -- in geography, technology, and regulation -- could be taken into account in a cooperative research program by administering some funds through groups determined by their common interests.
- Expense of research Collaboration would distribute the expense of costly research.
- Transfer of information and technology These functions are better accomplished by a group than by individual organizations.
- Ease and speed of implementating research results These actions are likewise facilitated by a group.
- Avoiding duplication of research Because companies have problems common to their operating environments, separately undertaken R&D can easily lead to duplication. Of course, multiple efforts to solve a single problem can also be beneficial. But they are better undertaken within a structure that allows coordinated planning and the exchange of information.

The collaborative R&D program for ship operation needs to be developed by the participants. The committee's deliberations respecting the many R&D programs reviewed in this study suggested general criteria for the projects to be undertaken:

- Results should be of use to all vessel operators in improving operating systems and in helping to have and make full use of the most efficient devices and methods.
- Projects should address common problems and provoke minimal reservations about proprietary information.
- Projects should lend themselves to coordination and achievement through multiple companies contributing and relying on the central management of a small industry committee.
- Projects should be selected that have potential to reduce costs significantly, and are likely to produce results that can be rapidly tested, analyzed, and implemented.

Respecting the consequences of collaboration, the committee concludes that the recommended research program (described in a succeeding section) will result in gains to the ship operating industry of the United States as a whole (relative to foreign competition) that will outweigh any consequent differences in competitive position between U.S. firms.

RECOMMENDATIONS

1. Without slighting the importance of long-term research goals, the committee recommends a research program that addresses the industry's immediate needs. The shipping industry's R&D program should concentrate on short-term projects (of 1 to 3 years), although it should also include a significant number (perhaps 20 to 30 percent of the total number of projects) of long-term, high-risk projects. Because of the immediacy of the industry's problems, its R&D even now emphasizes short-term projects that promise quick implementation and returns. These widely shared, short-term projects could serve well as the foundation on which a more balanced program including long-term projects could be built. The committee recommends research projects that address the two most significant kinds of expense in U.S. vessel operation; namely, fuel and manning.
2. The program should not be restricted to research in the narrow sense of the term, but also encompass information collection and dissemination, to bring to the U.S. ship-operating community the results of relevant research from other industries, other countries, and the U.S. military. In addressing issues such as manning, ship operation R&D should also encompass action research or on-board experimentation.
3. As a general guide, if not a rule, the committee recommends that project content be directed to those areas of research in which results are not so readily transferred to ship operation

overseas. The recommended research program, with its emphasis on action research in the behavioral sciences, would suggest that this guide would not be so difficult to follow. Research on engineering alone is that most easily transferred overseas.

Ship operation R&D should have a program structure that meets the following specifications:

1. The program should be directed through high-level industry initiation and sanction, rather than through the "bottom-up" style that has characterized research management in the past.
2. The program should foster the development and strengthening of companies' internal capability for R&D. This need not always entail that companies establish a separate R&D department, but it does entail establishing a research network within industry and between industry and government. Otherwise, no improvement in ship operation research is likely, whether in initiating appropriate projects or in implementing successful innovations.
3. The program's management should rely less on external consultants and government. Consultants should still play a role in research, but this role should be a supportive and technical one, rather than one of promotion and management, as is sometimes now the case.

   Perhaps the U.S. shipping community requires a better mix of research structures, but it would take some time and in some cases a shift of government policy, to move toward cooperative research structures like those of Europe and Japan. For some time U.S. ship operators will depend largely on the services of consultants and private research firms. This diversity does afford some protection from monolithic program structures but if the industry could exploit its diverse resources through integrated management, the benefits of coordination might be achieved without the expense of bureaucracy.
4. The program of research should be increasingly sponsored by industry, with government's initial assistance and eventual involvement limited to projects of the widest application and in those it can most ably and appropriately assist.

The committee's concern is not to eliminate public funding for industry R&D, but rather with the consequence of the expenditure of public funds through existing program structures. The title of this report reflects the committee's principal recommendation--that industry's role in research should be strengthened, both in funding and managing programs and projects. Government funding will be required to begin the program and continuing government support for long-term, high-risk research. To the degree that government financial assistance is recommended for an industry research program (and this seems to be the case for ship operation programs overseas), it appears that an indirect, rather than a direct, funding structure is indicated. This program structure requires and should foster the commitment of the ship operators themselves.

The committee considered several alternatives for this structure suggested by the features of many programs, and selected the option described in the succeeding section.

PROPOSAL FOR A SHIP OPERATION RESEARCH CENTER

The committee developed the outline of a structure for collaborative ship operation research from the information and analyses considered in the course of the study: a Ship Operation Research Center. It is, in the committee's opinion, the option most likely to succeed from project selection through implementation and diffusion.

The Ship Operation Research Center (SORC) would be sponsored and managed by industry to facilitate cooperation in research and development among members of the industry as well as between industry and government. The objectives of SORC would be to further the productivity and safe operating practices of the industry through collaborative selection, management, and evaluation of nonadvocacy research programs and projects. With regard to managing research, this entails gathering and disbursing funds for the intramural and extramural conduct of research, including the transfer of information and technology.

The members of SORC should include as many interested vessel-operating companies as possible. Insofar as possible, the membership should represent all segments of the U.S. merchant marine (deep-sea, Great Lakes, and inland waterway users). Additional criteria for membership should include the willingness to engage actively in directing the organization and its research projects and to pay an annual subscription fee. Although the subscription fee is intended to cover a substantial portion of SORC's cost, it is expected that MarAd funding would play a prominent role initially; and that the agency (like its overseas counterparts) would continue to sponsor specific types of projects.

Seafaring unions should participate in the center's work. Representatives might, for example, serve on the program's general advisory board and on project steering committees (when projects treat labor-sensitive innovations).

This form of union participation is important for the following reasons:

1. The types of projects undertaken (on productivity and industry competition) would be of vital interest to the unions and their members. Successfully implementating the projects' results would in these cases depend largely on gaining the experience, views, and support of the unions, and allowing them time to work out options through the membership.
2. The U.S. seafaring unions have been active in those training facilities for labor and management that have significant capability for research (such as simulators). Thus, their staffs already possess important technical and research skills which might be directed toward research that are not found in the seafaring unions overseas.

The key concept of SORC is the factor identified by the committee as critical to the success of a program of research for a specific industry: it must be managed by that industry. Instituting the concept might be complicated if parties peripheral to the industry were to play a directing role in its operation. Such organizations as trade associations, professional societies, universities, vendors, research organizations, or companies of other maritime industries (from the shipbuilding and ports and terminals industries) should have a role in the R&D program. They might provide suggestions and advice, subscribe to the center's publications, serve as contractors for its research projects, and perform any number of functions, but the industry's commitment alone determines whether any research and development work is applied, and the commitment needs to come from top management.

Considering the merits and drawbacks of a research organization geared to more than one element of the larger maritime industry, the committee found technical problems that these three industries share, but insufficient common needs to sustain a broadly based program. Overseas, multiple and various maritime industries are involved in one R&D program only when the principal sponsor is a government agency that is responsible for a number of the industries. A strong government role in industrial research yields results when the industry already has a strong research capability or orientation, and a research organization for multiple industries might similarly succeed if its constituents have well-developed research infrastructures. In the case of the ship operation industry, building the infrastructure should come first. In the committee's opinion, this is much more likely to occur through a single-industry research organization, one in which shared problems and interests are more likely to generate sponsorship and active participation.

Another argument for a multiple-industry research center concerns funding, rather than shared interests. The three segments of the maritime industry may be unable individually to generate funding for both the program's administrative costs and meaningful research. In an industry research center for a number of maritime industries, economies could then be effected. But the facilities needed are so different--a cavitation tank vs. an experimental ship, for example--that it is unlikely such economies could actually be realized. Such an organization lacks the factors identified by the committee as needed for a successful R&D program; among them, common interests sufficient to attract contributions to jointly undertaken projects, and the shared perception that the projects are of equal use to all partners (whether because of interdependence or enhance competitiveness in the world market). The number of such projects for these very different enterprises is small and occasional.

The desired amount of communication among separate industry research programs can be achieved by other means, and joint ventures between them can be planned and conducted by other means. Researchers or research administrators from the other maritime industries can serve on the technical advisory panel of the ship operation research center, and vice versa.

Constituting the board of directors for SORC is important, in the committee's view, and should be accomplished by elections in which the full membership participates of high-level managers and executive officers of ship-operating companies. A technical panel could assist in the selection and evaluation of the over-all program and projects, and the daily operation could be managed by an administrative staff under the direction of an experienced manager of R&D programs.

The center would incur both administrative and research costs. Subscription fees borne by member companies would be used principally to cover administrative costs and core program expenditures, while most research expenses would be provided for by contracts with individual companies, groups of companies, and government.

The committee recommends that, whenever feasible, cooperative research projects be conducted by the member companies themselves or by company personnel on loan to the center, to build a research infrastructure within the industry. The structure of the program should encourage the development of a network of researchers and practitioners whose careers combine periods of service to companies, universities, government, and the SORC. This building of in-house capability for research has contributed to the success of cooperative research programs in Europe and Japan. It also promotes greater industry participation in the directing of cooperative research and implementation of results from collaborative ventures.

Insofar as possible, ship operation research should encourage the participation of company researchers or of company employees with responsibilities for both research and operation. If the necessary research expertise is not available internally (within the companies or the SORC), then the contracts let with external contractors should provide for their close association with internal research personnel.

The committee's recommendations are not intended to discourage the use of consultants or the strengthening of external expertise in ship operation research. A strong base of peripheral research needs to be encouraged. The committee concludes from the evidence reviewed in the study that the long-term interests of this peripheral research community are also best served by strengthening industry's internal capability for research.

It would be desirable to locate SORC near some appropriate organization or facility within the ship operating community, but the committee's review of candidate organizations did not indicate an obvious choice.

The Ship Technical Operation Committee of SNAME is one possibility, but it does not now have the active participation of high-level ship-operating executives, perhaps owing to the industry's perception of SNAME as essentially engineering and design-oriented. Further, SNAME collects and disburses private (commercial) funds only as a unified organization, rather than through various research units, and this conflicts with SORC's need to collect and disburse industry contributions in support of its operation.

Trade organizations are concerned almost exclusively with the issues of operation that bear on national and international policy. and are for this reason unlikely to commit the time and resources necessary to establish an R&D center to serve objectives that are not central to their own chartered purposes. There are several such organizations in the United States, unlike European nations that have a single trade association. R&D programs have been effected through the national associations of ship operators in European countries, but owing to the fragmentation of the trade associations in the U.S., the necessary unity of purpose and organization is lacking for an R&D program modeled on these lines.

The operator and labor-oriented trade associations could be invited to review SORC's plan annually and to offer suggestions for research (much as the Ship Research Committee does for the Hull Structure Committee of SNAME). This might broaden the industry's participation in defining research priorities, or it might be redundant insofar as a number of companies belong to more than a single association, but might still serve to encourage the participation of high-level management and labor in an industry advisory group's external review of the SORC program plan.

The implication of these several considerations is that SORC should be initiated as a separate entity.

Since SORC will function initially as a contracting unit, its location near research facilities and laboratories is not so critical as its location near ship operators. It is important that the center's professional staff and ship-operating executives be able to meet frequently, especially those on the board of directors and advisory panel. This should contribute to building the industry infrastructure for managing research that is now absent.

ALTERNATIVE SOLUTIONS

Several alternatives to the recommended R&D center for ship operation were developed and discussed by the committee. The most promising among those that were not selected was an industry advisory group similar to those found overseas. Such a group, composed of ship-operating management and technical experts, might regularly and formally perform a number of functions for MarAd's current Ship Operation Research Program. The advisory group could recommend research priorities, make long-range program plans, establish research budgets, initiate and evaluate requests for proposals, monitor research, and disseminate results.

Forming an independent advisory group for MarAd's research and development in ship operation offers a number of advantages over the existing arrangement, but would probably not correct the principal structural shortcoming our study identified, by the committee's study; that is, lack of sufficient industry ownership of the program to ensure the attention and direction of high-level management in ship operation research. Such advisory groups function effectively overseas, where the industry has substantial well-established research infrastructures, but the committee doubts if the formation of an industry advisory group in the United States will by itself create an effective R&D program in ship operation.

THE NEXT STEP

Neither the committee nor MarAd can determine whether the program here outlined can be established. As the subtitle of this report indicates, the proposed program is one for industry, and industry alone can evaluate and act on the present recommendations. Because there does not now exist a central, all-inclusive body or organization which can bring industry together to discuss the implications of these recommendations, we consider it appropriate that the Maritime Administration take the lead in convening a gathering of high-level executives of the industry for that purpose. Once afforded that opportunity, further actions leading to organization of a SORC are clearly the option and responsibility of those industry leaders.

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APPENDIX A

SHIP OPERATIONS R & D DISCUSSION FORM

*1. COMPANY*___________________________________ *DATE*__________*1981*

*2. LOCATION*___________________________________

*3. PRIMARY CONTACT*___________________________ *TEL. NO.*__________________

OBJECTIVE: To determine the extent to which Ship Operations R & D is conducted/ emphasized in your company.

Kindly indicate which projects are continuous/ongoing:

1. FUEL TECHNOLOGY (ENERGY CONSERVATION)

2. MAIN ENGINE RESEARCH

3. AUXILIARY MACHINERY RESEARCH

4. HULL COATINGS

SHIP OPERATIONS R & D DISCUSSION FORM (cont'd)

*COMPANY*____

5. *"PEOPLE RESEARCH" (BEHAVIORISTIC..."HUMAN ERROR"...PROBLEMS, ETC.)*

6. *CONTAINER SECURING*

7. *REFRIGERATED CONTAINER SYSTEMS*

8. *COMMUNICATION BETWEEN VESSELS*

9. *SHIPBOARD MANNING*

SHIP OPERATIONS R & D DISCUSSION FORM (cont'd)

COMPANY ______________________

10. ACCELERATED INTRODUCTION OF SHIPBOARD COMPUTER SCIENCES

11. OTHER

GENERAL:

A. Is your R & D supported/assisted or financed other than by your own company?

B. Do you normally participate in government sponsored R & D projects? If you do, would you indicate which?

C. Do you augment your full-time "in-house" efforts by using outside consultants?

REMARKS: (Please add any comments you feel would be helpful)