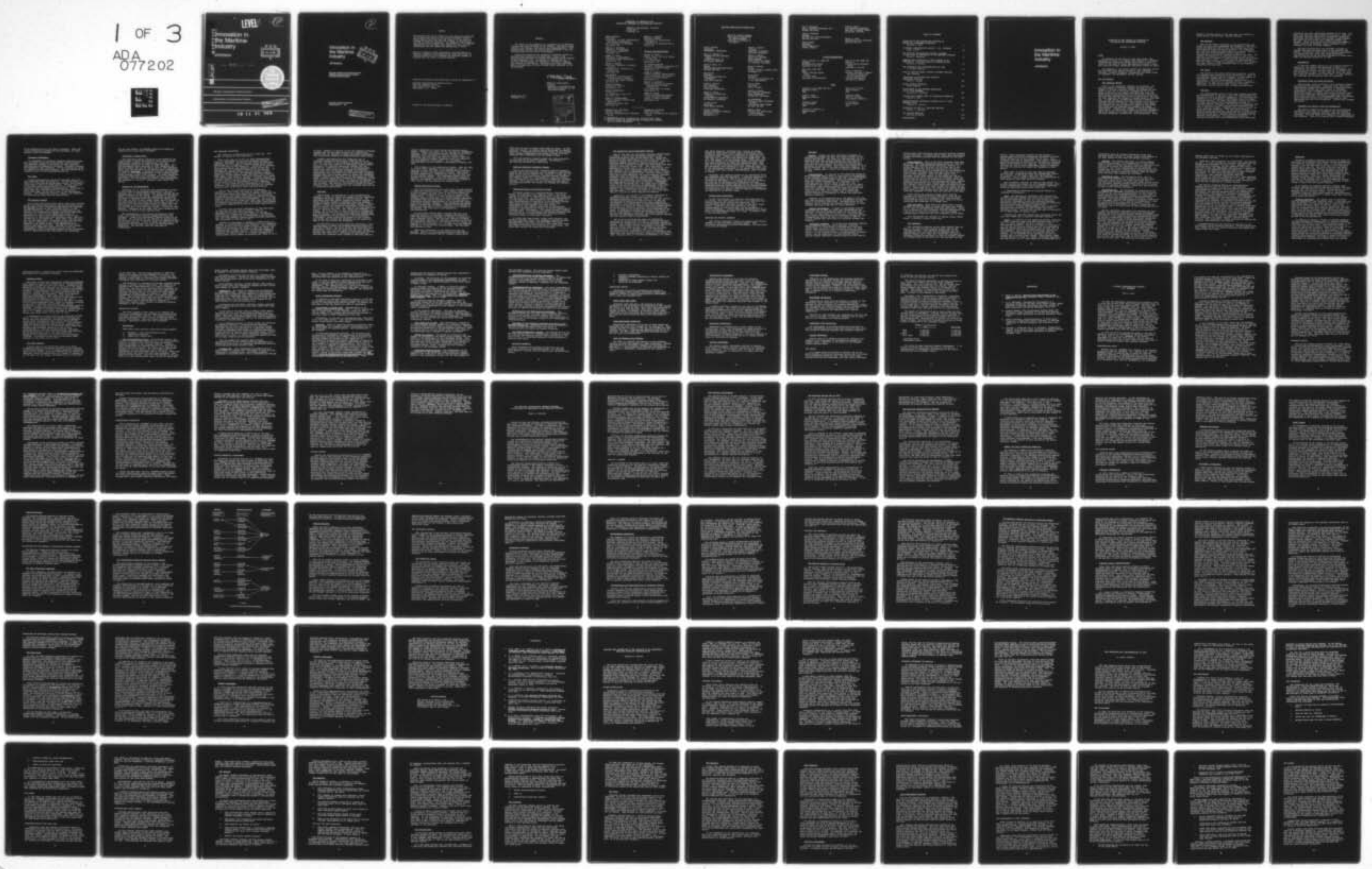
AD-A077 202 NATIONAL RESEARCH COUNCIL WASHINGTON D C MARITIME TRA--ETC F/G 13/10
INNOVATION IN THE MARITIME INDUSTRY.(U)
MAY 79 N00014-75-C-0711

UNCLASSIFIED NL

1 OF 3
ADA
077202



Innovation in the Maritime Industry

APPENDIX

See 1473 in back.

Maritime Transportation Research Board

Commission on Sociotechnical Systems

Innovation in the Maritime Industry

APPENDIX

MARITIME TRANSPORTATION RESEARCH BOARD
COMMISSION ON SOCIOTECHNICAL SYSTEMS
NATIONAL RESEARCH COUNCIL

NATIONAL ACADEMY OF SCIENCES
WASHINGTON, D.C. 1979

NOTICE

The project that is the subject of this report was approved by the Governing Board of the National Research Council, whose members are drawn from the Councils of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine. The members of the committee responsible for the report were chosen for their special competences and with regard for appropriate balance.

This is a report of work supported by the Departments of Commerce, Defense, and Transportation under provisions of Contract N00014-75-C-0711 between the National Academy of Sciences and the Office of Naval Research.

Inquiries concerning this publication should be addressed to:

Maritime Transportation Research Board
National Research Council
2101 Constitution Ave., N.W.
Washington, D.C. 20418

Printed in the United States of America

PREFACE

The report of the Committee on Innovation in the Maritime Industry has been published in two volumes. The first volume contains our finding, conclusions, and recommendations. This second volume contains the case studies developed to aid our deliberations and the report bibliography.

During the course of our extensive literature review, we selected many articles to be abstracted. Each of the abstracts was developed to address the specific major concerns of the committee, e.g., the process of innovation, the barriers and incentives to innovation, and ways to improve the climate for innovation. Because we felt they held some merit by themselves, we have included these abstracts in the bibliography.

Edward M. MacCutcheon
Chairman
Committee on Innovation and Technology Transfer in the Maritime Industry

Washington, D.C.
December 1978

COMMITTEE ON INNOVATION AND TECHNOLOGY TRANSFER IN THE MARITIME INDUSTRY

Edward M. MacCutcheon, *Chairman*
Consultant
Bethesda, MD

Harry Benford
Professor
Department of Naval Architecture and Marine Engineering
The University of Michigan
Ann Arbor, MI

Howard L. Gauthier
Professor in Geography
Ohio State University
Columbus, OH

James A. Jolly
Professor of Management
California State University
Sacramento, CA

Henry S. Marcus
Associate Professor of Marine Systems
Massachusetts Institute of Technology
Cambridge, MA

Huy Nguyen
Director of Distribution & Transportation Planning
International Paper Company
New York, NY

Markley Roberts
Economist, AFL-CIO
Washington, DC

Lester Rosenblatt
President
M. Rosenblatt & Son, Inc.
New York, NY

James P. Theoharides*
General Manager of Sales and Marketing
Prudential Lines, Inc.
New York, NY

Robert C. Waters**
Associate Professor
Department of Engineering Management
University of Missouri-Rolla
Rolla, MO

Liaison Representatives

Steven H. Davis
Chief, Vessel and Port Safety Technology
U.S. Coast Guard
Washington, DC

J. Anthony English
Director, Programs & Analysis Div.
Military Sealift Command
Washington, DC

James A. Higgins
Deputy Assistant Administrator for Commercial Development
Maritime Administration
Washington, DC

Daniel P. Maxfield
Chief, Technology Assessment Transportation Energy Conservation
U.S. Department of Energy
Washington, DC

James G. Smith
Operations Research Analyst, Naval Analysis Programs
Office of Naval Research
Washington, DC

* * * * * *

Marlene R.B. Phillips
Project Manager
Maritime Transportation Research Board

Stephanie Ziervogel
Staff Secretary
Maritime Transportation Research Board

---

* Formerly Director of Marketing, United States Lines.
** During service on committee was on Sabbatical working for U.S. Water Resources.

MARITIME TRANSPORTATION RESEARCH BOARD

Paul F. Richardson
Paul F. Richardson Associates, Inc.
Holmdel, New Jersey

Allen E. Schumacher
Chairman
American Hull Insurance Syndicate
New York, New York

Robert Taggart
President
Robert Taggart, Inc.
Fairfax, Virginia

Stuart W. Thayer
Vice President, Engineering
Lykes Bros. Steamship Company
New Orleans, Louisiana

Sheldon A. Vogel
Bigham-Englar-Jones and Houston
New York, New York

LIAISON REPRESENTATIVES

John D. Johnson, Jr., RADM, USN
Commander
Military Sealift Command
Department of the Navy

Henry Bell, RADM, USCG
Chief
Office of Merchant Marine Safety
U.S. Coast Guard
Department of Transportation

Henry R. Del Mar, MGEN, USA
Commander
Military Traffic Management Command
Department of the Army

Robert J. Blackwell
Assistant Secretary of Commerce for Maritime Affairs and Maritime Administrator
Maritime Administration
Department of Commerce

STAFF

Randolph W. King, RADM, USN (Ret)
Executive Director
MTRB

Harvey C. Paige
Executive Secretary
MTRB

Leonard E. Bassil
Project Manager
MTRB

Everette P. Lunsford, Jr.
Project Manager
MTRB

Marlene R.B. Phillips
Project Manager
MTRB

Richard W. Rumke
Executive Secretary
Ship Research Committee

S. Lynn Walton
Project Manager
MTRB

TABLE OF CONTENTS

Innovation in the Maritime Industry

APPENDIX

EVOLUTION OF THE CONCEPT AND ADOPTION OF
THE MARINE AND INTERMODAL CONTAINER

Francis G. Ebel

SCOPE

To elaborate on the title of this case study, this innovation is taken to encompass what amounts to a complete transportation system for marine cargo from its point of origin to the point of final destination utilizing a large unit load and without rehandling individual pieces of cargo.

The elements of the system include the container itself, the container ship, marine terminals, land transport vehicles, transfer equipment, integration with other forms of transport, and management control systems.

THE ENVIRONMENT

The Existing System

Prior to the widespread adoption of containers, the existing system of overseas shipment consisted in the shipper or freight forwarder loading the commodities into truck or rail car at his plant, transporting it to the marine terminal in the seaport from where the water leg would begin, discharging from the land vehicle, storage in the pier shed awaiting ship arrival, loading into the ship, and then repeating the process in reverse order at the other end. In some ports, an additional step was involved -- transporting the shipment from the railhead in the port to the ship terminal by lighter. While pallets were coming increasingly into use to reduce the amount of hand labor, more often than not packages were handled and stowed individually. Planning the stowage in the ship required great skill. In most cases a number of different shipments had to be stowed in the same hold, creating the need for extensive dunnaging, flooring off, and bulkheading. Since different stowage levels in the same hold are served by a common hatch, overstow was a serious problem.

The Terminal

Most of the marine terminals in the United States and around the world were antiquated and inadequate. They were poorly designed for traffic flow, and transit sheds were invariably cluttered and poorly lighted. Port congestion was a serious problem in many areas of the world. Some of this was due to the steamship lines' practice of concentrating sailings on a particular day of the week. For example, 50 percent of all sailings from the port of New York occurred on Friday.[3] In some foreign ports, ships might wait days for a berth. In many cases the terminals were publicly owned, or owned by a separate entity, and therefore not under control of the steamship line or the stevedore contractor who used them.

The Cargo

The nature of the cargo itself was a problem. A study of longshore labor published by the Department of Labor in 1932 defined general cargo as follows: "A large number of heterogeneous commodities in an endless variety of containers". The term mechanization carries with it an implication of some sort of standard article or repetitive operation. As long as the cargo clung to the above definition, little could be done to apply mechanization.

The Ship

The miscellaneous nature of the cargo likewise dictated the configuration of the ship, which had traditionally been designed to carry "anything" "anywhere." The philosophy and organization of ship design establishments were not cargo-handling oriented. The usual ship design process consisted of taking the owner's basic requirements in terms of carrying capacity and speed, and deriving the dimensions and form of the hull to attain the specified characteristics with a minimum of power. Whatever came out of this was the thing cargo was stowed in. Ship form and propulsion machinery held top priority. No one person or group in the design organization was responsible for the cargo-handling function of the ship. Even the overall arrangement of the ship was discriminatory. The propulsion machinery, navigating bridge, and crew accommodations were invariably located in the full, comfortable midbody of the ship. The space left over was good enough for the cargo. Even the structural designer tended to be unfriendly, frequently decorating the cargo spaces with pillars, frame brackets, and other odd bric-a-brac that hindered movement and stowage. Other cargo inhibitors were sheer and camber in decks, small hatch openings, crude, inadequate hatch closures, and lack of decent lighting.

The cargo-handling gear was accorded a minimum of engineering, with the result that it was primitive and unsafe. Incredibly, there were no regulatory requirements for testing the gear other than those established administratively by the Maritime Commission on ships built under the Merchant Marine Act of 1936.

Stevedoring

It has been common practice in the shipping industry to subcontract the loading and discharge of cargo to a stevedoring contractor. In this kind of arrangement, the party doing the actual work has little or no control over the facilities he uses. He must take the ship, the cargo gear, and the terminal as he finds them. In some respects, his interests are in conflict with the shipowner.

Longshore Labor and Labor Relations

Historically, labor relations in the longshore industry have been stormy worldwide. Longshore labor unions have traditionally opposed the introduction of mechanization or labor-saving devices that would result in increased productivity, with consequent threat of loss of jobs. Waterfront history is replete with horror stories of local union rules requiring unnecessary re-handlings and other obstructive practices. On the management side, enlightened labor relations policies and effective industry-wide bargaining were yet to be discovered. Strikes were frequent and costly.

Diversity of Control, Lack of Coordination

The several elements that make up the cargo-handling operation -- the ship, the stevedore, and the terminal -- are controlled by separate entities, each with different interests. This has acted as an inhibitor to improvement of this function. Each of the parties had a limited knowledge of and appreciation for the other's problems. There was little coordination between the ship designer, the ship operator, and the stevedore.

Steamship Management

The management of steamship companies historically has been extremely conservative and heavily tradition-bound. Sea experience appears to have been the most important qualification for managerial positions. Technical training and imagination were secondary. Little attention was given to research or long-range planning. This deficiency was an important factor in the containerization era.

The Fleet

A large proportion of the world's merchant fleet had been destroyed during World War II. The United States, as a result of a huge wartime shipbuilding effort, had on hand a large fleet of ships of prewar design. The Ship Sales Act of 1946 made these ships available to U.S. steamship operators, both subsidized and unsubsidized. Since many of these ships were virtually brand new and selling on attractive terms, the Act was a boon to the unsubsidized operator. The subsidized operator, however, was committed to replacing his ships with new construction.

The Mariner Program

Due to this glut of war-built ships, there was virtually no new cargo ship construction in the United States in the postwar period until the Maritime Administration undertook the MARINER Program in 1950, utilizing Title 7 of the Merchant Marine Act. This program was undertaken at the urging of the Department of Defense, which had identified the need for a fleet of high-speed cargo ships "in existence" for use as naval auxiliaries in time of war. Thirty-five of these ships were eventually built, and some saw service in the Korean War. While these ships did set a new size and speed level for merchant ships, and contained many useful refinements, the design was basically no different from prewar designs. The MARINER was still a typical break-bulk cargo ship. Although at first roundly criticized by commercial operators as too large and overpowered, thirty of them were acquired by the subsidized lines at depreciated prices and proved to be successful.

For the next decade, the MARINER became the standard of comparison for cargo ships worldwide.

Inflation in Labor Costs

The inevitable postwar inflation in the decade of the 1950s brought a severe escalation in labor costs without compensating increases in productivity. This was particularly marked in the case of longshore labor. In a well-documented study[5] published in 1961, Macmillan and Westfall showed that for the period 1947 to 1959 longshore labor costs had increased by 118 percent while productivity had actually decreased. A prediction made by the Department of Labor in 1932, that productivity in this industry would likely decline, proved to be accurate. In other industries, increased productivity had reasonably kept up with higher wage rates. For the economy as a whole, labor productivity had increased at a rate of 3 percent a year during this period.

Summary of the Environment

Combining all of the factors and circumstances recited in this review of the shipping environment in the pre-container era, it became obvious that cargo handling was the dominant weakness in the system. In addition to the direct costs, two other factors further accentuated the problem. The wages of shipboard labor were escalating rapidly, and this cost, as well as other vessel costs, must be charged to the cargo-handling cost during the ship's stay in port. In addition, with the trend toward higher sea speed, the port stay assumed a larger proportion of total voyage time. At sea the ship was a very efficient vehicle. In port it was a disaster. Depending on the trade, port costs accounted for 60 percent or more of total system's cost.

The consequences of this struck the domestic trades first, since they were in direct competition with land transport. Coastal and intercoastal operators went out of business. The situation for the operator in foreign trade was also bad, but not as serious, since his competitors were in the same condition. Still, if profit margins were to be improved by cutting costs, the point of attack was well identified. The time was right for some kind of breakthrough.

THE CONTAINER REVOLUTION

The history of containerization is a long one. This account is limited to the recent past.

Much credit must go to the U.S. Army Transportation Corps for development of the first extensive container transport operation. Motivation came primarily from their experiences in the supply of overseas armies during World War II and again in the Korean War. Protection of precious cargo during transit and temporary storage rather than economics was the principal attraction to the military. In the immediate postwar period, with the spectre of huge stacks of crushed, torn, and weathered military supplies piled high on open wharves around the world still fresh in their minds, they turned to the metal container as at least a partial solution to their problem. A careful analysis of the full range of military cargo established that 40 percent of the total could be containerized to good advantage. The result of their study was the introduction of the Conex container, with standard dimensions suitable for transport by sea as well as by truck, rail, and army vehicles.

Cost is not the overriding factor in military operations. Very often, the value of timely receipt of critical spare parts and supplies by armies in the field can be counted in lives rather than dollars. The protection against mechanical damage and weather afforded by the metal container constituted a welcome improvement. Not to be lost sight of, too, was the larger unit load, with its potential for improved ship discharge rates, and quicker ship dispatch in severely congested ports such as had been experienced in Korea.

By 1965, when our major involvement in Viet Nam began, the Army and Air Force jointly owned a fleet of approximately 100,000 Conex containers. As the war escalated, this number was nearly doubled. Satisfaction with container shipment was so widespread in the military that full containership services using van-sized containers were introduced to Viet Nam in 1967.

Whether by coincidence or example, a sudden flurry of interest in containerization also appeared in the commercial shipping field in the early postwar period. Some visionary people were predicting the advent of container ships, and inventors were flooding the Patent Office with designs of containers and transfer systems. The Maritime Commission picked up the idea and built a C-3 vessel equipped with overhead deck cranes capable of handling unit loads of up to

30 tons. However, it was not to be; the commercial shipping industry was not yet ready to part with tradition and wrestle with the logistics problems and system innovations that large-scale adoption of containerization would entail.

Limited experimentation with commercial use of containers during this period was, like the use by the military, inspired by the protection afforded by the metal box. In this case, security of high-value cargoes against pilferage, the universal waterfront disease, was the motivation. Conditions for success of containerization during this early period were anything but propitious. Cargo ships were not designed to handle this type of cargo efficiently, with the result that the boxes were frequently damaged while being hoisted aboard or during the horizontal movement required to stow them in the wing spaces of 'tween decks. Return cargoes were frequently not available, so the boxes had to be returned empty. In spite of the problems and the vocal opposition of the ever-present detractors, the idea survived. The military continued to expand its Conex container fleet, and commercially the container held its own in specialized applications.

Sea-Land

Oddly enough, it remained for a land transportation company to strike the spark that flamed into the integrated, intermodal transport concept of containerization. The experiment began when McLean Industries, parent company of McLean Trucking, acquired a steamship line, Pan Atlantic Steamship Company (later renamed Sea-Land Service). Malcom McLean, a clever and ingenious businessman, conceived the idea of carrying his trucks on a ship for the long haul from the Gulf ports to New York. The concept was developed in stages. The first step, in 1956, consisted in carrying the trailers on the spar deck of tankers operating between New York and Houston. The feasibility having been demonstrated, McLean proceeded with the design of a roll-on/roll-off trailership. After carrying the project to the contract plan stage, this concept was abandoned and the switch was made to the lift-on/lift-off principle.

In 1957-1958, six C-2 type ships were converted to full containerships equipped with shipboard-mounted cranes for load and discharge. The ships carried 226 thirty-five foot containers. Four of the six ships were put into service between East Coast and Gulf ports, and the other two between New York and Puerto Rico. Following the usual pattern, problems with longshore labor erupted in San Juan, and as a result commencement of this service was delayed several months. However, the beauty of this concept was immediately apparent. Since the highway vehicle was made up of easily separable units consisting of tractor, chassis, and container, the ship need only carry the latter, while the use of the wheeled highway components could be limited to the land segments of the system. So, the modern containership, and the concept of intermodal transport, was born.

The economics of the system were evident. When the ship is at sea, water transport is the cheapest of all. By handling a large unit load, high cargo-handling costs were overcome and port time drastically reduced. High cargo-handling productivity, combined with low per-ton-mile cost at sea, spelled success. The subsequent success story of Sea-Land is well known. After this successful coastwise venture, the company instituted an intercoastal service in 1962, and by 1966 had entered the foreign trade.

Matson Navigation Company

High cargo-handling and port costs also motivated Matson to look into containerization. This company, which operated a service between the West Coast of the United States and Hawaii, decided something had to be done to improve port productivity. In 1956, in a move uncharacteristic of the industry, Matson established an in-house research department to analyze their entire operation, with the objective of discovering possible improvements to the system that might solve their economic problems. Using sophisticated systems analysis techniques, including a computer fleet simulation model, they were able to test a wide variety of changes to the system. The study led to the adoption of containerization.

At this point, Matson made a further departure from customary practices of steamship companies by setting up their own engineering department to develop the details of their container system. Like Sea-Land, Matson introduced the new system cautiously by carrying containers on the deck of conventional freighters. The success of this venture in 1958 led to the conversion of a C-3 type ship, the HAWAIIAN CITIZEN, to a full cellular containership. The ship went into service in 1960.

There were differences in the Matson and Sea-Land systems. Instead of the shipboard-mounted cranes used by Sea-Land, Matson developed special terminal cranes which could also be used to handle other types of cargo. In this particular aspect, the Matson system has become the general practice. A detailed analysis of the trade, as well as West Coast highway requirements, led Matson to adopt a 24-foot container size, differing from the industry trend.

With the technical aspects worked out, there was still the big question of labor acceptance. Fortunately, a satisfactory agreement was negotiated.

American Hawaiian Steamship Company

During this period (1957), American Hawaiian Steamship Company, which had withdrawn from the domestic trade but had money in its capital reserve fund, invested a large sum in a paper study of an intercoastal container system, including the complete design of a trailership to carry 538 thirty-foot trailers and a very sophisticated, completely automated terminal. After going so far as to build and test part of the automated system, the project was dropped for economic reasons.

Containerization in the Foreign Trade

The early pioneers in containerization, Sea-Land and Matson, were engaged in the domestic trades. The first attempt at large-scale containerization in foreign trade was made by Grace Line. In 1961, Grace converted two war-built, C-2 type ships, the SANTA ELIANA and the SANTA LEONOR, to full containerships for operation in its Caribbean service. These ships each had a capacity of 476 twenty-foot containers and were equipped with deck cranes. Unfortunately, this venture failed due to insufficient planning -- principally the failure to obtain cooperation of longshore labor in Venezuela. The unions refused to handle the containers. This misfortune reverberated throughout the industry and was a severe setback for containerization, especially among the subsidized operators.

At about this same period, a West Coast operator, the American President Lines, also decided to test the concept. Two SEA RACER class ships, the PRESIDENT LINCOLN and PRESIDENT TYLER, put into service in 1961, were built with one complete container hold serviced by a deck crane. The ships each carried 126 twenty-foot containers.

The Subsidized Ship Replacement Program

Just at the time the intermodal container concept began to blossom, a major ship replacement program by the subsidized operators was getting under way. During the period 1958-1965 approximately 130 new cargo liners of 23 different designs were contracted for and built. Under the operating subsidy agreements, operators holding such contracts were required to replace all their ships when they reached a statutory 20-year life. (New legislation subsequently changed this to 25.) All of these ships, with one exception, were conventional break-bulk cargo ships. The exception was the MAGDALENA class ships built by Grace Line for its South American trade. The four ships in this group were highly mechanized for cargo handling, including overdeck cranes for handling containers, sideporters, elevators, and conveyors for handling palletized cargo. The contracts for these ships had already been awarded before the SANTA ELIANA venture ended in disaster. Subsequent Grace designs contracted for a few years later provided little in the way of container accommodations, other than conveniently sized hatch openings for stowage in hatch squares. This represented the extent of recognition of containerization in a whole new fleet of U.S. cargo ships just as a new era in ocean shipping was dawning.

Apparently, the success of the domestic operators in launching container services was overlooked by the subsidized operators in foreign trade. In the late sixties the Maritime Administration made an effort to spur the introduction of containerization and other imaginative approaches to ship design when the Maritime Subsidy Board announced a new policy of making construction subsidy awards on the basis of obtaining the most ship productivity per dollar of subsidy, the productivity to be expressed in ton miles. A productivity formula was devised, and, while it was far from perfect, it did have the desired effect of steering the subsidized operators away from obsolete designs and into various forms of unitization.

The first big breakthrough among the subsidized operators in foreign trade occurred in 1966 when Sea-Land announced the inauguration of a weekly container service to Europe. This brought Sea-Land into head-to-head competition with the United States Lines, the dominant U.S.-flag operator in the North Atlantic. The reaction was swift. Two years earlier, in December 1964, U.S. Lines had contracted for the construction of five C-4 break-bulk type ships with some limited container capability for delivery in 1968. Shortly after the Sea-Land announcement, U.S. Lines, with MarAd approval, proceeded with a series of design changes on these ships already under construction, which ultimately resulted in their completion as jumboized full container ships. However, the delivery of these ships in 1968 left U.S. Lines two years behind the competition. The year 1966 proved to be the turning point. Since that time, up to the present, no conventional break-bulk cargo ships have been contracted for under the subsidy program. Even some of the newly delivered break-bulk ships, such as the APL Seamasters, were converted to full container ships. All of the new designs constructed in the period 1966-1977 were of the unitized type, either containerships, barge carriers, or RO/ROs.

Obviously, the planning process of the subsidized lines was something less than admirable. A detailed exposition of the planning process of some of the individual lines is contained in Reference 1. As pointed out in that analysis, not only had the advantages of containerization been demonstrated by two unsubsidized operators, but government-sponsored research studies published by the National Academy of Sciences in 1959 and 1963 demonstrated the economics of containerization in foreign trade and supplied a methodology for application to specific cases.

Foreign Flag Acceptance

By the late sixties, the container revolution was in full swing. What had started out as a U.S. innovation was quickly picked up by foreign-flag operators, and containerships began to appear in most of the world trade routes. Currently, there are upwards of 500 full containerships in the world fleet, and an estimated 1.5 million containers. A recent Maritime Administration report lists 104 containerships under U.S. flag. Of these, 43 are in the Sea-Land fleet.

HARDWARE AND RELATED ELEMENTS

This section describes briefly the hardware and related elements of the intermodal container system. With everything undergoing continuing development, the term state of the art is avoided.

20

The Ship

Concept. Perhaps the most remarkable phenomenon of container development has been the instant success of the initial ship design. The first all containership, the C-2 conversion that the Sea-Land Company put into service in 1958, was built with an internal vertical-cell type of structure and large hatches to utilize the "direct-drop" principle of cargo stowage. This basic idea proved to be so highly efficient that it has been universally adopted. It is rare, indeed, when a "first try" concept stands the test of time.

Configuration. In contrast to the break-bulk system in which relatively small units of cargo could be accommodated in the "shaped" stowage areas of the ship, the containership must have "squared up" stowage spaces to accommodate the large unit loads (containers). To compensate for the resulting loss of internal space in the hull, the containership must carry a large proportion of its cargo above deck. Deck stowage accounts for a third or more of the cargo, depending on whether the boxes are stowed two, three, or four high. The extensive deck stowage has necessitated an increase in beam, and, in some cases, special ballasting arrangements to obtain the additional required stability.

Compared to the break-bulk ship, the depth of hull has also been increased substantially to accommodate the maximum number of containers below deck. Increased depth is the cheapest way to increase the internal capacity of the ship. Six-high stacking in the hold is fairly standard.

General Arrangement. A change in philosophy from the break-bulk era to give the cargo more consideration has resulted in locating machinery spaces in the finer part of the ship, in some cases all the way aft. There has also been a trend toward locating the navigation bridge and crew accommodations toward the ends of the ship in order to provide maximum open deck areas for container stowage and handling.

Structural Strength. The direct-drop container handling method dictates very wide hatch openings, requiring concentration of longitudinal strengthening of the hull girder upper flange in a narrow stringer plate and sheer strake. For very large ships, it has been necessary to resort to a box structure built of longitudinally stiffened plates, and the application of high-strength steels. Another unusual structural problem arises from the heavily concentrated loads resulting from six-high vertical stacking of the containers. To absorb these loads, deep longitudinal girders with well-stiffened webs are provided in the inner bottom.

Cargo Handling. Most of the early container ships were built with their own shipboard-mounted cranes for load and discharge. As containerization developed, however, it became apparent that the place for the crane was in the terminal. Matson had made this decision at the outset. While the performance of the shipboard crane was technically satisfactory, the added weight and space did result in a loss of cargo capacity. With the gear ashore, this equipment is put under control of the people who use it. The gear itself can be better and more flexible, since the design does not have to be limited by the space and weight limitations of the ship or have seagoing qualities. Exposed machinery deteriorates very rapidly under sea conditions. The terminal crane can have a much higher utilization factor than the gear on the ship, which stands idle during the sea voyage. Crane operators in the terminal can acquire greater skill using the same machine every day than they could using different equipment on every ship that arrived at the dock.

Hatch covers are generally simple steel pontoons equipped with identical lifting fittings to those on the containers so they can be handled by the crane spreader. Cargo-handling rates are extremely high. Thirty or forty containers per crane-hour is a common rate.

Size and Speed. While there has always been a steady increase in size and speed of ships with time, the changes in the case of containerships have been spectacular. Ships with a capacity of 2000 containers (20-foot equivalents) and a speed of 30 knots are in service. The more common characteristics would be 1000-1200 containers and 23 knots.

This development has resulted in smaller fleets (fewer ships) to service a given trade route.

The Container

The intermodal container in use today evolved from the body of the over-the-road highway trailer used in the trucking industry. The important differences are the requirements that the cargo unit be separable from the wheeled chassis and be built with sufficient strength to withstand lifting and handling, as well as stresses imposed by stacking loads in the ship cell, ship motions, and sea action. Other important features include absence of protuberances and precise dimensional tolerances to permit smooth handling in the cell guides of the ship. Rail transport also must be considered. This usually reduces to providing sufficient strength in the end walls to withstand impact loads caused by car coupling. Lifting and securing fittings are also of great importance, since the handling rate and the security in transit are dependent on good design.

Many types of material have been used in container construction. Aluminum has been the overwhelming choice, due primarily to its light weight and anticorrosion properties. Steel, plywood, plastics, and combinations of these materials have been used with success.

The intermodal container of today is the product of careful engineering analyses by the steamship lines, truck trailer manufacturers, and various standards committees, backed by experience gained from actual use.

A comprehensive discussion of container design is contained in Reference 2.

Size. The majority of steamship lines operating in foreign trade have adopted the 20-foot and 40-foot length with 8 foot width and 8.5 foot or 8 foot height, as originally recommended by both the American Standards Association (now the American National Standards Institute) and the International Standards Organization. Unfortunately, although understandably, the two domestic operators who started it all have stayed with their individual sizes. Sea-Land does provide some 40 capability in its newer ships in foreign trade.

Recently the term TEU (twenty-foot equivalent units) has come into common use to indicate container capacity.

Types. In addition to the common dry-freight container, a number of special types have been developed and are in use. Of these, probably the most important is the refrigerated container. There are a number of versions in use, but one of the more popular ones has an electrically powered refrigerating unit recessed into the back wall of the container. For over-the-road operation, current is supplied by an engine generator set mounted under the chassis. In the terminal and on shipboard the unit is plugged into a central power supply. Other special types include open tops, tanks for liquids, automobile carriers, and open trays. All of these types are circumscribed by a rectangular frame of standard dimensions fitted with standard corner castings to permit handling and stowage in the same fashion as the usual dry-freight container.

Chassis. For highway operation, a skeletal chassis carries the container. It is essentially a light steel frame on which is fitted the fifth wheel for coupling to the tractor and fittings for supporting and securing the container. Due to the construction of the container, the chassis does not have to furnish beam strength but must be sufficiently rugged to withstand braking loads and shock loads resulting from landing the container.

Carriage by Rail. For carriage by rail, the U.S. railroads have provided CFC (container on flatcar) cars. These cars, which are 89 feet long, are built with a cushioned undercarriage to absorb shock loads and are fitted with automatic securing devices which mate with the corner castings of standard containers. These cars will carry two 40-foot or four 20-foot containers.

Standardization. Any discussion or chronology of the development of intermodal containerization must include an account of the role of standardization. In 1956, when it became apparent that everybody planning to experiment with containerization was contemplating a different size of container, the Maritime Administration convened a meeting of U.S. steamship lines for the purpose of attempting to curb the proliferation of sizes, and, if possible, reach agreement on a limited number of sizes, at least for the subsidized fleet, so there could be some standardization in the ships.

Shortly thereafter, and before any consensus had been reached, the American Standards Association established Committee MH-5 for the same purpose, and Marad withdrew from the picture. This committee drew wide representation from the entire transportation industry and related industries. Subcommittees were formed to study dimensions, design criteria, testing, lifting and securing fittings, marking, etc. By 1959 agreement was reached on nominal dimensions. The standard consisted of a modular series with nominal lengths of 10, 20, 30, and 40 feet and a standard cross section of 8 feet by 8 feet. The lengths were based on the fact that 40 feet was the maximum length of trailer permitted on the highways in all 48 states. Ultimately, actual dimensions were assigned so that two of the 20-foot size could be coupled and occupy the same overall length as one 40-foot, and, similarly, two of the 10-foot size could form one 20-foot unit. The width was dictated by U.S.

highway limits and the height by rail tunnel clearances on the European continent.

Inevitably, when standards are established, some parties get hurt. In this case Matson, Sea-Land, and Grace Line had already made investments in other sizes. However, the standards were voluntary, and the committee felt that at this early stage the commitments made were not so great that a switch to the standards would be prohibitive. Grace Line did switch, but Matson and Sea-Land held to their original selections. In 1961 the International Standards Organization (ISO) entered the picture with the establishment of Technical Committee TC-104. This Committee acted rather quickly in endorsing the U.S. sizes. They also participated in selecting standards for other features on which the MH-5 Committee was already working.

The general reasoning behind the standardization movement was that only in this way could universal interchange be achieved and the full benefits of intermodal containerization realized. In an effort to support this philosophy, the Maritime Administration made adherence to the standards a requirement for obtaining construction subsidy or mortgage insurance for ships. (Subsequently, as a result of congressional hearings prompted by pressures from steamship companies using nonstandard sizes, this requirement was dropped.) To encourage containerization, the containers were declared eligible for mortgage insurance. With the exception of the two U.S. operators mentioned, practically all of the steamship lines in foreign trade have adopted the 20-foot and 40-foot sizes. In the intervening years since the standards were first established, a number of changes have been introduced. The 8 foot 6 inch height has been added as an alternate, and additional lengths, notably the 24-foot and 35-foot, have been included in the ANSI standard. In addition to dimensions, standards have been established for weight capacity, strength design criteria, test requirements, corner castings for lifting and securing, identification, and marking.

Standardization has led directly to the birth of the flourishing container-leasing business. Recent figures show that roughly one-half of marine containers and chassis are leased rather than owned.

Terminals

Terminals originally designed for break-bulk ships and boom-winch cargo-handling gear quickly became inadequate as the volume of container traffic grew. It was here, in the terminal, that big gains had to be made if the container concept was to pay off. The result has been that major general cargo ports have found it necessary to build new special container terminals. The principal features of these terminals are long quay-type berths served by rail-mounted container cranes and a large upland paved area for container storage. There is a lesser requirement for covered storage transit sheds, and these need not be adjacent to the docking area as in the break-bulk system. Also of major importance for a container terminal is easy access to major rail and highway networks.

As an example of a modern container terminal, Port Elizabeth serving New York and New Jersey covers 1165 acres of land, has three miles of wharf, 22 ship berths, and is equipped with 19 container cranes. Due to the large investment required, large-scale container operations have tended to become concentrated in fewer, large ports that can afford these facilities.

Handling Equipment. The primary item of container-handling equipment is the container crane. While there are many variations, the most common type is rail-mounted for positioning along the length of the ship, has a lift capacity of 40 tons or more, and has an outreach over the ship of a hundred feet and a similar amount over the land. Most cranes handle containers with rectilinear motions in a plane at right angles to the ship. Large-capacity wheeled cranes have also been developed and are used in some ports to supplement the regular dock cranes during heavy demand periods or during emergencies.

In addition to cranes, a variety of wheeled equipment has been developed by manufacturers of materials-handling equipment to transport containers from storage areas to the crane hook and to stack them. Some operators prefer to store the containers on chassis which are then towed to the loading point by yard tractors. Others use straddle carriers or similar vehicles for yard handling. For very large operations, it has been necessary to develop computer-aided systems for controlling storage of containers awaiting shipment and planning ship loading to ensure stability and avoid overstow problems. The overall result is a great improvement in cargo-handling productivity over the old break-bulk system. Productivity thirty times the break-bulk rate would be a conservative estimate.

Longshore Labor

The threat of lost work opportunity caused the longshore labor unions to oppose the introduction of containerization, particularly in East and Gulf Coast ports. Attempts by the employers to reduce the gang size on the dock to the number of men actually needed to handle the containers was steadily resisted, so that potential labor cost savings could not be realized. Another obstacle to achieving savings was the matter of stuffing the containers. While this operation could be accomplished at much lower labor rates at consolidation terminals, the longshore unions insisted that this work must be reserved for them when the cargo originated in an area within 50 miles of the port. In 1964, the U.S. Labor Department made a study of container handling in the Port of New York and concluded that greater flexibility in gang size would be achieved through container handling. A special mediation board in 1964 recommended that the gang size for container handling be reduced from 21 men to 17. However, the unions continued to oppose any changes that would result in the loss of jobs.

A breakthrough in labor relations did occur on the West Coast. In 1960, an agreement was worked out between the Pacific Maritime Association, representing the employers, and the ILWU, representing labor, which reconciled the objectives of the employers and the union. This agreement, named the Mechanization and Modernization agreement, has brought a lasting peace on the West Coast labor front that permitted the steamship operators to get on with containerization. The men registered before 1958 were protected from loss of work, and the savings made possible by the mechanization were to be shared with them. Meanwhile, the situation on the East Coast has remained volatile. A prolonged strike over the container issue occurred in the latter part of 1977.

The Ship Operator

A shift from the old break-bulk system to a fully integrated shipper-to-consignee container service resulted in some major changes in the steamship operator's business. Under the old system, cargo was delivered to his dock in the home port, and his responsibility was limited to loading it on the ship, the sea voyage, and depositing it on the dock at the other end. The new system imposed an additional burden of arranging the land segments of the trip. In addition to operating a fleet of ships, he must now also operate a large fleet of containers and chassis scattered throughout the hinterlands of the ports served.

The operation of a shipper-to-consignee container system requires a greater capital investment. The industry has changed from a labor-intensive to a capital-intensive operation. The cost of the container ship is probably not greater than the break-bulk ship, since the added cost of container features such as cell guides and deck stowage fittings are largely offset by absence of 'tween decks, elimination of cargo-handling gear, and simpler hatch covers. The container ship, with its vastly improved port turnaround, is a much more productive ship. On the other hand, a great deal of capital must be invested in containers, chassis, and a variety of expensive handling equipment in the terminals.

INFLUENCING FACTORS

The basic purpose of this study is to identify the forces or circumstances that motivated the innovation and influenced the ultimate success. The preceding sections have been developed in such a way as to make the major factors self-evident. They are further developed in this section. Inhibiting factors are also discussed.

Motivation

There were three principal motivating forces present:

1. Economic -- the cargo-handling crisis.
2. Competitive pressure.
3. Search for a better way.

The Cargo-Handling Crisis. As described earlier, the failure to improve labor productivity in the cargo-handling function in terms of both cost and time was bringing financial disaster to the shipping industry. Longshore labor productivity had remained static in the face of the postwar inflation in wages. The result was a substantial increase in the cost-per-ton of cargo handled and no improvement in port turnaround time of the ship. Ships were getting larger and faster and also more expensive. Crew wages were also rising. Since the only purpose of the port stay is to load and discharge cargo, all of the ship costs while in port, including capital costs and crew wages, must be charged to the cargo-handling function.

The effects were first felt in the U.S. coastwise and intercoastal services. Except for some industrial carriers, this once-flourishing trade practically disappeared in the postwar period.

Other domestic services, notably Matson's West Coast to Hawaii trade, were also feeling the squeeze and were forced into looking for drastic remedies.

<u>Competition</u>. The source of competition was different for different trades. Domestic coastal and intercoastal services, while protected from competition from foreign-flag lines and U.S. subsidized lines, were in competition with truck and rail. The land carriers had done a better job in controlling costs, and the result was the demise of the water carriers in the pre-container era.

By adopting the intermodal container concept, Sea-Land reduced cargo-handling costs to the point where they could again compete.

In the case of the West Coast to Hawaii trade, Matson was faced with the hard choice between finding a way to reduce their port costs and charging their shippers higher rates. The latter alternative would have been an invitation for additional competition to move in, so they proceeded to investigate containerization.

As to companies engaged in foreign trade, the situation was somewhat different. Construction and operating subsidies put the U.S.-flag carriers on an equal footing with their foreign-flag opposites in a particular trade. Steamship conferences also tended to eliminate competition by the practice of pooling cargo and fixing rates. Foreign competitors on the same itinerary generally suffered the same high port costs. As long as everybody obeyed the rules of the game, competition was minimized.

The real competitive pressure which brought containerization to the foreign trade was apparently the appearance of Sea-Land, an aggressive unsubsidized operator, in the lucrative North Atlantic trade.

<u>A Better Way</u>. Many individuals are endowed with an inborn desire to improve their environment in some way and, consciously or subconsciously, are always analyzing processes or mechanisms with a view to discovering a "better

way." In our country, it is frequently referred to as "Yankee ingenuity," although it has never been proven that Americans have any monopoly on this characteristic.

In the case of ship port operations as practiced in the 1940s, it did not require any great perspicacity even for a layman to observe that here was a broad area for improvement. The loading dock was a scene of congestion, disorder, danger, and back-breaking hand labor, a place that the Industrial Revolution had never reached. The situation was overly ripe for innovation.

Other Influencing Factors

In addition to the basic motivating factors, a long list of influencing factors that played an important part in the success of containerization can be recited. No attempt has been made to list the factors in order of importance.

Willingness to Assume Risk. Implementation of an innovation inevitabily involves risks -- risk of capital and risk of reputations. In any endeavor, there are only a limited number of individuals and organizations willing to lay their money or their reputation on the line.

Fortunately, in the case of containerization, there were a few risk takers around -- men like Malcom McLean, Stanley Powell, Frank Besson, and Lewis Lapham.

Research. While it cannot be precisely evaluated, there is little doubt that research played a significant part in the development of containerization. The following are a few examples.

a) Government-Sponsored Research. The Maritime Cargo Transportation Conference, the predecessor of the Maritime Transportation Research Board (MTRB), organized within the National Academy of Sciences at the request of the Departments of Commerce and Defense, published in the early 1950s a number of well-documented, authoritative studies on the economics of container transportation. The first of these, the S.S. WARRIOR, documented for the first time the cost in dollars, time, and man-hours involved in each of the seven segments of the maritime shipping system, thereby exposing the true port costs of the break-bulk general cargo system. Others of particular importance included the NEAC study, Maritime Transportation of Unitized Cargo, and Inland and Maritime Transportation of Unitized Cargo. These studies were particularly useful because they introduced a methodology for studying the system.

b) Matson. The decision by top management to establish in-house research and engineering departments led this company directly into containerization of their West Coast to Hawaii trade.

c) Technical Papers. A number of technical papers, published under the auspices of the Society of Naval Architects and Marine Engineers in the early 1960s, attracted attention to cargo-handling problems and the advantages of containerization; in particular, Competitive General Cargo Ships, 1960, and Ship Design for Improved Cargo Handling, 1962, can be cited.

d) American Hawaiian Steamship Company. While it eventually turned out to be only a paper exercise, the development of ship and terminal designs for an intercoastal container system undertaken by this company in 1957 provided useful information.

e) Pan Atlantic (Sea-Land). This was an important exercise carried to the point of producing complete plans and specifications of a RO/RO trailership. The information developed in this venture led to the abandonment of RO/RO in favor of the lift-on/lift-off system which has been universally adopted.

Ship Sales Act of 1946. This legislation, enacted in the early postwar period, enabled U.S. steamship companies to acquire good war-built ships at bargain prices. This was particularly beneficial to the unsubsidized operators, since it enabled them to buy and convert some of these ships to containerships with a minimum of capital investment.

Growth of Trucking. The growth of trucking at the expense of railroads in the United States probably had some effect on the development of the intermodal system. Just the effect of seeing so much cargo arriving at the pier in over-the-road trucks may have influenced the selection of the cargo unit of the trailer as the unit load for the integrated system. Also, a trucker was the original innovator of the intermodal system.

Interstate Highway System. The commencement of the construction of the federally funded interstate highway system in the 1950s was a boon to long-distance trucking, making it the predominant carrier for the land segment of the intermodal system. This was the largest public works project ever undertaken by any government.

Interchangeability of Highway Equipment. The standardization of the "fifth wheel" coupling of chassis and tractor by the Truck Trailer Manufacturers to permit complete interchangeability of highway truck trailer equipment became an important ingredient of the intermodal system.

Standardization of Containers. The early achievement of standardization of the container under the auspices of ANSI and ISO was undoubtedly one of the most important factors in the rapid development of containerization. Convening a committee with worldwide representation provided a forum for the interchange of information and for spreading the gospel. Without standardization the feature of interchangeability is lost, and with it the dream of a "universal" system. The standards have been extremely beneficial, however, even though some operators have chosen to ignore them and go their own way. Putting a check on the proliferation of sizes and standardizing structural requirements and lifting fittings has greatly facilitated the growth of the system.

Mechanization and Modernization Agreement. The agreement between the U.S. West Coast steamship operators and the International Longshore Workers Union which permitted the mechanization of terminal operations must be classed as one of the biggest factors in the development of containerization.

Extension of the Mortgage Insurance Provision of the Merchant Marine Act. Extension of the Title XI section of the Act to cover containers aided the spread of containerization by easing the capital financing.

The Marad Productivity Formula. The introduction by the Maritime Subsidy Board of a productivity formula as a basis for awarding construction subsidy funds contributed to the shift of the U.S. subsidized operators from break-bulk to unitized ship types.

Ancillary Benefits

While improved cargo-handling productivity was the principal attraction of containerization, the following other benefits accruing from the system have influenced the growth:

- Savings in packaging;
- Improved customer satisfaction (better outturn of shipment);
- Reduction in cargo damage claims; and
- Reduction in pilferage.

INHIBITING FACTORS

Offsetting the factors influencing the growth of containerization were a number of negative factors that tended to inhibit or delay containerization development. A few of these are discussed here.

Labor Union Work Rules

Longshore labor has had a long history of bitter opposition to the introduction of mechanization that carried the threat of a loss of jobs. This factor was particularly strong in ports like New York, which were plagued with a surplus of labor. In Bombay, an automatic grain loader rusted away on the dock while the longshoremen continued to bag grain by hand as they had always been accustomed to doing.

Labor-Management Relations

Enlightened leadership on the part of both unions and management has been late to appear on the waterfront. Open warfare has been the order of the day, and strikes have been frequent and long. Industry-wide bargaining has yet to be achieved. The West Coast M&M agreement discussed earlier was the first big breakthrough.

Lack of Research and Planning

The level of research and planning in the steamship industry has been low compared to other industries. Several case histories of individual companies are discussed in Reference 1. Unless research is fostered and recognized at high levels in management, innovation is not likely to occur.

Conservative Management

Perhaps just because it is a very old business, steamship operation has been generally noted for its conservatism and traditionalism. This kind of atmosphere tends to stifle initiative and innovation. One illustration of this is the history of government efforts to promote higher ship speeds. In the late 1930s, the CIMMARRON class of tankers were built with additional power to give these ships the speed the Navy would need if the ships were to be utilized as fleet oilers. This additional power was paid for by the government as a defense feature, since the oil companies who operated the ships maintained they could not operate them profitably in commercial trade at the higher speed. Subsequently, however, the operators did utilize the additional power and regularly operated these tankers at the higher speed.

A similar situation occurred in the case of the MARINER class cargo ships. As a result of the protestations of the subsidized operators that the 20-knot designed speed was uneconomical, the ship sale price was reduced to correspond to an 18-knot speed. Again, it was discovered that after going into service the ships were being consistently run at the 20-knot speed and, to a man, the purchasers agreed to buy the additional power.

Steamship Conferences

Membership in "conferences" is quite common in the foreign liner trade. The conferences do bring stability to the business by establishing pooling arrangements and standardizing tariffs, but by so doing tend to stifle competition and therefore innovation. The early reaction of the conferences to containerization was to charge premium rates for this mode of shipping.

Capital Investment

The greater capital investment required to operate a large-scale intermodal container system must be considered as an inhibitor. On the other hand, this factor could be changed from negative to positive for a company that has sufficient capital.

Government Subsidy

Subsidies to the shipbuilding and shipping industries authorized by the Merchant Marine Act have the merit of putting the U.S. operator on an equal footing with his foreign competitor while maintaining the high standard of living for his employees. However, they do extract a price in the form of restrictions such as a limit on profit, which adds to the difficulty of attracting investors. They also have a tendency to act as a crutch to inefficient management.

Government Regulation

Rehandling of cargo from one vehicle to another at the waterfront, which occurred in the break-bulk system, provided an ideal situation for customs inspections. Under the new system, the loaded container can be transferred from one transport mode to another without disturbing the contents, thus limiting the opportunity for customs examination.

Tariffs for land transport are regulated by the ICC, and for water by the FMC, so that both agencies must be dealt with in the intermodal rate-making process.

Inadequate Port Facilities

The development of containerization was inhibited in certain undeveloped areas of the world served by ports with only primitive handling equipment and transport vehicles.

Shipper Education

General lack of an adequate program for educating the shipper on the advantages of containerized shipment has probably been a deterrent to the growth of the shipper-loaded container mode.

THE FUTURE

In a recent paper an official of Matson, one of the early pioneers in container shipping, warned that the Golden Era of Containerization is over. The big, early gains realized from the new technology have been partly overtaken by inflation, and the cost of capital has replaced port costs as the big economic factor.

The containerization experiment is now some 20 years of age. There is no doubt that it has found worldwide acceptance. But, are we better off? Has it brought long-run benefits or are we back where we started? Have we merely improved one economic factor at the expense of another? The answers to these questions are not easy to come by. Intuitively, one feels that progress has been made. Proving it with numbers is difficult.

Certainly, from a technological viewpoint, intermodal containerization is a success and it would be difficult to imagine going back to the old break-bulk system. The intermodal system providing "shipper-to-consignee", "door-to-door" service is a much more orderly, logical system. It is "a better way." The huge capital investment that has already been made in ships, containers, and specialized terminals would alone virtually rule out any turning back.

The growth of containerization in some trades has been nothing short of phenomenal. Figures recently obtained from the Port Authority of New York and New Jersey show that 75 percent of all general cargo passing through this port is now containerized. Approximately 70 percent of the vans are shipper loaded. They are also confidently projecting future growth as indicated in the following figures:

	*Number of Containers TEU	Long Tons
1975	1,750,000	11,680,000
1976	2,040,000	13,100,000
**1977	2,000,000	13,000,000
1978 (est)	2,250,000	14,500,000

*Includes RO/RO
**Longshore strike

The first 20 years featured hardware development. It is likely the future gains will come more in the area of organizational and management streamlining of the system, particularly the intermodal aspects.

REFERENCES

1. Henry S. Marcus, Planning Ship Replacement in the Containerization Era, Lexington Books, Lexington, MA, 1974.

2. L. A. Harlander, "Engineering Developments of a Container System for the West Coast Hawaii Trade," paper presented at Northern California Section, Society of Naval Architects and Marine Engineers, June 1959.

3. Raymond Newman, "The Relationship Between Ships and Terminals," paper presented to the New York Section, Society of Naval Architects and Marine Engineers, March 1965.

4. Robert Pfeiffer, "Containerization, 19 Years After Inception," unpublished speech presented to Seatrade Conference on Pacific Shipping, San Francisco, June 1977.

5. Douglas C. MacMillan and T. B. Westfall, "Competitive General Cargo Ships," paper presented at Annual Meeting, Society of Naval Architects and Marine Engineers, November 1960.

A FEDERAL DEMONSTRATION PROJECT: N.S. SAVANNAH

John G. Wirt

In 1955, the Eisenhower administration announced a plan to build the world's first nuclear-powered merchant ship, as part of the U.S. Atoms for Peace program. This ship was later called the N.S. SAVANNAH, after the first steam-powered ship to cross the Atlantic ocean. Like its steam-powered predecessor, the N.S. SAVANNAH had a history of mixed successes. Because of development problems, it was launched later than originally planned. No sconer were the shakedown cruises completed than it had to be detained in port for a year because of a union dispute. Success finally came in a series of demonstration voyages over the next two years to ports around the world. Large crowds came aboard at each stop to see this purported ship-of-the-future. But in subsequent service as a general cargo ship, the N.S. SAVANNAH cost considerably more to operate than could be earned in revenues, casting doubt on the idea that nuclear-powered merchant ships could be commercially successful.

In 1970 the ship was retired and given to the city of Savannah, Georgia, as a memorial to President Eisenhower. The total cost of the N.S. SAVANNAH to the federal government had been over $100 million, and the Maritime Administration still has to pay a small amount each year to provide safeguards against some radiation hazards.

DEMONSTRATION GOALS

Whether the N.S. SAVANNAH was a success or not depends on how one views its purposes. As a "peace" ship, the N.S. SAVANNAH helped to pave the way to using the atom for commercial purposes. It demonstrated that nuclear power could be safely applied for practical purposes and provided valuable experience in developing workable safety measures. As a "merchant" ship, the N.S. SAVANNAH was not successful and probably set back the introduction of the innovation of a nuclear-powered merchant marine for many years. These two different purposes, as well as many constraints, were imposed on the N.S. SAVANNAH project by the exigencies of the political process. The ensuing compromises that had to be made in the ship's technical design rendered it less suitable for either purpose than it could have been and led to a series of events that even obscured the successes that were achieved. The technical experts realized the difficulties, but saw the N.S. SAVANNAH project as a wedge in the political process that could be capitalized upon to build the technological and institutional base for a nuclear-powered merchant marine.

President Eisenhower's original concept was to build a ship that could sail around the world to dramatize the harnessing of the power of the atom for the benefit of mankind. His goal was to change the prevailing image that nuclear power was mainly an instrument of war. The White House saw, and there was further testimony in Congress by Admiral Rickover and others, that the technology was not yet available for the ship to be a demonstration of the commercial feasibility of nuclear propulsion for merchant ships. Advancing the idea that the atom could be used for peaceful purposes, whether to propel a ship or to generate electric power, was the overriding initial need.

It was suggested to the White House that the quickest way to get an atomic-powered ship to sea would be to install a spare reactor from the Navy's development program that had just produced the U.S.S. NAUTILUS submarine. No other reactor existed that was even remotely suitable for installation in a ship; any other approach would require a major research and development effort. Using a reactor developed by the military for defense purposes, however, was inconsistent with the concept of a "peace ship"; moreover, its use might set a precedent for military control by the federal government, not only in nuclear power for merchant shipping, but also in other applications. For these reasons, the Eisenhower Administration was reluctant to use the spare U.S.S. NAUTILUS reactor, even though it offered the simplest solution. More important was the need to establish the institutional precedent (which the N.S. SAVANNAH eventually did help to achieve) that there should be civilian control of nuclear programs for civilian purposes. Part of the institutional change was to gain declassification of the necessary technical knowledge, then tightly held by the military.

Chairman Bonner of the House Merchant Marine and Fisheries Committee and other Committee members supported the President's idea of building an atomic ship, but for a different purpose -- to take the first step toward a commercial fleet of nuclear-powered merchant ships. The Committee thought that a nuclear fleet could return the decaying American merchant marine to the eminence over the fleets of other nations that it had decades earlier. The testimony of Admiral Rickover and others that the Navy reactor would be extremely expensive to operate in a merchant marine application convinced the Committee that a new reactor should be developed that would be as economically efficient as possible, even though this would require more time and expense than the Administration had planned. Time was a critical factor because the Atoms for Peace initiative, for which the ship project had been conceived, was developing rapidly. Chairman Bonner criticized the Administration's proposal as a plan for building a "...sideshow ship, or a carnival ship, or a Mississippi riverboat."

Another major obstacle for the nuclear-powered ship project was conflict between the Merchant Marine and Fisheries Committee on the one hand and the Joint Atomic Energy Committee on the other. The Joint Atomic Energy Committee had complete jurisdiction over all activities of the federal government in atomic energy, which hampered the efforts of the Merchant Marine and Fisheries Committee to promote a nuclear-powered merchant marine. Members of the Joint Committee testified in the House of Representatives against the efforts of the Merchant Marine and Fisheries Committee to pass a bill authorizing the construction of a nuclear-powered ship. The White House had to make special overtures to the Joint Committee, which finally paved the way for passage of a bill.

TECHNICAL DESIGN

The bill was finally signed on October 15, 1956, nearly 1.5 years after the President's initial announcement of his plans. The President's statement accompanying his signature of the bill clearly showed the shift that had occurred during the negotiations with the Congress, from an objective of building a peace ship to one of building a "...floating laboratory, providing indispensable information for the further application of atomic energy in the field of ocean transportation." The House Senate conference report stated the new purpose even more strongly in specifying that this "...first experimental application of nuclear power should be a practical merchant vessel of combination passenger and cargo design, and that a new reactor of the most advanced design possible for a practical merchant ship should be developed" (emphasis added). This new objective was a technological contradiction. Responsibility for managing the design, construction, and operation of the ship was assigned to a joint project of the Maritime Administration and the Atomic Energy Commission.

The technical experts in the Maritime Administration had argued that a large, bulk freighter or tanker would have provided a much more economical vessel. The White House directed that, to be useful as a peace ship, it had to be sufficiently small to enter municipal harbors around the world and carry passengers. An all-passenger ship could have been designed, but that would have been prohibitively expensive to build because of the cost of providing accommodations.

The compromise was to build a small, combination passenger and general cargo ship, even though it was clear that the resulting vessel would not be commercially efficient in either service. The design was to modify a standard MARINER class freighter hull to accept a reactor and to provide for passengers. Additional compromises in outfitting the ship to give it a more streamlined and pleasing appearance further reduced its efficiency in cargo service.

Development of the propulsion system and safety measures required solutions to many technical problems. A decision was made to build a low-enriched, pressurized-water reactor, because it offered the best operational characteristics, even though no prototype had ever been built. The U.S.S. NAUTILUS-type reactors and the Shippingport demonstration of a reactor for central-station electric power generation provided some operational experience and technology but were differently designed. Other central power station reactors were under development at the time, but they were much larger than what was needed for the N.S. SAVANNAH and had not been operated commercially. The state of knowledge about small, low-enriched reactors was so crude at the time that the development contractor discovered that if they had followed their initial design specifications they would not have been able to make the reactor go critical. Nevertheless, a reactor was produced that worked well, even though a substantially longer development period was required than was originally planned. Contrary to conventional R&D practices, no prototype was built; the only model constructed was installed in the N.S. SAVANNAH -- a step for which the project team was heavily criticized by the Navy.

Further difficulties were encountered in finding a shipbuilder, since all the yards with nuclear experience were booked by the Navy and did not bid on the Savannah project. The shipyard eventually chosen had no nuclear experience and furthermore was in bankruptcy. This meant that the N.S. SAVANNAH project team literally had to lead the shipyard through the process of building a nuclear ship, a far more intricate and exacting process than building a conventional ship. This was another way in which the lack of nuclear technology in the associated industry delayed the project.

DEMONSTRATION OPERATIONS

After launching N.S. SAVANNAH in early 1962, the team began to run into labor problems, partly because of the implications of nuclear propulsion for the crew and partly because of unrelated political conflicts among the unions involved. The first firm selected by the government to operate the ship had contracts with separate unions: deck officers were members of the International Organization of Masters, Mates, and Pilots, which was aligned with the National Maritime Union (NMU), whereas the engineers were represented by the National Maritime Engineers Beneficial Association, which was aligned with the Seafarers' International Union (SIU). Because of the technical knowledge required to operate a nuclear-powered ship, the engineers wanted to be paid more than the deck officers, whereas on conventional ships deck officers had always been paid more. Also, the SIU and the NMU were bitter rivals. The impasse was not broken until a year later when the Secretary of Commerce finally canceled the first operator's contract and contracted with another one in which both the deck officers and the engineers were members of the same union. Meanwhile, the N.S. SAVANNAH had to be taken out of service and was tied up in port. These labor problems turned nearly everyone against the N.S. SAVANNAH, from Chairman Bonner to President John F. Kennedy. Kennedy and his Secretary of Commerce had to deal with the problems and did not have the same commitment to the ship that Eisenhower had shown.

During the next year, the N.S. SAVANNAH cruised around the world, visiting many ports so people could come aboard for trips and view the new ship for themselves. These voyages were a great public relations success for the United

States, although they were somewhat too late to make a significant contribution to the Atoms for Peace initiative because of the delays that had occurred.

Subsequent to its demonstration cruises, the N.S. SAVANNAH was operated under charter for an additional 5 years as a general cargo ship in regular commercial service. At this stage the design compromises and technical shortcuts that were made in building the N.S. SAVANNAH came to the surface. The reactor worked well, but the ship was not a good freighter. The passenger compartments and the swimming pool became wasted space when they were closed off; the winches and other freight-handling gear were too light; and crew turnover was high. All of these problems increased the costs of operation compared to a conventional ship. Revenues from the N.S. SAVANNAHs operations failed to approach the direct and indirect subsidies that were provided to maintain operations. (The federal government gave the N.S. SAVANNAH to the charter company for $1.00 a year.) Then, despite the expenses of the ship operations, the Johnson administration was prevented from withdrawing the ship from service by Congressional outcries.

A futile search began for a better use of the ship. And, compounding these difficulties, Congress required the Maritime Administration to fund the substantial operating costs from its small R&D budget. All of this contributed to a general perception in many quarters that the N.S. SAVANNAH had been a failure. Long forgotten were the reasons why it was built and why it was not the ship that it could have been. The lessons are twofold: politics and the commercial application of new technology do not mix well, and a technology should be well in hand before being sold as ready for commercial application.

SECOND-GENERATION DEVELOPMENT

Throughout the period when the N.S. SAVANNAH was being developed, and during the initial years of operation, the N.S. SAVANNAH project team was actually working behind the scenes to develop much more advanced reactor designs and study efficient applications of nuclear power to merchant shipping. Using the base of popular support initially created by the N.S. SAVANNAH project, the team wanted to proceed with the development of a second-generation fleet of ships that would be much closer to the commercially successful vessels that had been envisaged. A much-improved reactor was eventually developed and tested. Design studies showed that for nuclear ships to be commercially successful they had to be (a) much larger than any ships then on the seas, (b) dedicated to a highly specialized service like bulk transport or containerized freight, an innovation that was only beginning to be introduced at the time, (c) operated at high speeds, and (d) built in fleets rather than singly, and with their own port facilities. All these features together were necessary to offset the much greater capital cost of a nuclear-powered ship as compared to a conventional one.

But each requirement implied a major innovation in merchant shipping. (For example, hulls weighing several hundred thousand tons -- the required range of efficient nuclear-powered ships -- have not been built until recent years.) Consequently, attempts to convince the administration and the Congress on building a fleet of second-generation ships fell on deaf ears, and then the N.S. SAVANNAHs problems further clouded the picture. The second-generation reactor has been used in the nuclear-powered merchant ship built by the Germans and also in the one built by the Japanese. There have also been some land-based applications. Because many of the innovations seen by the N.S. SAVANNAH team as necessary to the successful merchant shipping application of nuclear power have not become realities until recent years, it appears that, while the visions of the team were correct, they were probably premature by at least a decade. Current studies of nuclear-powered merchant ships recommend the same kinds of design features for commercial feasibility and are beginning to indicate that the gaps in the development of ships that would be commercially profitable can be bridged.

PROJECT RESULTS

Despite the difficulties encounted by the N.S. SAVANNAH project, results were achieved in both advancing technology and developing an institutional base for nuclear-powered merchant shipping that should be more widely recognized. Technical contributions were the reactor, which provided valuable design experience; the safety and containment systems, which worked well and showed how costs could be minimized; and the crew training program, which showed that regular merchant seamen could be trained to operate a nuclear ship. The institutional effects were (a) the experience that was gained in working with foreign governments and federal agencies to establish port safety requirements and clearance procedures; (b) the precedents set in negotiating agreements on liability with foreign governments; (c) the contributions, however difficult to trace, to declassifying nuclear technology; (d) the precedent of having congressional committees other than the Joint Atomic Energy Committee oversee nuclear projects; and (e) possibly some encouragement given to operators and unions to accept higher levels of ship automation. (Ships with automated control rooms have been built since, whereas before the N.S. SAVANNAH, there were none.) Additionally, the N.S. SAVANNAH provided some valuable baseline data for setting insurance rates for nuclear powered ships. However, the labor problems that plagued the N.S. SAVANNAH were apparently not solved. Equally important, the high costs of the project still have lingering effects.

THE NATIONAL SHIPBUILDING RESEARCH PROGRAM: A CASE STUDY OF INNOVATION IN THE MARITIME INDUSTRY

Linda L. Jenstrom

During the past two decades, increasing attention has been given to examining the process of industrial innovation and technological change. The federal government has sponsored a variety of projects and programs in an effort to stimulate the innovative process in both defense and non-defense industries. Although the results of federally supported research and demonstration efforts have generally been mixed, one project, the National Shipbuilding Research Program, has achieved substantial gains.

The achievements of the National Shipbuilding Research Program are particularly impressive because the program focuses on a sector of the maritime industry that traditionally has had few of the characteristics usually associated with ongoing technical change. The shipbuilding industry has been forced to cope with a slow growth rate, unstable market demands, heavy capital investment requirements, low investment returns, and a high rate of staff turnover. Such conditions usually foster security-seeking behavior, not risk-taking. Consequently, an analysis of the positive impact of the National Shipbuilding Research Program on the climate for and rate of innovation within this industry is of particular importance.

The National Shipbuilding Research Program is a collaborative effort of the federal government and the shipbuilding industry. The program is unique in that it is founded on the premise that innovation and technological change can best be fostered when research is undertaken as a joint venture of government and industry. The objectives of the program are to improve the productivity of the shipbuilding industry and to reduce government subsidies to the industry.[5] Since its inception in 1971 (through FY 1978), over 125 projects have been funded by the government, at a cost of $21 million. The industry has contributed approximately $8 million to these projects in the form of manpower, materials, and facilities.[8] The National Shipbuilding Research Program has been judged highly successful in an independent comparative study of federally funded demonstration projects,[1] and in both formal[2] and informal assessments[5] conducted by the program participants.

A careful examination of the genesis and development of this program yields a considerable amount of useful information about the innovative process within the maritime industry. On one level, the program itself can be viewed as an innovation. It embodies a new philosophy, has an unusual management design, and is without precedent in the history of U.S. government-maritime industry relations. On a second level, examination of the way the National Shipbuilding Research Program functions provides a unique perspective on the innovative process. The program exists to create and ensure the use of new technologies in shipyards. Thus, analysis of the mechanics of the program, its successful and unsuccessful projects, and the programmatic changes that have taken place sheds light on the factors that can inhibit or encourage technological change.

Finally, the National Shipbuilding Research Program has helped create a new environment within the shipbuilding industry. Many of the barriers to change that existed in 1970 have been substantially reduced. New opportunities for intra- and inter-industry cooperation have been opened. The credibility of the federal government has been enhanced, and there is new recognition of the importance of the shipbuilding industry to the U.S. maritime industry as a whole. To understand the impact of the National Shipbuilding Research Program, it is necessary to begin with a look at the conditions prevailing in the industry at the time the program was founded.

TIME FOR A CHANGE

As the decade of the sixties drew to a close, there was widespread recognition of the need for substantial changes in U.S. maritime policy. Significantly, the thrust toward a new approach to the problems plaguing the shipbuilding industry can be traced independently through the political sphere, the private sector, and the U.S. Maritime Administration (MarAd). It may be that the initial success of the National Shipbuilding Research Program was a product of convergent and complementary political, private, and bureaucratic aims.

The Economic Environment

The post-World War II decades brought a steady decline in the economic strength of U.S. shipyards. In the years immediately following the war, over 7 million deadweight tons of ships were sold by the U.S. Maritime Commission (now the U.S. Maritime Administration) to U.S. operators at bargain-basement prices.[7] Consequently, orders for new construction were few and far between. Further, U.S. operators, unlike their foreign counterparts, adopted a policy of depositing capital in construction accounts as a hedge against future needs for replacements or repairs. Foreign operators continued to reinvest capital in new ships that secured competitive advantages through innovations in design and equipment. Unfortunately, orders for new ships generated by foreign operators generally went to foreign shipyards since cost differentials effectively excluded the U.S. yards from realistic competition.[3] Thus, both the U.S. merchant fleet and the U.S. shipyards fell further and further behind their foreign counterparts.

At the end of World War II, there were 57 U.S. shipyards actively building oceangoing vessels. By 1970, there were only 14 major U.S. yards.[6] These 14 yards can rightfully be called the survivors. These were the yards that were able to limp along on the sporadic orders generated by U.S. operators, the Navy, and other branches of the government. In general, the orders fluctuated as the international scene fluctuated. For example, the Korean War, the closing of the Suez Canal, and the Viet Nam War brought temporary increases in the market demand for new ships. Unfortunately, each increase was closely followed by a fairly precipitous drop.[4] Without a predictable and stable workload, shipyard managers had little incentive or opportunity to improve their facilities. The erratic market was not conducive to the development of a planned production approach or to the maintenance of a stable, skilled work force.[6]

The downward spiral of the U.S. maritime industry is well documented. By 1970, the U.S. merchant fleet was no longer among the top five fleets in the world. There were low returns on industry investment, and U.S.-flag vessels carried an ever-declining share of world trade. Although U.S. foreign trade had been steadily increasing, rising from 120 million tons in 1950 to 470 million tons in 1970, the U.S.-flag share of this market had dropped from 53 percent to 6 percent during the same period.[4] Clearly, the provisions of the Merchant Marine Act of 1936 had proven unequal to the task of supporting either an adequate shipbuilding industry or an adequate U.S. merchant fleet.

The Merchant Marine Act of 1970

By 1970, political inaction was no longer a defensible position. Some argued the urgent need to pass legislation that would revitalize U.S. maritime interests. Others held that the federal subsidy program should be dropped entirely. When the dust settled, the nation had a new legislative mandate known as the Merchant Marine Act of 1970. As proposed by President Nixon and, ultimately, passed by Congress, the 1970 Act was the first major overhaul of national maritime policy in three decades.

The Act affirmed the importance of merchant shipping to the welfare of the country. It provided for ten years of federal support to both the shipbuilding and the ship operating industries. It extended subsidy payments to non-liner services and authorized negotiated contracts between operators and builders, with subsidy payments going directly to the builder. The Act also expanded the existing authorization for federally supported research and development efforts.

Prior to passage of the 1970 Act, there was no technical program within MarAd to support the shipbuilding industry by conducting research aimed at identifying less costly and more efficient ways of constructing ships. The 1936 Act had, however, provided authorization for federally sponsored research projects conducted in collaboration with ship operators. Such projects were generally aimed at improving ship design, ship machinery, and cargo handling. As the provisions of the 1970 Act were being formulated, MarAd officials worked to have the 1936 authorization expanded to include the shipbuilding industry. The Act, as passed, specifically included shipbuilders, thereby giving MarAd the authority to launch a new program. Further, the President's message which accompanied the act explicitly supported the establishment of a cooperative research and development program. The message called for an enlargement and redirection of maritime research programming with a greater emphasis on practical applications and coordination with industry.[10]

MarAd was given responsibility for implementation of programs designed to enable the industry to meet the objectives of the 1970 Act. These objectives were quite specific. Plans called for the construction of 300 new ships in ten years. The proposed building program was valued at about $6 billion, with approximately $2 billion provided by the government in the form of subsidies. In an effort to stabilize the industry and assist in the development of long-range planning, MarAd undertook a variety of projects. Among these was the development of a new program of shipbuilding research to be conducted in partnership with the industry. The new program was christened the National Shipbuilding Research Program.

The Maritime Administration (MarAd)

The National Shipbuilding Research Program was not an afterthought. In the late 1960s, a new concept of research and development management had begun to emerge in the Office of Advanced Ship Development (OASD), a division of the Office of Commercial Development of MarAd. The premise was that development projects should not be initiated without a realistic measure of industry interest in the potential results. In the latter months of 1969, a proposal for the formation of an industry council to advise MarAd on research and demonstration projects was presented to the Maritime Administrator by J.A. Higgins, who was then the Director of OASD, and J.J. Garvey. (Mr. Higgins is now Deputy Director of the Office of Commercial Development, and Mr. Garvey is Director of the Shipbuilding Research Program Office.) The Maritime Administrator lent his support to the developing plan.[10]

With shipbuilding specified in the authorizing legislation, and with the general reorientation of federal non-defense research and demonstration efforts, the OASD staff felt that it could move forward with a clean slate to implement a program that would be truly responsive to the needs of shipbuilders. A basic philosophy of the new program was an attempt to avoid previous errors committed in the name of maritime research and demonstration. In particular, the OASD staff was determined to fund only those projects that could and would be used by industry.[10]

The task of designing and implementing a viable industry-government collaborative research and demonstration program was formidable. The first step was to define the program. It was concluded that, to be in compliance with the intent of Congress and the President, the program must emphasize practical applications and be conducted in close cooperation with the shipbuilding industry. Further, the projects sponsored by the program should be (a) of a scope and nature to require cooperative development; (b) directed toward reducing government subsidies as well as shipbuilding costs; (c) of a near-term nature; (d) limited to improving the shipbuilding process; and (e) supported through cost-sharing between government and industry.[5]

The second major step was to find a means of ensuring that the new program would be truly a joint venture between government and industry. There were few, if any, precedents. In particular, a reliable means had to be found of bringing together industry representatives and ensuring that they, not the government, defined the program's research objectives. OASD staff felt that it would be advantageous to cooperate with an existing group of industry representatives, since such a group would be more likely to be self-directed.

A search began for an appropriate group to represent the managerial and technical views of the industry. The selection was critical, since the group was expected to participate actively in all aspects of the technical management of the program, including setting priorities, assigning responsibility for projects, providing technical direction, and assisting in arranging appropriate demonstrations. In addition, it was important that the group selected be characterized by inclusivness; that is, the group should be open to individuals with a vested interest in the industry and with valid reasons for involvement. After exploring several alternatives, the ideal candidate group emerged -- the Ship Production Committee of the Society of Naval Architects and Marine Engineers (SNAME).

SNAME: The Ship Production Committee

The founding of SNAME's Ship Production Committee provided the final link in the convergence of political, administrative, and private industry interests that led to successful launching of the National Shipbuilding Research Program. Established in 1893, SNAME is a professional association with approximately 14,000 members. In 1939, SNAME started a Technical Research Program to provide limited funding for selected projects in a variety of areas. SNAME's Technical Research Program now includes projects focused on marine systems, hull structure, hydrodynamics, ship machinery, and ship technical operations.[9] Notably, prior to 1969, SNAME-sponsored research projects did not include ship production as an area of interest.

In 1969, a group of ship production engineers and managers sought to remedy this omission by establishing a forum within SNAME specifically for professionals involved in ship production. The group was displeased by heavy public criticism of the industry and keenly aware of the growing discrepancy between the technical capabilities of

American and foreign shipyards. It was interested in finding ways of expanding the technical knowledge base and developing new solutions to the problems mutually faced by all of the shipyards. The members of the group felt that shipyard engineers should be working with ship operators in designing new vessels, rather than simply receiving specifications from naval architects. The low status of ship production engineering in the maritime hierarchy was evidenced, the group felt, by the lack of a technical committee for specialists in ship construction. The formation of a Ship Production Committee in SNAME was urged. The proposal received strong support from top-level shipyard management and was formally approved by SNAME in July 1969.[10]

The newly formed Ship Production Committee had several characteristics which were destined to contribute substantially to the success of the National Shipbuilding Research Program. Its membership predominantly consisted of senior technical and managerial personnel from the shipbuilding industry. It included representatives of the Coast Guard, the Navy, MarAd, and the American Bureau of Shipping. In addition, the Ship Production Committee was less than six months old and had not yet established a firm operating program. Finally, it was organized under the auspices of a recognized and prestigious professional society, and had the support of most U.S. shipbuilding firms.

THE OBSTACLE COURSE

Although there were significant factors stimulating the evolution of the National Shipbuilding Research Program, there were also significant barriers to its implementation and subsequent functioning. In the course of its seven-year operation, some of these barriers have been reduced or eliminated. Others are targets of new programming efforts, and some are beyond the realistic scope of a technical development program.

Industry Competition

In 1970, there were a number of obstacles to establishing the new program. One of the most significant obstacles was the nature of the industry itself. Shipbuilding was, and still is, a competitive industry. Personnel, particularly production personnel, were actively discouraged from sharing their information or expertise with competing firms. The lack of any formal professional group for production personnel had effectively limited the development of a sense of camaraderie and mutual interest. It is important to note, however, that the Ship Production Committee was founded independently and in advance of MarAd's efforts to establish a cooperative program with the industry. Although the shipyards were still reluctant to abandon their long-standing competitive practices, the economic realities of the late 1960s underscored the need to explore new approaches to the practical problems of ship production. As the program progressed and the financial and practical advantages of cooperative action were demonstrated, the yards gradually modified their competitive stance. The identification of solutions to mutual problems came to be viewed as a mutual advantage.

Industry Priorities

A second major obstacle to the new program was the low priority given research and demonstration efforts within the shipbuilding industry. On a national level, studies showed that shipbuilders spent less than one-quarter of one percent of their annual revenues on developmental research.[5] Factors contributing to this low level of interest in research included the potential cost of downtime due to failure of experimental systems, the cost of insurance to cover direct losses and consequential damages during tests, and the potentially small profit to be derived from an innovation.

The new program allowed MarAd to assume the impact of many of the risks associated with technical research and demonstration. Although the program is based on government-industry cost sharing, the government provides funds for all direct costs; industry provides facilities and overhead costs.

Government Credibility

A third major obstacle was that the industry tended to take a dim view of the effectiveness of government-sponsored research programs. During the initial series of meetings between OASD staff and the Ship Production Committee, members of the committee were skeptical. There was a general feeling that the OASD staff was not proposing anything new and that the program would collapse after a short time. There was doubt that the government really wanted advice. Rather, it was assumed that the new program was simply a marketing strategy designed to sell industry on a preconceived plan for technological improvement.[10] Finally, should the program succeed, the industry representatives felt that OASD would use the success to increase its own share of the MarAd budget and ultimately assert total control over the program. The concept of bureaucratic empire-building was all too familiar to the shipbuilders. The OASD staff went about overcoming this mistrust in the only practical way, through concrete demonstrations of their intent to ensure that the program was responsive to the industry and cooperatively managed.

Legal Issues

The atmosphere of suspicion surrounding the initial meetings held to discuss the new program was heightened by the traditionally adversarial role of MarAd vis-a-vis the industry. The MarAd subsidy program had a history of contract disputes that had strained government-industry relations. Further, many of the yards had recently been charged by MarAd with violations of the Equal Employment Opportunity regulations. Finally, the shipyards were wary of running afoul of the government's antitrust laws.

On the strength of the changes in the Merchant Marine Act of 1970 and the public statements of the administration outlining the need for cooperative research and development programs designed to increase the technological capacities of industry, the spokesmen for OASD set about persuading industry representatives that the new program was not a violation of antitrust laws. OASD staff visited the top executives of all the shipyards to discuss the new program. During the course of these visits, they explained that the program would not exclude any American yard from participation and that the prices of ships would not be discussed at any of the meetings. The OASD staff also explained that there were precedents in the law firmly establishing the right to exchange technical information in organizations that are a part of a professional technical society. Finally, the OASD staff argued that, in a joint effort, there would be a joint assumption of any legal risks. Following this series of meetings, all of the shipyards, with the exception of one, which stayed out of the program until 1973, began to participate more actively in the new program.[10]

Program Strategy

The program strategy employed to overcome these obstacles was straightforward. The strategy had four elements: (a) encourage the shipbuilders to define their common needs and outline projects with a potential for meeting those needs; (b) arrange for the projects to be housed within the industry itself; (c) provide mechanisms to ensure the joint management of the projects; and (d) encourage implementation of the results of successful projects. By May 1971, the first list of industry-generated projects had been developed, approved by the Ship Production Committee, and funded by MarAd. By mid-1972, all of the shipyards, save one, were increasing their active participation in the National Shipbuilding Research Program, and the preliminary results from the program were favorable.[10] Key to this early success was the unique way the program was organized.

ORGANIZATION OF THE NATIONAL SHIPBUILDING RESEARCH PROGRAM

The National Shipbuilding Research Program has three major components. Industry plans and program recommendations are generated by the Ship Production Committee and its technical panels. Government management of the program is carried out by the Shipbuilding Research Program Office, Office of Commercial Development, MarAd. Program execution is carried out by Program Managers housed within the shipyards responsible for the administrative management of specific program areas.

The Ship Production Committee

The first component, the Ship Production Committee, is composed of top-level shipyard managers. In general, they represent the production side of their organizations rather than the finance or marketing sides. Representatives from the Coast Guard, the Navy, and the American Bureau of Shipping also serve on the Committee. Specific research projects are generated by technical panels that operate under the Committee's direction. The responsibilities of the Ship Production Committee include providing policy guidance on the overall direction of the program to the technical panels and to the MarAd office and reviewing individual projects submitted for consideration by the technical panels. Projects approved by the Ship Production Committee are fowarded to the Shipbuilding Research Program Office for funding.

The technical panels are structured to address areas deemed important to the improvement of the ship construction process. They may be established or discontinued as needed. In general, the technical panels are composed of mid-level engineers with production experience. Each panel has between six and forty members, with one representative from each of the major shipyards serving on most of the panels. In addition, each panel has a MarAd representative and, if appropriate, invited representatives of relevant regulatory bodies.

The technical panels meet individually four to six times a year to discuss production problems and possible solutions, develop specifications for new projects, and review the status of ongoing projects. Annually, each panel forwards specifications and budget recommendations for new projects to the Ship Production Committee. The Committee may ask a technical panel to modify its proposals or may approve them without change. Approved projects are forwarded to MarAd for funding consideration. If funds are allocated, the technical panel is asked to participate in the selection of project sponsors and/or contractors. Technical panels also act as advisors to Program Managers on technical issues arising in the course of project implementation.

The Shipbuilding Research Program Office (MarAd)

The second major component of the program is the Shipbuilding Research Program Office of MarAd. This office is responsible for government management of the program. The office is small, consisting of a director and one assistant and, therefore, has been able to maintain flexibility in dealing with the industry. The Shipbuilding Research Program Office has divided its budget into four major areas: facilities; manpower and motivation; ship producibility; and shipyard automation. In general, the technical panels are grouped under these headings as shown in Figure 1.

The annual list of approved projects, with technical and economic justifications, is fowarded by the Ship Production Committee to this office for review. The recommended projects are evaluated on the basis of economic and technical criteria, and priorities are established. The recommendations, or portions of them, are then submitted to the Maritime Administrator for approval within limits of the available budget. During the first seven years of the program, approximately 75 percent of the projects submitted

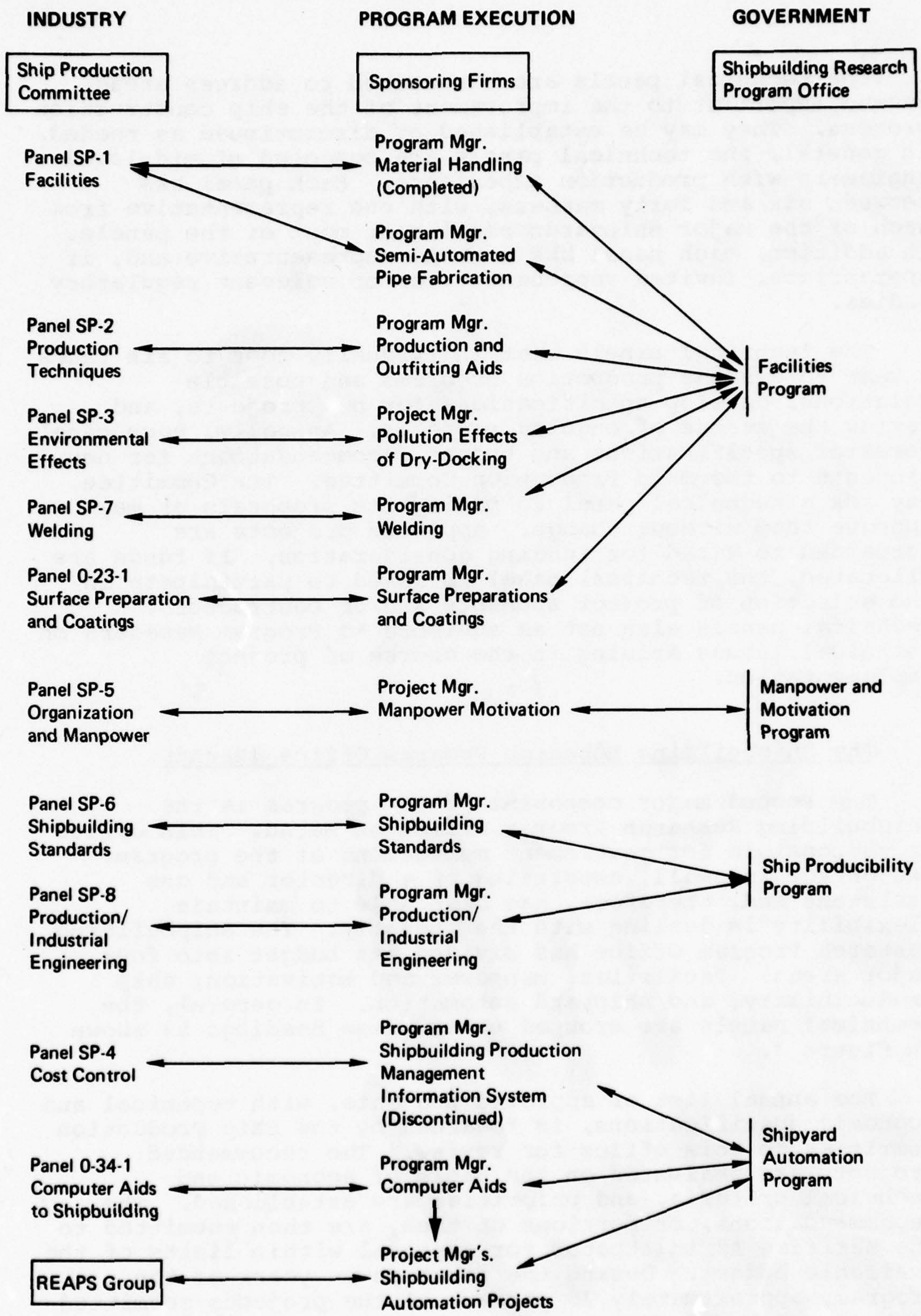


FIGURE 1

NATIONAL SHIPBUILDING RESEARCH PROGRAM

by the Ship Production Committee were approved by the Maritime Administrator. In addition, two programs were terminated on advice of the Ship Production Committee.[8]

Program Managers

Under the joint direction of the Ship Production Committee and the Shipbuilding Research Program Office, individual shipbuilding companies take responsibility for implementing groups of approved projects addressing specific areas. Projects are carried out under a cost-sharing contract negotiated between MarAd and the sponsoring company. Two criteria are used to select sponsoring companies. First, the company must be recognized as having a high level of technical expertise in the subject area. Second, the company must demonstrate a strong commitment to carrying out research under the guidance of the Ship Production Committee. This commitment is usually demonstrated by the willingness of the company to shoulder at least one-third of the cost of the program. At present, there are six companies acting as primary sponsors and three acting as secondary sponsors. These companies are responsible for conducting fifty-four projects in six program areas.[8]

Each of the primary sponsors selects a senior engineer to serve as full-time Program Manager. The Program Manager is responsible to both the Ship Production Committee and the program office of MarAd. The administrative functions of the Program Manager include responsibility for preparing contract specifications, soliciting bids, and monitoring projects and contracts. In addition, Program Managers conduct an ongoing review of the major technical decisions required during the implementation of various projects and provide or secure technical assistance for project staff as needed.

Newly funded projects are assigned to one of the Program Managers. The Shipbuilding Research Program Office confers with the Ship Production Committee in the assignment of specific projects to appropriate sponsoring companies and in the selection of any outside contractors. All projects, including those for which a contract must be let outside of the shipbuilding industry, are placed under the control of a Program Manager employed in one of the sponsoring shipyards.

The cost-sharing formula used by the program is simple. Direct costs, such as the salaries of the Program Manager and his staff and contract expenses, are paid by MarAd. The sponsoring shipyards assume all overhead costs, including office space and materials, and provide plant facilities for any projects conducted in shipyards. MarAd considers this to be an optimal cost-sharing formula since it minimizes paper work and does not require a cash outlay from individual firms.

THE INNOVATIVE PROCESS

The organization of the National Shipbuilding Research Program supports the innovative process in several important ways. First, the established mechanisms for selecting problem areas and defining potential projects ensure that new projects are reality-oriented, meet a problem that has industry-wide ramifications, and are defined after pooling all available technical knowledge. Second, the program structure facilitates the identification of new areas of research. Third, the program design incorporates a means of ensuring that the industry arrives at a consensus on research priorities. Finally, the structure of the program facilitates the rapid dissemination and use of research findings.

The Technical Panels

The activities of the technical panels are crucial to the success of the overall innovative process. Since the panels are composed of managers and engineers with line responsibility for ship production, the research projects generated by the panels are usually those that address the most pressing production problems of the industry. This arrangement fosters rapid adoption of research results. Further, since the technical panels concentrate on particular production areas, they tend to generate research projects that are interrelated. One project often complements another or leads to another. Thus, the technical panel structure fosters cumulative technological development.[10]

Greater use of existing information has been an important by-product of the technical panels. Since the process of formulating specifications for individual research projects usually requires pooling technical information, redundant research projects are avoided. As the work of the technical panels has progressed, a number of identified problems have been solved simply by sharing available data. Although the cash savings to both government and industry have not been calculated, a significant number of redundant research projects have been aborted on this basis.

In addition to assuring a reality-oriented approach to research, the technical panel structure has enough flexibility to permit program expansion in promising new areas. For example, by late 1972 the Facilities Panel had developed four successful projects in the area of welding. The Welding Program Manager recommended to the Ship Production Committee that a new panel be formed to focus solely on this area. The Welding Panel was approved by the Ship Production Committee and has proven to be one of the more effective panels in the program. Similarly, the Surface Coating and Preparations Panel emerged from successful projects generated by the Production Techniques Panel.[10]

Conference Strategy

Program expansion may also occur through the identification of new problem areas by the Ship Production Committee or by MarAd. The staff of MarAd's Shipbuilding Research Program Office has developed a problem-oriented conference technique that has proven useful in opening discussions in new areas. The technique reflects the basic philosophy of the program in its simplicity and non-directive approach.

When new problem areas are identified, the Shipbuilding Research Program Office convenes a two- or three-day conference for shipyard representatives and relevant technical experts. After an initial welcoming meeting, which includes presentations on the nature of the problem or problems to be addressed, control of the meeting is turned over to the participants, who assume responsibility for the remaining conference agenda.[10] Usually, MarAd staff does not participate in working group discussions.

The first conferences of this type were learning experiences for all concerned. Initially, industry representatives were convinced that MarAd officials intended to present the government's solutions to the identified problems at some point during the working sessions. Therefore, the conference participants waited patiently in their working groups, often for as long as a day. When it became clear that MarAd staff did not intend to join the working groups, the industry representatives took command and addressed the issues at hand.

Using the problem-oriented conference technique, new programs have been generated at the request of the Ship Production Committee in the areas of Ship Producibility and Marketing. The recently initiated Research and Engineering for the Automatic Production of Ships (REAPS) program grew out of a conference on the application of computers in ship production, a problem area identified by MarAd staff.

Establishing Priorities

The emphasis on a bottom-up approach to establishing research priorities through the technical panels has not precluded imaginative use of the program's framework to influence research priorities from the top down. Until 1975, the Ship Production Committee approved roughly equal numbers of projects for each technical panel at a total cost that was approximately equal to the projected budget of the Shipbuilding Research Program Office. In an effort to refine the priority-setting system, MarAd and the Ship Production Committee have agreed to a new means of establishing priorities that results in an allocation of resources to those technical panels able to develop the most cost-effective project proposals.

The Ship Production Committee now ranks its final recommendations according to low, medium, and high priority projects. The Shipbuilding Research Program Office requests funds sufficient to support all high-priority and some medium-priority projects and chooses the projects it judges to be of most value. The primary criteria used by MarAd and by the Committee in selecting projects is the potential cost-benefit of the expected project results. An objective formula for calculating estimated cost-benefit has been developed and adopted by both groups. The new system has tended to reward those panels able to generate projects that are of greatest potential cash value to the industry.

Dissemination and Implementation of Research Results

Finally, the National Shipbuilding Research Program fosters innovation by providing for rapid dissemination of research results and by encouraging rapid implementation. The members of the Ship Production Committee and the technical panels are prime movers in this dissemination and implementation process.

Since both top-level and mid-level shipyard managers and engineers are involved in the conception and management of the projects, they have a vested interest in making use of the results. If the results are ignored, their peers and their management may question why the projects were selected and supported in the first place. Moreover, these people are in key production positions. In short, they have both the motivation and the capacity to speed implementation within their companies. Finally, many of the projects are performed in individual shipyards, and most shipyard opt to continue or expand the projects at the conclusion of the demonstration phase. Therefore, in most cases, demonstration leads smoothly into practice in at least the originating yard.

The principal means of formal dissemination of project results is through demonstrations held in the sponsoring shipyard's facilities. Program Managers are responsible for organizing these demonstrations upon the completion of each project. Representatives from all of the shipyards in the country are invited. Although each shipyard is required to pay all expenses of staff who participate, attendance at demonstrations averages between 100 and 200 industry representatives.[10]

The demonstrations are judged by MarAd to be more effective than written reports in disseminating project results. The impact of seeing a new procedure or process in operation in a familiar setting is significantly stronger than any verbal description. Experience indicates that innovations are most likely to be adopted when they are considered to be of sufficient value by front-line personnel to warrant the risk of persuading top-level management to agree to the change.[10]

Projects that are contracted to current or potential suppliers to the shipbuilding industry have an additional dissemination mechanism. In many instances, the supplier decides to produce and market the equipment developed under federal contract to shipyards and, in some cases, to other industries. Although marketing by supplier firms is an important diffusion mechanism of the National Shipbuilding Research Program, its effective operation often depends on the supplier's willingness to undertake production and marketing. This decision is based on the supplier's perception of profit potential.

Last, and probably least important as a dissemination mechanism, is the distribution of final project reports. Program Managers are responsible for sending these formal reports to selected production managers in every shipyard. Information about the National Shipbuilding Research Program is also distributed through the MarAd Office of Public Information and through the committee structure of SNAME. The latter method has proven particularly effective. SNAME is enthusiastic about providing this service and underwrites the cost.[10]

PROJECTS AND BARRIERS

The large number of projects carried out under the National Shipbuilding Research Program precludes a complete discussion here. Nevertheless, a brief review of selected projects will help illustrate the impact of the National Shipbuilding Research Program, as well as identify some of the major barriers to change it has encountered since 1970. The most successful projects have been those which address improvements in existing operations. Projects attempting to apply technologies from other industries to the problems of shipyards have been less successful. Only recently have projects addressed some of the more entrenched barriers to innovation and technological change such as standards and regulations. However, these latter projects are of interest as indicators of the success of the overall effort to improve the innovative capacity of the industry.

The Welding Program: A Success Story

One of the biggest success stories in the program has been in welding. This project-group is notable for several reasons. It included one of the first projects that was successful without requiring research funds. It also provides a good example of the development of complementary research efforts. Finally, the welding program has had its share of setbacks, notably in the area of supplier withdrawal from marketing a newly developed product.

When the National Shipbuilding Research Program was started, four independent welding projects were included. One of these, the development of American-made gravity electrodes, was remarkable both for its success and its brevity. The process of drawing up the specifications for the electrodes relied on pooled technical information and produced a document that articulated the needs of the industry so clearly that an existing vendor agreed to produce and market the product. There was no need to fund a research or demonstration effort. While this is not an isolated example, it provided early and concrete proof to the industry of the value of a cooperative approach to problem solving.

Of the other original welding projects, two are of interest because they illustrate the impact of suppliers on the innovation process. One project was aimed at developing an American capability for one-sided welding of ship hull plates. The second was aimed at developing an improved automatic butt-welder. One-sided welding had a high potential cost savings. Moreover, a suitable machine was available from a foreign supplier, although the price was prohibitive. The automatic butt-welding project was aimed at developing a machine for welding erection master butts in all three positions: the bottom shell, the side shell, and the bilge radius. Vertical welders were available but had proven less than satisfactory in shipyards.[5]

Both projects were sponsored by a major shipyard under the direction of the newly formed Welding Panel. Both were completed successfully and demonstrated. There the similarity ended. The one-sided welding project was terminated after the demonstration. The company responsible for developing the project was a major supplier to the marine market. Yet, despite repeated assurances that the market for the product could be substantial, the company opted not to attempt to produce the product at competitive prices.[5]

The developer of the butt-welder, however, took a leadership role by developing an advanced general-purpose machine from the basic designs used during the project. The new machine was designed and built before all required welding processes for the bottom plate and bilge radius had been developed. Subsequently, another shipyard and a major supplier of products used in the welding process joined in supporting the non-federally funded research efforts needed to enable full use of the new welding machine.[5]

Recent trends in the types of projects undertaken by the Welding Panel illustrate the progressive nature of the innovation process. Innovation, once begun, tends to expand into more difficult and complex problem areas. For example, the problems encountered in the development of the new vertical-butt welding machine suggested the need to re-examine the standards for vertical and horizontal electroslag and electrogas welds. This initial foray into the area of standards and regulations was suggested by the representative of the industry regulatory body serving on the panel. As a result, other projects aimed at evaluating welding standards which restrict productivity have been formulated, but progress is slow. In general, standards and regulations tend to operate as barriers to innovation.

The Welding Program: Barriers to Practical Change

As mentioned above, the welding program has encountered barriers to change and had its share of setbacks. The different fates of the one-sided welding project and the butt-welding project illustrate some major barriers to innovation in the industry. First, the shipbuilding industry is dependent on and imbedded in a larger framework of American supplier industries, yet the industry has a relatively low purchasing power. For example, shipbuilders spend more for steel than for any other material, yet their purchases total less than 2 percent of the total steel mill output.[10] Therefore, shipyards lack the necessary economic leverage to induce supplier industries to develop new products.

The National Shipbuilding Research Program has not been able to overcome this supply-inertia entirely. Although the program provides the economic stimulus to develop new products, the decision to mass-produce and market these products is left in the hands of the suppliers. Because of the relatively low purchasing power of the industry, what may appear to be a substantial market from the point of view of the shipyards is, from the point of view of the supplier, not sufficient to warrant the capital investment required to produce and market the desired product. Experience indicates that the larger the supplier company, the less likely it will be to undertake production and marketing.

Government patent regulations also operate as a barrier. Patents on equipment developed under government contract through the program are in the public domain. Therefore, the supplier has no market protection. This barrier tends to discourage the larger companies currently supplying the industry. Few larger companies have been bidding on the available development contracts. Most bids are received from smaller companies that are new to the shipbuilding market. Although public domain ruling on a particular patent may be appealed, the company filing the appeal must prove that it made a substantial capital investment in the development process. Moreover, such appeals are usually time-consuming and costly. The net effect of the government patent regulations is to place a false ceiling on the potential profits to be derived from a new product. If a new product is highly profitable, competing companies may enter the market immediately and benefit from the labors of the originating company.

Other government standards and regulations also operate as barriers. The government regulatory agencies have traditionally been quite conservative. In response, the industry is reluctant to attempt innovations that might run afoul of the regulatory process and cause expensive production delays.[10] As illustrated by the Welding Panel, the inclusion of representatives from regulatory agencies on the technical panels is helping to reduce this barrier. The regulatory agencies are better informed about the production needs of the industry, and the industry has more opportunities to explore the willingness of the agencies to reevaluate standards and regulations.

In evaluating the overall success of the welding effort, it should be noted that this panel is working to improve existing operations. There is little or no expectation that this aspect of shipbuilding will change substantially in the near future. Other successful panels have also focused on stable and labor-intensive areas of shipbuilding such as fitting, outfitting, painting and surface preparation, and materials handling. Panels that have met with less success are those that address the development of new technologies for the industry or the transfer of technologies from other industries. The history of efforts to incorporate computer technology into the ship production process illustrates some of the barriers to more extensive technological change.

Computer Aids to Manufacturing

There have been three separate attempts to form a technical panel to address the coordinated development and implementation of computer aids to manufacturing in the shipbuilding industry. Originally, this effort was organized under the direction of the Computer Aids to Shipbuilding Panel. This panel proved ineffective because the majority of its members lacked any experience with computer aids to production, and the panel was formed at a time when most technicians in the industry considered computers functional only in the area of ship design. Thus, lack of experience in an essentially new technological field inhibited the development of research projects aimed at transferring the new technology into the shipbuilding milieu.

In a second attempt to incorporate computer technology, a major project was launched to develop a shipbuilding production scheduling and control system. Christened the Shipyard Production Management Information System (SPMIS), the project was started in 1973 and dropped after eighteen months. Although not completed, MarAd considers the project partially successful since the project was allocated an initial budget of $3.5 million and was terminated after an outlay of only $170 thousand.[8] There is general agreement that this project was begun too quickly. The project specifications were formulated before either MarAd or the technical panel had a clear picture of the needs of the industry. As a result, the project's contractor designed a sophisticated computer system that simply could not be absorbed by the industry. The ongoing feedback mechanisms of the National Shipbuilding Research Program ensured early and cost-saving termination of the project.

The third effort to utilize computer technology to improve ship production has met with greater success. This effort, the Research and Engineering for the Automated Production of Ships (REAPS) project, was conceived concurrently with the SPMIS project and is now in full operation. The REAPS project focuses on the development and implementation of a computer system for controlling numerical steel cutting machines. In 1973, after consultation with the industry, MarAd determined that the best computer-controlled cutting systems available had been developed abroad. The original plan was for MarAd to purchase an exclusive license for the best of these foreign systems and lease rights at a lower cost to any U.S. yards willing to install them. Five yards expressed interest; the Autokon system was leased, and the REAPS project was formally started. After installation of the Autokon system in the five yards, a decision was made to expand the capabilities of Autokon by developing a fully automated system to convert plans for whole sections of ships into cut steel. The project was also to include the development of training programs and user's manuals. These efforts are now under way.[10]

The REAPS project has broken new ground in several ways. For example, it is the first major project to be undertaken that will ultimately require a redistribution of the workload in shipyards. With full computer control, steel can be cut so accurately that there is less need for trimming and fitting in final assembly. However, in order to achieve full computer control, the design department must be more exact in specifying the dimensions of the ship's surfaces. Previous experience has shown that innovations requiring organizational changes, such as redistributing work loads, are less likely to be adopted. However, research suggests that innovations requiring organizational change are more easily adopted when the organization participates in their development.[10] It is hoped that the participatory approach that characterizes all the projects sponsored by the National Shipbuilding Research Program will facilitate the adoption of far-reaching innovations such as the REAPS system.

The financial arrangements and program management of the REAPS project also represent significant departures from the formula used with other National Shipbuilding Research Program projects. The shipyards participating in the REAPS program contribute 50 percent of the total cost of establishing the system in their yards. A cash outlay is required of the yards rather than the usual commitment to assume overhead expenses. The Ship Production Committee does not exercise direct control over the project. Progress reports are submitted to the Committee to keep them informed, but project control is vested in the Project Manager, the sponsoring firms, and MarAd. The Ship Production Committee is fully in accord with this arrangement since the technology involved in the REAPS system is complex and essentially beyond their field of expertise.

In tracing the history of efforts to incorporate computer technology into the ship production process, two barriers to the innovative process have been illustrated. First, a persistent obstacle to developing projects that focus on the transfer of new technology into the industry is the lack of practical experience with the new technology. Since research priorities and research specifications are formulated by front-line production personnel, it has been difficult to bridge the gap between radically new approaches and the current operating procedures in the yards. Second, the extent of organizational change required to incorporate a new technology tends to operate as a barrier. The history of the REAPS project indicates that this barrier may be more likely to be overcome when the participating yards are in control of the development of the project and when their financial commitment to the project is increased.

Fortunately, the National Shipbuilding Research Program has proven sufficiently flexible to incorporate new approaches to overcoming the barriers to the introduction of major technological changes. Further, as the welding effort illustrates, projects that focus on innovation aimed at improving existing methods have tended to generate successive projects and/or new problems requiring solutions. Moreover, these successive projects tend to become more sophisticated and more innovative. Such efforts tend to expand in the direction of increased supplier participation, increased concern with production methods, and willingness to tackle the more entrenched obstacles to technological change.

EVALUATING THE NATIONAL SHIPBUILDING RESEARCH PROGRAM

The National Shipbuilding Research Program was evaluated in conjunction with an independent study of federally funded industry research and demonstration programs. It has also been formally assessed by an ad hoc committee of SNAME, and assessed more informally by the staff of the Shipbuilding Research Program Office. The findings of each of these studies will be briefly reviewed.

The Rand Study

In 1976, the Rand Corporation published the results of a detailed study of 24 federally funded research and demonstration programs aimed at stimulating change in non-defense industries. The objectives of the study were to identify major factors associated with successful demonstration projects (as defined by the degree of commercial implementation of the results) and to formulate guidelines for federal agencies to use to improve the results of future projects. For the purposes of the study, projects were selected that involved activities undertaken on a sufficient scale or with sufficient technological grounds to permit rapid translation into commercial use. In other words, demonstration projects were selected that were based on technologies that were well understood but had not been widely adopted.[1]

Three criteria were developed to measure the success of the projects in translating the technology into practice. A project was considered an <u>information</u> success when it was able to reduce uncertainties about the operation of the technology in a real-world setting to the point that potential adopters were able to decide whether or not to adopt, and regulators were able to decide whether or how to regulate. A project was considered an <u>application</u> success to the extent that the local adopters were satisfied with the reliability of the system and the quality of the goods or services. A project was considered a <u>diffusion</u> success to the extent that the technology had passed into use as a result of the activity. Projects were ranked yes or no on the information criterion; high, medium, or low on the application criterion; and little or none, some, and significant on the diffusion criterion.[1]

For the purposes of this study, the National Shipbuilding Research Program was analyzed as a program rather than project by project. The overall program was judged to be an information success. It was noted that the principal area of uncertainty reduced by the program's activities was the relative cost advantages of specific technological innovations. The program was ranked high as an application success, indicating that the adopters of the technological innovations demonstrated through the program were well satisfied with the quality and reliability of the new methods or machinery. Finally, the program was ranked as a significant diffusion success, indicating that a significant amount of technological change had occurred in the industry as a result of the program. Of the 24 federally funded programs studied, only six, including the National Shipbuilding Research Program, received the highest ratings on all three criteria.[1]

In addition to the report on the findings of the study, a companion volume of in-depth case studies was published by Rand. A number of the conclusions reached in the case study of the National Shipbuilding Research Program are worthy of note. As the first significant research and demonstration program in the area of ship production, the program has been successful in creating a more positive atmosphere for technological change. As the program has evolved, the shipyards have begun to initiate and support their own innovative projects (often based on findings of projects originally supported through the program). Furthermore, equipment suppliers, an important source of technological change in many other industries, have traditionally not generated many innovations for the shipbuilding industry. Because of the program, equipment suppliers are now beginning to respond to the needs of the industry. The program has been particularly successful in increasing communication between shipyard professionals who had previously worked in isolation from their peers in other firms. Some Program Managers have begun to act as information gatekeepers to the industry in their particular fields of expertise. Production specialists and engineers are beginning to rely on these gatekeepers for information on new equipment and techniques. The participation of representatives of regulatory agencies on some technical panels is producing change. Several agencies are beginning to reconsider some of their policies in a more constructive light.[10]

On the negative side, the Rand case study points out that the program will probably have to be funded at a much higher level before fundamental changes in the industry can be realized. It notes that the federal funds provided through the National Shipbuilding Research Program account for only approximately 0.02 percent of the industry's revenues.[10] In discussing this point, however, MarAd officials maintain that the program is funded at a level consistent with its goal of producing innovations that can be realistically absorbed by the industry. Conceding that a 20 percent increase in the funding level might yield a 20 percent increase in absorbable technological changes, MarAd nevertheless believes that any increase over 30 percent would begin to overload the industry. The returns on research and demonstration investments, in terms of their rate of adoption by the industry, would rapidly diminish.

The Rand case study also notes that the National Shipbuilding Research Program alone cannot stabilize the market for U.S.-built ships nor can it compensate for the lack of incentive for cost-cutting in the shipbuilding industry. This latter factor is seen by Rand as a direct consequence of the protected environment engendered by the federal subsidy program.[10]

In sum, the Rand report rates the National Shipbuilding Research Program as one of the best federally funded research and demonstration efforts aimed at fostering innovation in industry. Although there are, in Rand's view, industry problems that cannot be addressed by the program, a number of substantial positive changes in the shipbuilding industry have resulted from the program's activities.

SNAME's Assessment

In 1975, the Ship Production Committee started its own effort to document the effects of the National Shpbuilding Research Program. An ad hoc committee composed of three members of SNAME was charged with responsibility for ascertaining the effects that 23 of the program's projects had on each of 6 shipyards. The information for the assessment was to be obtained by personal interviews in the shipyards as well as by observation.[2]

A total of 138 observations of the implementation of sponsored research projects was made possible by interviews at the 6 shipyards. Each observation of the extent of implementation of a particular innovation was assigned a numerical value according to the following scale: 0 = no implementation; 1/2 = qualified implementation; 1 = unqualified application. The 138 observations received a total score of 71.5. Thus, the application rate for the 23 projects was 52 percent.[2]

The ad hoc committee found that in most cases in which a shipyard reported no application of a project's results, the shipyard personnel were, nevertheless, knowledgeable about the results. The committee therefore concluded that the program had been successful in disseminating research information. The committee also found that the program had been very effective in bringing together professionals to deal with common problems, and that the Ship Production Committee had been successful in preventing inclusion of projects that would benefit only one or a small number of shipyards.[2]

MarAd's Assessment

The staff of the Shipbuilding Research Program Office has not published a formal evaluation of the impact of the program on the industry. It has, however, conducted a continuing assessment of the effectiveness of the program as a part of its general program management function. In April 1976, Jack Garvey summarized his view of the program's impact in a presentation delivered at the SNAME Philadelphia Section meeting. In brief, it was noted that in 1970 the innovative process had been effectively blocked in the shipbuilding industry. By 1976, the program had significantly increased the propensity to innovate within the industry. A new pool of industry innovators had been formed, and the program had over 150 active participants. The technical content of the projects had become more sophisticated, the vendor community more cooperative, and shipyard management more aware that the application of new equipment and methods is beneficial to their organization.[5]

Based on their experiences with the program, the staff of the Shipbuilding Research Program Office had arrived at a number of conclusions about the innovative process in the shipbuilding industry. First, that technological improvements can reduce costs and have the potential to improve the profitability of the industry. Second, small incremental improvements can be more effective than major breakthroughs. Third, in addition to providing resources, management must provide an environment conducive to innovation. Fourth, a cooperative program can be more effective in removing institutional constraints to innovation than programs conducted within individual firms. Finally, that the program appears to have been more effective in creating the necessary information pool and the mechanisms for disseminating this information than in creating the environment necessary for effective innovation.[5]

Two major barriers that have inhibited creation of the maximal environment for innovation had also been identified. The mechanisms controlling government support of projects legislated by the Merchant Marine Act of 1970 are standard federal research and demonstration contracting procedures. Unfortunately, these procedures were designed for the procurement of research services for government use and do not recognize the cooperative nature of the program. Within the industry itself, the instability of the market precludes justification of any long-term investments in research or adoption of new technology. Consequently, investments in new technology that cannot ensure capital recovery during the life of an ongoing contract are avoided.[5]

The three views of the program summarized here are remarkably consistent. The program is judged successful by both the federal and the industry participants. When compared with other federally sponsored commercial research and demonstration projects, the program received the highest possible marks. There is general agreement on the contribution the program has made to strengthening the innovative process in the shipbuilding industry. There is also a consensus that some of the major economic barriers to innovation in the industry cannot be significantly altered by the program. Nevertheless, the sense of enthusiasm and vigor that permeates the National Shipbuilding Research Program gives grounds for real optimism about the future. The program has not begun to exhaust its potential sphere of impact. There are new challenges to be met. There is a clear commitment to meet them.

ACKNOWLEDGEMENT

The author is grateful to Mr. J. J. Garvey, Director of the Shipbuilding Research Program Office, Maritime Administration, for providing much of the information used in this study.

REFERENCES

1. W. S. Baer, L L. Johnson, and E. W. Merrow, Analysis of Federally Funded Demonstration Projects: Final Report, (R-1926-DOC), Rand Corporation, Santa Monica, CA, 1976.

2. J. V. Banks, J. T. Gilbride, and J. F. Goodrich, "Report of an Ad Hoc Committee to Investigate the Implementation and Impact of the National Shipbuilding Research Program on Commercial U.S. Shipbuilding," unpublished, prepared April 20, 1977.

3. J. M. Barker and R. Brandwein, U.S. Merchant Marine: A National Perspective, Heath Lexington Books, Lexington, MA, 1970.

4. G. L. Cavanagh, "U.S. Shipbuilding Industry: Influence of Conglomerates," unpublished M.S. Thesis, Massachusetts Institute of Technology, May 1970.

5. J. J. Garvey, "The National Shipbuilding Research Program 1971-1976," paper presented to the Philadelphia Section, Society of Naval Architects and Marine Engineers, April 9, 1976.

6. J. A. Higgins, "A National Shipbuilding R&D Program -- Challenge and an Opportunity," Naval Engineers Journal, June 1972.

7. S. A. Lawrence, U.S. Merchant Shipping Policies and Politics, Brookings Institution, Washington, DC, 1966.

8. Shipbuilding Research Program Office, U.S. Department of Commerce, Maritime Administration, unpublished data, March 1978.

9. Society of Naval Architects and Marine Engineers, SNAME's Technical and Research Program in 1978. Society of Naval Architects and Marine Engineers, New York, 1978.

10. J. G. Wirt, "Shipbuilding Research, Development, and Demonstration Program," in Analysis of Federally Funded Demonstration Projects. Volume 3: Supporting Case Studies. U.S. Department of Commerce, National Bureau of Standards, Experimental Technology Incentives Program, Washington, DC, 1976.

BARRIERS AND INCENTIVES TO THE ADOPTION OF AN INNOVATION: MARITIME SATELLITE COMMUNICATIONS

William H. Penrose

The world watched and listened when man first set foot on the moon, demonstrating our ability to communicate across as well as travel the awesome reaches of space. That event changed profoundly the everyday life of man on earth. We now watch and listen, in real time, to sports, theatrical, and news events from all parts of the globe. Space-age communications technology routinely extends the power of the computer to help solve problems half a world away. This same technology is now available to improve the operation and financial performance of our ocean transportation system, if only the challenge of change can be met.

SYSTEM CAPABILITIES

Commercial satellite communications service to the marine world started in 1976, with the successful geosynchronous orbiting of three MARISAT satellites over the Atlantic, Pacific, and Indian Oceans. When the third earth station is completed in mid-1978, 24-hour service will be available to all MARISAT-equipped ships operating in the primary maritime areas of the world. The system user can depend on constant, high-quality service, because satellite radio frequencies are not subject to the propagation anomalies so common to marine radio, telegraph, and telex services. Many nations allow use of the system in port, since the narrow, highly directional signals do not interfere with nearby broadcasting stations. The ability to use the system in port and the fact that the shipboard terminal operates automatically means that a ship may be contacted directly at all times. (Even when signal propagation conditions are ideal, the conventional marine telegraph system is available only about 22 percent of the time.) The narrow, directional signal also ensures the privacy of communications via satellite.

Ashore, no special MARISAT terminal is required; any telex, TWX, or telephone set will do. There is no manual message handling at the satellite earth stations; once a circuit has been allocated, message transmission is immediate and direct, allowing discussion and decision by both parties during a single call. Historically, communications by the marine telegraph system have meant message delivery delays of from 8 to 24 hours. In addition, the direct connection makes practical the direct entry of data from the ship into a shore-based computer.

Direct connection extends the power of the computer to those at sea in a practical way. Economically efficient high data rates may be achieved by coupling a small on-board minicomputer to the shipboard terminal. Drawings, charts, and other graphic material may be transmitted by using an ordinary office telecopier in company with the MARISAT terminal. Finally, the system has a collective-call feature that allows a single telex message to be simultaneously addressed to all MARISAT-equipped ships of the same flag or company, or to all such ships in the same geographic area.

INDUSTRY ACCEPTANCE

There seems little question that MARISAT marks the beginning of a new era in ship-to-shore communications. It is, perhaps, the single most significant advancement in marine radio service since Marconi. At this point, it is apparent that MARISAT will be able to meet the needs of the maritime community for many years to come. That being the case, one might well ask why so few ships have adopted MARISAT during its first 20 months of commercial availability?

In our rapidly developing technological society, change is almost a way of life. For those accustomed to new ideas, the conservative seaman may seem out of place in the modern world. However, conservatism is a force to be reckoned with. Generally, new ideas are not readily accepted in the marine world. Some reasons for this seemingly contrary attitude are contained in this quotation from "Survival at Sea" by Commander G.W.R. Nicholl, RN:

> "The seaman is traditionally cautious and conservative. These are characteristics born of long contact with an element which permits no liberties; an element quick to anger, a fury against whom the finest tempered steel is of no

> avail; even in its most halcyon mood, the sea's smile is reserved and distant. However solidly strong the ship, it can only be hoped that the sea will tolerate it for a lifetime, for it might well be engulfed on its maiden voyage. Progress in maritime matters is, therefore, generally evolutionary and not revolutionary. It cannot thus be wondered that innovations are accepted with caution."

The transition from sail to steam required more than a century to complete. Fourteen years after patent 7777 was granted to Marconi, it took the sinking of the TITANIC to force legislation through the Congress to require fitting of radio transmitters and receivers to all U.S.-flag ships. In more recent times, several U.S. shipping companies sustained severe economic setbacks because they continued to build break-bulk cargo ships long after the container concept had been accepted.

A ship master promoted to fleet manager does not automatically shed his conservatism when he steps ashore. On the contrary, these habits are usually reinforced by the requirements of the new position. Financially successful shipowners have learned the importance of providing a competitive service at least cost. This means that the fleet manager must exert continuous pressure to keep ship operating expenses to a minimum. He is essentially a "conservator" who must make do with the tools at hand. Under the circumstances, it is quite natural to question the need for another, more expensive, radio system -- especially since international treaties require retention of the marine telegraph system. Treaty requirements aside, there is no question that the MARISAT system is more expensive than marine telegraph. This will be true as long as MARISAT is viewed as nothing more than a substitute for marine telegraph and as long as fleet managers believe that marine telegraph service is adequate for effective fleet management purposes.

Satellite communication is, of course, much more than just a substitute for the marine telegraph system. In terms of global coverage, signal quality, availability, privacy, services available, and economic efficiency, the system represents a quantum leap forward in service to the maritime community. By the same token, ocean transportation today is not the same as the system that existed just a few years ago. Advances in marine transportation technology, expansion of intermodal systems, uncertainty in the world at large, and the need for effective communications between merchant ships and U.S. military forces have changed the basic nature of the problem. The sheer size and cost of present-day ships -- the high cost of depreciation, insurance, fuel, and other operating costs; the need for increased management attention to the details of operations afloat to reduce voyage delays -- all point to the pressing need to improve the effectiveness of merchant ship communications.

INDUSTRY-GOVERNMENT COOPERATION

To demonstrate the benefits of satellite communications to the maritime community, MarAd initiated a jointly funded industry-government project. The program included the installation of satellite communications terminals aboard several U.S.-flag ships, the creation of a computer-based message-handling system to link ships at sea with company offices ashore, and the development of a number of "test plans" to facilitate use of the new system by the participants. The idea was that the companies would become familiar with the system and, once convinced of the potential benefits, would proceed independently to use the system to the best advantage.

Several participants soon realized that, to make the best use of the satellite system, it would be necessary to integrate the ship system into the shoreside management information system. Such an integration would necessitate the development of computer software -- an investment few were willing to undertake on a one-ship, experimental basis. Faced with this realization, the participants used the system primarily as a substitute for marine telegraph. Although most participants recognized potentially important gains that could be achieved by bringing the computer into the operations department, few could convince top management to make the move. There is some evidence that top management may be reluctant to make such a substantial investment at this time because of uncertain conditions in the industry.

LABOR-MANAGEMENT ACCEPTANCE

The radio-electronics officers' unions have supported the move toward satellite capability. There have been several minor incidents of an apparent lack of cooperation on the part of individual radio officers, but this has been traced to a breakdown in communications between the operator and management ashore. The American Radio Association-Radio Officers Union (ARA-ROU) group of radio-electronics officers asked the Maritime Administration to provide to their union school, on the same basis terminals were installed aboard ship, a satellite terminal that the union could use to train its members in operating the new equipment. This request, unfortunately, has been delayed for a variety of reasons, with the result that the radio-electronics officer groups now feel left out.

Short of outright legislation, there are several steps that the federal government can take to facilitate the use of satellite communications services by the U.S. merchant fleet. A move on the international level to eliminate the treaty requirement for marine telegraph equipment aboard satellite-equipped ships would be a major step. Also, the subsidy act might be revised to provide retrofit construction subsidy for the purchase and installation of satellite equipment aboard existing ships. One important step would be to design, implement, and demonstrate the actual working of an integrated ship-shore management information system, based on the use of satellite communications in conjunction with the corporate computer system. The ready availability of adaptable computer software for such a system will make it much easier for individual companies to commit funds for the installation and operation of shipboard satellite terminals.

THE INNOVATION AND IMPLEMENTATION OF LASH

L. Arthur Renehan

The LASH (Lighter Aboard Ship) ocean transportation system is probably the most dynamic form of new marine technology to be introduced in the last 50 years. Container ships, surface-effect ships, LPGs, and RO/ROs notwithstanding, it is still the most dynamic; that is, adaptable, motive, and responsive to changing circumstances. The genesis of an idea is rarely easy to trace; the innovator himself is usually uncertain of exactly when his creation took form. Innovation most often results from many original thoughts, several starts, and a variety of problems. In this study, our task is simplified by the fact that the innovator has maintained a close relationship to his creation. Ten years of work preceded the finished product, and today it is still being refined.

We will attempt here to define the instruments that brought the LASH system of ocean transportation to the trade routes of the world. Although economic, political, and social factors bear on every innovation, we will concentrate on the ship itself, the crane, the barges, and the system resulting from their operation. Our interest will be primarily concerned with the technology of the LASH barge-carrying vessel.

THE ENVIRONMENT

In 1964, the world was just awakening to the realities of intermodal transportation on an international scale. The "container revolution" had become an overworked expression for the dramatic change that had taken place in the intercoastal trade of the United States. But most shipowners, true to their conservative natures, considered containerization a special solution to a local problem. Cargo-handling costs and labor problems in U.S. ports, Puerto Rico, and Hawaii were unique; the rest of the world was not ready for such drastic changes.

As a consequence of this conservative thinking, the plans and specifications for a dramatically different ocean transportation system were lying in the drawer of the desk of a naval architect in New Orleans. Jerome L. Goldman had developed plans for a unique barge-carrying ship some years earlier and had put them aside, convinced shipowners were not yet ready to accept it. Actually, little new construction of general cargo ships was being contemplated at the time. The World War II fleet had been replaced by American owners with similar, but faster, break-bulk vessels, and few were thinking of replacement programs. Most trade routes were overtonnaged; the U.S. export trade had not yet expanded, and the charter market languished.

THE DEVELOPMENT

Despite this state of the industry, a pair of entrepreneurs -- Spyros Skouras, father and son -- had confidence in the future and had plans to expand their small fleet. A few years earlier they left the motion picture business to purchase Prudential Lines, a small, subsidized, profitable liner company operating from the East Coast of the United States to the Mediterranean. They approached the Maritime Administration with a proposal to build ships and increase the scope of their operation, which would in turn increase the amount of their subsidy.

Nicholas Johnson, a rather unconventional Maritime Administrator who had publicly chastised the industry for its conventionalism, advised the Skourases that it was his intention to reduce subsidy payments. The only way that he would authorize construction subsidies would be for new technology. He wanted innovation, and he wanted the industry to propose it.

The Skourases, with their Hollywood background, were not deterred by this. They turned to Jerome Goldman, who had designed the PRUDENTIAL SEAJET type for them -- an innovative and successful break-bulk ship. When asked if he had any new ideas for ships, Goldman told them he had a new intermodal system that he feared the industry was not yet ready to accept. Spyros Skouras and his father urged Goldman to come to New York to present this idea to the Prudential Lines managers. The first reaction of the Prudential staff was lukewarm, and Spyros Skouras suggested that the proposal be studied in-house for a few weeks, and scheduled a return meeting with Goldman. At the second meeting, management endorsed the concept, and it was decided to apply to the Maritime Administration for construction and operational subsidies.

The idea for a barge-carrying ship had developed gradually in the mind of Jerry Goldman. He knew the fundamental needs of the industry were to solve the problems of high cargo-handling costs and extensive port time for expensive ships. He quite naturally considered barges, as his practice was located in the river port of New Orleans, and his firm had designed several barges of various types. The economic transport of barges across oceans was the hurdle. The Navy Landing Ship Dock intrigued him, but a single tier of barges resulted in insufficient cargo and revenue for the cost of the ship, and a double tier of barges would require a depth of more than 70 feet of water -- an impractical requirement for world ports. He eventually arrived at the idea of using a gantry crane to lift barges over the stern and stow them in cells.

THE TECHNOLOGY

The technology for the cranes was available. Two manufacturers, Alliance Manufacturing Co. and Morgan Engineering Co., both located in Alliance, Ohio, had the capability of producing cranes with 500 long-ton lifting capacity. As these cranes were being used in steel mills, it was necessary to adopt them to shipboard utilization.

Barge size was an intriguing problem, as so many conflicting factors were involved. The standardized final design resulted from years of work and consultations considering the following:

- Quantity of cargo mix at load port and discharge port;
- Maximum capacity of crane;
- Cost per unit vs. capacity;
- Weight per unit vs. deadweight of vessel;
- Maximum hatch size for ease of cargo handling;

- Interior height for cargo accommodation;
- Maneuverability under tow; and
- Width of locks and waterways.

The LASH barge is the essence of simplicity, a steel box 61 ft, 6 in. (18.75 M) long, 31 ft, 2 in. (9.51 M) wide, with an overall height of 13 ft. (3.96 M). Its hatch opening is 44 ft x 26 ft (13.41 x 7.92 M). It draws 1 ft, 6 in. (0.45 M) when light and 8 ft, 8 in. (2.66 M) when loaded in saltwater. It has a load capacity of 375 long tons and a bale capacity of 19,900 cubic feet.

It is testimony to the designers that the final design of the LASH barge has proven successful to the extent that it is easily integrated into a mixed Mississippi River tow, and, despite strict and complicated rules, is towed in mixed tows regulated by the Rhine River Commission.

THE SEABEE

At this point we should note what must be regarded as one of the strangest coincidences in the history of marine innovation. Simultaneously with Jerome Goldman's development of the LASH vessel, another New Orleansian was at work trying to find an intermodal use for river barges. Frank Nemec, President of Lykes Bros. Steamship Co., working entirely independently of Goldman, developed a barge-carrying ship that eventually become known as the SEABEE. His approach followed similar lines in that he tried the submersion/flotation method of the Landing Ship Dock and rejected it for its draft requirement. The SEABEE uses an elevator system and larger barges than LASH, but its final development proceeded along similar lines and experienced the same delays and frustrations.

PRUDENTIAL/PACIFIC FAR EAST LINE

Prudential Lines now entered a protracted period of development with the Maritime Administration. The agency supported the project, but its mood of subsidy limitation resulted in numerous revisions of financial proposals and consequent delays. Spyros Skouras proposed a 15-ship LASH fleet that would trade worldwide, but MARAD would not agree, insisting that Prudential confine itself to its existing trade route. To gain economies of scale in construction, Mr. Skouras was successful in convincing Pacific Far East

Line (PFEL) of the merits of LASH for a ship replacement program. He was thus able to initiate a proposal for eleven ships for the two companies -- five for Prudential, six for PFEL.

Invitations for construction bids were extended to all major U.S. shipbuilders, with three responding. The lowest of these was Avondale Shipyards Inc. at New Orleans. In November 1967, more than 5 years after his system had been designed, Jerome Goldman witnessed the contract signing between Avondale Shipyards, Prudential Lines, Pacific Far East Lines, and the Maritime Administration for the construction of the first LASH vessels.

Unfortunately, this was not the end of delays. Avondale at this time was experiencing serious production problems in U.S. Navy ships, which prevented the start of work on LASH. It was not until November 1971 that the first ship, LASH ITALIA, was delivered to Prudential.

A comment frequently heard from foreign sources is that LASH is a military-oriented system whose construction was advocated and supported by the Department of Defense. Like all ships built with government construction subsidy, the American LASH vessels are intended to serve as naval auxiliaries in time of war, but LASH is certainly not a product of military interest -- its development was entirely commercial.

INTERNATIONAL PAPER COMPANY

Although general-cargo liner owners may have been showing limited interest in new technology at that time, other owners of special carriers for proprietary cargoes were preparing new ships for service. Lumber shippers in Scandinavia and the Pacific Northwest were trying large engines-aft ships with large, open hatches and fast-acting cranes. Swedish paper manufacturers were working on a system to consolidate terminals, employ unit loads, and use specially designed ships to reduce costs for newsprint, kraft paper, woodpulp, and lumber.

In this country, International Paper Company, the largest paper manufacturer in the world and the largest volume exporter in the United States, was shipping its products in the same manner it had for 40 years. The incentive to change was weakened because in 10 years there had been little increase in ocean freight rates, and hence in costs. Overtonnaging had depressed the general cargo market. Ships were aging, however, stevedoring and cargo-handling costs were going up, and Scandinavian competitors were experimenting with new technology. International Paper felt the problem required attention.

The Problem

The Export Traffic Department of International Paper Company held a position in the structure of the corporation quite common in major manufacturers at that time. It was a "reaction group" -- that is, it did little to initiate change or exert an influence on the economics of a sale. Like most major corporations, International Paper had not yet recognized the impact of transportation and distribution costs on sales and profits. Traffic Departments merely processed orders. They purchased the best transportation available at the time the order was to be shipped, without influencing the size or quantity of the order, where it was produced, port of loading, or port of discharge. It would be a monumental task to change the system of international distribution.

To involve all departments with the problem and to find an objective viewpoint, the Export Traffic Department suggested that the company obtain the services of an outside consultant. The firm of Drake, Sheahan, Sweeney and Huff, physical distribution specialists, was engaged to study the problem and to find answers to the following questions:

1. Does International Paper Company ship a sufficient quantity of export tonnage that can be combined to achieve economies of scale?

2. How would a new transportation system influence manufacturing and production?

3. What would be the effect on sales?

4. Could various commodities -- linerboard, woodpulp, special papers -- be combined and coordinated in production and sales into a single transport system?

5. Would a new system produce savings?

The Drake, Sheahan, Sweeney and Huff study provided positive answers to these questions. There was a need for a system; it would be beneficial, and savings would result. The question remained, what kind of a system?

Swedish papermakers had a lead in new forest products shipping technology at that time. Swenska Cellulosa A.B., with three paper carriers on order, was working on a plan that would change their marketing plan and their entire distribution system in Europe and the United Kingdom. Aware that a major competitor in the most important overseas market was implementing such changes, International Paper Company accelerated its own study of the problem.

The Analysis

Matson Research Company, a subsidiary of Matson Navigation Company, was selected to perform the advanced study and was asked the following questions:

1. Will economies of ocean transportation offset possible additional costs of production and inland transportation? How much?

2. Will changes in loading ports adversely affect inland distribution costs of products for the domestic market?

3. Are special terminals required at loading and discharge ports? If so, how many? What type? At what cost?

4. What type of ship should be used? Size? Method of cargo handling? Speed? Number?

5. Will the cargo-handling system create labor problems? Damage cargo? Result in savings?

6. What is the itinerary of the ship? Will it satisfy customer requirements? Is it lowest cost?

And last and most important:

7. What about customer acceptance? Will the ship change customer order requirements? Will it require changes in customer inland routing at destination (currently through 29 ports in Europe and the United Kingdom)? To what result?

The galley wireless of the shipping industry is perpetual and pervasive. Conversations with stevedores, terminal operators, and port authorities are bound to lead to inquiries from shipowners. To those inquiries from quality owners from whom a serious, reliable proposal could be expected, International Paper did respond with a request for offers.

While the Matson study proceeded to evaluate the resulting change, three American ship operators and one Norwegian company submitted proposals for forest-product carriers. Each intended to use large, open-hatch ships, two or three as necessary, equipped with fast gantry or pedestal cranes. The terms of all these offers were attractive. In terms of tons of paper carried over the life of the contract, each proposal represented very large savings in ocean freight.

But, to International Paper Company the intended solution was incomplete. In a meeting shortly after the offer was received, the Export Traffic Manager explained to Niels H. Johnsen, President of one of the proposing companies, Central Gulf Lines, that those break-bulk types of forest-product carriers were a shipowner's solution. They solved the carriers' problems of slow cargo loading and vessel turnaround but did not completely solve the problems of the paper company. Rapid cargo handling could be achieved by unitizing woodpulp, using vacuum clamps, large holds, and fast cranes. By limiting the number of loading ports, fast vessel turnaround would result. These are important vessel economies. However, they were large ships, totally dedicated to a single shipper.

Sixteen to twenty thousand tons of paper would have to be accumulated in a special terminal. Sophisticated lift trucks would be needed to move it from place of rest to shipside. At the discharge port the process would be reversed. At the completion of unloading, the vessel would sail after a fast turnaround, and the paper company would be left with 16,000 to 20,000 tons of paper to redeliver to trucks, rail cars, or barges for transporting to the customer or the warehouse.

The Alternatives

At this point Niels Johnsen of Central Gulf said, "Have you ever thought of LASH?" The International Paper Export Traffic Manager replied he was familiar with the system, but it was probably very expensive -- such a sophisticated crane and all those barges.... "Let us put some figures on it", Johnsen replied.

In a few weeks Central Gulf returned with a proposal for a LASH ship and barges with numbers that surprised everyone.

Compared to the break-bulk type of forest-product carriers, LASH costs per ton of cargo carried appeared to be competitive. Thus, at about the mid-point of the consultants' study, a new element was considered: How would a LASH system, as proposed by Central Gulf, work for International Paper?

Matson Research had at this point found there were no insurmountable problems in manufacturing and sales that dollar savings would not solve. They had concluded that a forest-products carrier with fast-acting cranes was the feasible alternative and were analyzing the systems approach to its use. With the LASH proposal as a consideration, the study became an evaluation of three alternatives:

1. Geared forest-products carrier;

2. LASH; or

3. Conventional break-bulk vessels.

<u>The Solution</u>

The most important unknown factor in LASH was the feasibility of the barge for forest products. Kraft linerboard and certain types of woodpulp have high stowage factors and are relatively low value. Both are critical points ruling against carriage in a container. In the intended application for International Paper, it was essential that a suitable payload be achieved in a barge. The problem was first attacked with pencil and slide rule. Although the final numbers were encouraging, there remained doubt, due to the roll shape of linerboard and the uneven contours of some woolpulp bales.

Next, a scale model of the barge was built, into which the project manager spent hours fitting scale-sized linerboard rolls made to conform to specific customer order size. Even this was not conclusive, and it remained for the production department of provide an answer, when the manager of the Panama City, Florida, mill offered to build a full-size mockup of a LASH barge. As the Panama City mill produced both linerboard and woodpulp for export and had an ocean terminal, the test situation was ideal. By trial and error it was found that indeed a suitable payload for all commodities of all practical size mixtures could be loaded in a LASH barge.

To take full advantage of a barge system, the shipper quite naturally must make use of all intermodal opportunities. The location of the International Paper Company's mills was most favorable to water transportation. The principal export mills were at Panama City, Florida; Natchez, Mississippi; Pine Bluff, Arkansas; and Bastrop, Louisiana; all near water-loading points; a new mill to open soon was being built at Vicksburg, Mississippi, close to the river. To further support the concept, many of the export customers were already directing that their orders be transferred to barges at Tilbury for transport to warehouses in the River Thames and into barges in Rotterdam for shipment to Duisburg and Cologne. This advantage in collection and distribution was estimated by Matson to mean an additional saving of $1 million per year at 1967 prices.

The Ports

Curiously enough, although this intermodal feature was important, it was not the most significant factor in the comparison with the geared forest-products carrier. It became evident as the study developed that port authorities were unable to evaluate LASH. As they are primarily in the real estate business, and LASH evidently would not require very much of their kind of real estate, they had trouble developing enthusiasm for the system. Yet, it was a major development in shipping; it would provide employment in their ports and bring prestige to their community. It could not be ignored. They decided on a wait-and-see attitude.

However, they did help it. As far as International Paper was concerned, the Port of New Orleans gave LASH substantial support when quoting terms for a terminal for geared forest-products carriers. The Crescent City port offered to provide land for which the paper company would pay rent and on which the paper company could build a terminal at its own expense. The port would then lease the facility to the paper company. Estimated cost of the terminal in 1967 was $4,400,000. The terminal would be used by the forest-products ship three or four days every three weeks, and the rest of the time it would be used for storage and accumulation of a large quantity of paper. By comparison, the LASH barges could be docked and discharged with any amount of cargo at any existing terminal in the port, or at any up-river terminal.

The Decision

In May 1967, Matson Research had completed its work. The evidence showed a LASH system, as proposed by Central Gulf, presented exceptional opportunities for savings, and a geared forest-products carrier would provide good savings at less risk. It was time to present the findings to the Executive Committee for decision.

The decision would be made by a committee consisting of the President, Executive Vice President-Manufacturing, Executive Vice President-Sales and Marketing, Senior Vice President-Overseas Division, and the Treasurer of the company. The President was new to the job, having been head of the Canadian subsidiary, which depended on exports for the major share of its earnings. He had come up through the "outside" departments -- woodlands and manufacturing -- and was not a desk-bound type. He was a hands-on manager who wanted prompt decisions. It was obvious a new shipping system stimulated his imagination.

The systems were described, and the advantages and disadvantages explained. Three alternatives were present: a LASH system, a system that employed geared forest-products carriers, or existing tonnage chartered as the opportunity occurred. It was obvious management wanted a system. There were sound savings available, $3,750,000 per year in LASH, $1,680,000 per year in the forest-products carrier. But, LASH held the risk factor. The technology was untried and untested; the unknowns were infinite. Would barges work? It all depended on a single unit of mechanism, a solitary crane. Labor's reaction was crucial and unpredictable. In contrast, the forest-products carrier was safe; the technology had been tested, and the savings were assured. The ships could be introduced to service soon and labor problems were very unlikely. Despite this, because the benefits were far greater than those derived from any other means of transport, and the risks were not insurmountable, the Traffic Department and consultants recommended the LASH system.

At the completion of the presentation, the committee went into executive session, and 2 hours later the Traffic Department had a decision -- negotiate a contract with Central Gulf for a LASH system.

90

The Agreement

From June through September 1967, International Paper Company and its lawyers negotiated with Niels Johnsen to reach a contract that would be equitable and adequately cover any eventualities in a new and complicated shipping system. The project suffered a setback midway in these negotiations when Central Gulf advised International Paper that the Japanese shipyard from which they had received prices for the ship had informed them that costs had escalated and a new quotation would be 20 percent higher. This increase would have caused a complete review of the project had not Central Gulf offered a compromise proposal. It was suggested that this increase be paid from their revenues when these revenues surpassed a certain minimum figure. In this manner both parties shared the risk of the cost increase and the benefit of additional revenues. Agreement on this point reflected the spirit of cooperation and the progressive mood of the two companies.

Eventually a contract was agreed on that assigned responsibility for such diverse functions as number and condition of barges, places and times of delivery of barges, interval between deliveries, number and frequency of voyages, insurance, and towage. In general, International Paper Company would pay for barge towage to and from its loading and discharge ports. It would load and discharge the barges and arrange for its own terminal, and Central Gulf would operate the LASH ship, lift barges on and off, and place barges in a fleeting area. In the fall of 1967, the contract was signed and construction began on ACADIA FOREST, the first LASH vessel ever to be built.

The Manager of Information Systems at International Paper expressed the mood of company personnel as the planning began for the introduction of LASH when he said: "This is the first time in my life I have ever experienced an adequate lead time for a program. The ship has to be built, doesn't it?" In spite of this lead time, a great deal of work had to be done. Arrangements for terminals and barge fleeting areas on both ends, towing contracts, and negotiations with government bodies on documentation of cargo and barges required a great deal of time.

Logistics Management

Perhaps the most interesting by-product of the new system was its effect on the company's overseas marketing program. A computer program was designed to provide transportation costs from each production mill where an order could be place to each actual and potential customer in Europe and the United Kingdom for each product in various quantities to be shipped in LASH barges. When completed, this program, reportedly the largest ever prepared for a logistics system, produced information that directed important alterations in the company marketing plan. Meaningful changes in transportation and distribution costs were reflected in net return on certain specific sales and prompted a redirection of the sales effort. This illustration of logistics management had a broad effect on the structure of International Paper Company and, ultimately, led to the creation of a Distribution and Transportation Department, headed by a Corporate Vice President.

Labor-Management Concerns

Not all the planning was so productive, however. The many hours of meetings and travel devoted to negotiations with the International Longshoremen's Association proved to be mostly fruitless. Erik Johnsen had succeeded his brother as President of Central Gulf when Niels became Chairman, and Erik personally undertook the labor relations assignment for LASH. He initiated conversations with the presidents of the two New Orleans ILA locals. These talks made progress. Eventually, an agreement was reached whereby the barges would be stowed by a gang of the same size as that used on other river barges, and the shipboard gang would be the same size as employed on a containership. The New Orleans presidents, when agreeing to this formula, added it would require approval at the national level by Teddy Gleason in New York.

Erik Johnsen had several meetings with Gleason in an attempt to obtain his approval. But each time, after much talk, Gleason evaded the issue, saying he could not make a decision until he had seen the ship and observed the entire loading operation. The stall is a familiar tactic in collective bargaining, with the advantage always flowing to the negotiator who is not under pressure. Gleason waited until the day ACADIA FOREST was due to arrive in New Orleans for the first time, having rebuffed repeated invitations from Central Gulf and the Shipping Association to negotiate an agreement. He appeared in New Orleans, notified the local presidents that any agreement they may have made with Central Gulf was invalid, and ordered them not to cross any picket lines.

The picket lines appeared in the form of National Maritime Union sailors, who had a contract with Central Gulf for American-flag ships and were picketing the Norwegian-flag ACADIA FOREST as a "runaway flag" vessel. This ruse did serve to delay the vessel and create the under-pressure atmosphere of a labor dispute that serves the union's objectives. The ILA would not work the ship until an agreement was finally reached in which the union was paid a royalty for each ton of cargo loaded in LASH barges. The royalty was to be paid into a fund to compensate for unemployment due to mechanization.

A sample of positive planning was illustrated by the means used to convince European towboat operators that LASH barges could be towed. In his efforts to negotiate towing contracts with Rotterdam towboat owners, and particularly with Rhine River towboat operators, Erik Johnsen was constantly faced with the question of navigability of the LASH barges. Photographs and models depicted a large steel box, devoid of shear, rake or bow taper -- a block that, in the minds of Rhine River men, could not be moved safely in their waters. Convinced that such an unenlightened attitude required basic hands-on experience, Erik Johnson arranged for a group of towboat people from Dutch, German, and French towboat companies and the Rhine River Commission to fly to New Orleans as his guests. They participated in actual trial tows of LASH barges in the Mississippi, and after a day of moving LASH barges along the levee, they returned home, converts to the new system.

THE EXPERIENCES OF LASH OPERATORS

After 9 years of service, it is generally agreed that LASH, as employed by International Paper Company, is an indisputable success. ACADIA FOREST was followed a year later by a sister, ATLANTIC FOREST, both vessels becoming the basis for a successful, self-supporting shipping subsidiary of the paper company. Others have had mixed results.

Prudential Lines suffered misfortunes from the outset in its LASH venture. The consequences of the shipbuilding delays were critical. For a time, it appeared that the line would pioneer intermodal shipping in the Mediterranean with a revolutionary system, but the delayed delivery of LASH ITALIA coincided with the inauguration of container service by Sea-Land and American Export Lines. From then on, it was head-to-head competition between LASH and containers, and in this confrontation LASH was at a disadvantage.

The cargoes of the western Mediterranean trade route, from the United States East Coast to southern Spain, France, the West Coast of Italy, and Greece, are mainly finished consumer products, machinery, and foodstuffs in both directions. The American exporter of air conditioners and importer of olives and wine are shipping comparatively small quantities each week. They want frequent, regular service to and from their and their customers' warehouses. In this competition, to provide a liner service between modern ports in the industrialized world, LASH is at a major disadvantage against containers.

As if the service disadvantage were not enough, LASH began operating on the East Coast under the burden of heavier labor costs than containerships. In one of those paradoxes that the shipping industry provides so well, the LASH system, which is more akin to break-bulk, and therefore more labor-intensive, was penalized more for its "mechanization" than containerships.

It may have been intra-union rivalry or the mood of the bargainers at the time, but when the first Prudential LASH ship entered service, it immediately encountered a labor stoppage, first from the unlikely source of the deck officers' union, which had recently allied itself with the longshoremen, and then from the longshoremen themselves. When these disputes were finally settled, Prudential found itself operating with larger gangs, more restrictive work rules, and the same royalty payments Central Gulf had in U.S. Gulf ports. Without a "base" cargo of bales or rolls of paper, bagged goods or a similar homogenous commodity, productivity gains in barge loading cannot be achieved, and LASH on the East Coast failed to gain economies in cargo handling.

These handicaps notwithstanding, other lines proceeded to order LASH ships. PFEL encountered the same type of competition from containerships as Prudential, with similar results, and it has had to modify its system. Delta Line, Combi Line (the only foreign line to date), Waterman Line, and Central Gulf are all operating LASH ships ordered specifically for their particular services, and all are successful. Of the 21 LASH ships in operation as barge carriers today, 14 are in what could be considered profitable employment. In each of these cases, some or all of the following factors pertain:

- Inland waterways are utilized on at least one leg of the trade route;

- Neo-bulk cargoes (bagged goods, bales, rolls or bundles, such as forest products) make up a portion of the carryings; and

- Congested ports or ports of lesser-developed countries are included in the trade route.

There are firm indications of continued expansion of the LASH fleet. Waterman Steamship Company has contracted to build two additional ships, and the Soviet Union is in the process of building an unknown number.

The Russian government purchased the plans, specifications, and rights from Friede and Goldman, with the blessing of the U.S. government, and is now building LASH ships of 40, 60, and 80-barge capacity. No one in the western world really knows the intended use of these ships; it is certainly likely they will appear in commercial use in world trade routes.

Jerome Goldman has just completed an evaluation of future employment of LASH and has reached some interesting conclusions. He has found that, of all of the vessels of 15,000 or more tons now being built, or whose keels will be laid in 1978, 80 percent are of the break-bulk type. He further submits that, based on actual costs recently obtained from shipyards, LASH proves to be a less costly investment than break-bulk ships. Goldman explains this surprising premise on the following:

- He has initiated several economies in the LASH design based on construction and operating experience gained in the last 10 years;

- Construction cost differences between LASH and break-bulk ships have narrowed;

- Three LASH ships, each with two sets of barges, can carry the same or greater quantity of cargo in the same period of time as five break-bulk vessels; and

- Three LASH ships, each with two sets of barges, will have the same construction cost as five break-bulk vessels.

Therefore, Goldman advises, a shipowner could build and operate three LASH vessels more profitably than five break-bulk vessels and perform a greater amount of shipping activity. If this argument proves to be convincing, this large break-bulk ship market may turn to LASH.

THE FUTURE

In the search for the perfect world, we must ask what could be done to improve the existing situation. Most operators of LASH vessels are satisfied with the ships and the barge system and believe that if they had to do it over again they would order LASH ships. Pacific Far East Line is the conspicuous exception to this conclusion. They have converted their remaining four LASH ships to containerships, having previously sold two to Farrell Lines. Prudential Lines, in its long-range plans, intends to operate its three remaining vessels on its subsidized trade route to the Mediterranean, with itineraries tailored to utilize the proven features of LASH. By concentrating on North Africa, Middle East, Turkish, and Black Sea ports, they will market their service toward construction materials and equipment, machinery and oil-well supplies, and cargoes suited to barges and ports where barges are more effective than containers.

The single major misgiving of all LASH operators is the handicap of a labor contract that reduces their advantages in comparison with the container and RO/RO ships they compete with. Although the LASH ship is highly automated, the loading and off-loading of a barge is performed by the giant crane, operated by one man with the guidance of a "talker". The longshoremen's contract requires that the ship hire two gangs, a total of 42 men, for this work. By comparison, a containership loading with one container crane can hire one gang of 21 men. It is ironical that a system featherbedded to the extent of LASH must pay a royalty into a fund intended to compensate for unemployment of longshoremen.

Longshoremen rarely renegotiate a contract to favor management, but this unfortunate agreement is a significant barrier to LASH operators and the one they would most like to change if given the opportunity.

Another change that would have made LASH more versatile would be a container capability. The Prudential container mode was unsuccessful because it served to delay the ship in port and showed that the two systems, barges and boxes, were incompatible in that particular application. There is a need to accommodate containers in every shipping system dealing with general cargo today, and it should be designed into LASH. Either container barges should be developed or a cellular or on-deck arrangement should be designed that would not totally exclude containers.

AD-A077 202 NATIONAL RESEARCH COUNCIL WASHINGTON D C MARITIME TRA--ETC F/G 13/10
INNOVATION IN THE MARITIME INDUSTRY.(U)
MAY 79 N00014-75-C-0711

UNCLASSIFIED NL

2 OF 3
ADA
077202

Farrell Lines has conducted a careful study of the barge and container mix on its LASH ships in the West Coast-Australia trade. They have concluded it is necessary to accommodate containers and have retained the container crane and container cells in certain holds. The ideal configuration in their trade route lies between 66 barges and 250 TEUs (twenty-foot equivalent units) and 46 barges and 610 TEUs.

It is a reasonable conclusion that a LASH ship is no different from any other type; its success and profitability depend on the way it is used and where it is used. Efficiently operated on a suitable trade route, it is a profitable shipping system.

PORT OF SEATTLE GROWTH
THROUGH MODERN CUSTOMER SERVICES

John Dermody

The concept of the function of a maritime port has changed over the years. The change is best shown by contrasting the following two quotations (emphasis added):

> The basic function of...ports is to provide the facilities and services required to transfer cargo and passengers efficiently <u>between ships and shore</u>.[1]

> The function of a port is to provide for efficient and least cost <u>inter and intramodal transfer</u>, inspection, storage, form change and control of cargo.[2]

If a port is considered only a way point at which cargo is transferred from one mode of transport to another, then the efficiency of the transfer procedure is paramount. The following demonstrates the importance of time in transit and the costs involved at the modal transfer point:

> It is estimated that if the world's ports were to improve their ship, feeder and cargo transfer capacity in line with available ship and feeder technology as much as 60% of port time and related costs could be saved. This would not only reduce port costs by about $15 billion, but also increase shipping capacity by about 20% for a total benefit of about $25 billion which constitutes well over 30% of all expenditures for shipping and port costs in international trade.[2]

> Shipping has been recognized by shipowners and shippers alike as one link in a through-transport system extending from producers to consumers. The total cost concept allows a high degree of investment to be made at certain sectors of the transport system, and higher charges to be levied there if necessary, if by so doing total costs are reduced.[3]

The old saying "time is money" is especially germane to modern port activity. The greatest saving in total cargo transport time can be made during the port transfer process, not the feeder or shipping transport segments:

> On the Australian trade conventional cargo liners spend 50% of their time in port, container ships spend only 12% of their time in port activities. With this increased productivity, nine container vessels are capable of replacing seventy out of the eighty or ninety conventional ships normally employed on the Euro-Australia Service.[3]

But saved ship time is not the only cost saving. Savings are realized by keeping cargoes moving:

> The function of a port is not to provide a separate service, but to serve as an integral part of a chain of transport links designed to move cargoes from origin to destination points. Ideally, therefore, the port should provide a capability of continuous flow transfer between land and ocean transport modes. Because of differences in unit vehicle size, of capacity per unit time between ocean and land transport mode, as well as because of problems of effective transport scheduling, direct and continuous inter or intramodal cargo transfer is usually possible only for a fraction of the cargo flow through ports.
>
> Ports serve as multipurpose, special purpose, regional or transshipment ports. The major characteristic of ports today is that they are continually changing and subject to dynamic planning.

> Although many ports still largely operate as break-bulk general cargo ports with most of their facilities serving all types of ships, many modern ports today are largely composed of specialized facilities each of which serves one type of ship, cargo form, or both.[2]

The ports of the world had an enormous challenge to meet in the late 1950s which, if met, would commit them for decades:

> An important consideration is the fact that while the many port users improve their technology continuously and while it takes just a few years to introduce new shipping or feeder transport technology, it takes many more, 5-10 years, to introduce major improvements or changes in ports. Such improvements are as a result of the long development time and large unit cost made only very intermittently and are generally planned for economic lives which greatly exceed those of ocean and land transport users. It is for this reason that cargo transfer and port technology must be planned for a very long future time horizon to assure that technological obsolescence does not occur too early in the economic life of such developments.[2]

This study traces the recent growth of the Port of Seattle (POS), which, by deliberate effort, has become a multi-purpose, multi-terminal port deriving most of its business by providing the services expected of a transshipment point on the great circle route between Pacific Rim ports and central and eastern North America.

The 1911 report by Bogue, "Plan of Seattle," foresaw the essential ingredients.

> The prosperity of a port is not dependent on natural advantages so much as a systematic development of the broadest lines to attract foreign and domestic commerce.... The city offering the most conveniently arranged harbor terminals and furnishing sites for industries and jobbers near well-organized water and rail transportation facilities is the city whose

> businessmen will be able to underbid their competitors and win prosperity for themselves and their commonwealth.[4]

GROWTH

A few examples of the growth of the Port of Seattle are mentioned to demonstrate the success of the policy of providing good customer services.

Tonnage handled by the Port of Seattle rose 52 percent in the 10 years ending in 1968, but the value of the cargoes handled increased 70 percent in the same period. This was largely because the port was able to capture a greater portion of high-value containerized general cargoes during those years.

The speed with which ships can be turned around at POS today is easily shown by the Port log. A typical example is the log for the vessel LION GATES BRIDGE. She docked at Pier 18 from Tokyo at 0800, 28 January 1978, on voyage No. 47. The day shift started at 0900 with three cranes and handled 783 containers. The night shift, using two cranes, handled 353 containers. The next day shift handled 429 containers, including some repositioning, and was finished by 1500. The ship sailed at 1515, 29 January for a total time in port of 31 hours, 15 minutes.

During this study, numerous examples were discovered demonstrating how the Port reacted to and took advantage of modern needs and equipment. However, as will be shown later, it was not innovations in hardware, or the "tools" of the port business, that led to success; it was the management decisions to acquire the tools and the professional staff to use them that were the important innovations.

Nevertheless, it is useful to report some of the modern techniques now used by the Port before discussing key management innovations. Frankel[2] stressed the new technological developments to which modern ports must respond, which are in the areas of:

- Increased continuity of cargo flow;
- Better integration of conflicting feeder and ship loading and storage requirements;

- Adaptation of optimum cargo form, containment, and parcel size of ship and feeder requirements (physical form change of cargo in port);
- Modern magnetic or electronic marking and read-off system;
- Modern (often computerized) cargo inventory, and flow control systems, location control, and warehouse planning;
- Improved cargo transfer and transport devices;
- Controlled and planned cargo inspection (spot test, etc.);
- Environmental control for cargo quality and port ecological control;
- Improved ship-handling, mooring, and docking methods; and
- Facility use and planning such as berth allocation, and equipment and manpower assignment.

Each of these areas of technology as applied to POS is discussed briefly below.

<u>Increased Continuity of Cargo Flow</u>

Modern equipment such as cranes and stackers were installed beginning in the 1960s, and backup space was acquired and converted to van storage. Warehouses left over from break-bulk shipping days were torn down to make yard space. Plans remained flexible during the early days of container technology. New freight terminals have two-thirds less warehouse space than previous ones, to provide yard storage for containers.

<u>Better Integration of Conflicting Feeder, Loading, and Storage</u>

Ideally, it would be most efficient to offload a container directly onto the flatcar or truck that would transport the cargo to its destination. This is seldom possible. The POS, therefore, has provided not only backup space and equipment to store and stack containers in the interim, but also a place where cargoes can be efficiently marshalled, inspected, and cleared through U.S. customs.

Physical Form Change of Cargo in Ports

The Port of Seattle's tariff specialists advise shippers on the advantages, if any, to be gained in changing the form, packaging, and parcel size of goods during their transshipment through Seattle. The Port fosters this activity by coordinating the needs of customers with the capabilities of local freight forwarders.

Magnetic or Electronic Marking and Read-off Systems

A control tower at the largest terminal has proved successful in tracking containers, eliminating the need for marking or read-off systems.

Computerized Inventory and Flow Control, Location, and Warehousing

In the early 1960s the Port of Seattle developed a computer accounting system using punch cards and batch processing. In 1966, a management service firm retained to study the system developed the following recommendations:

- Create a new organization within POS to handle data processing, as distinct from computerized accounting;
- Purchase hardware and develop programs based on on-line, real-time computing capability; and
- Base the program on the bill of lading (not the container) since the BOL is the primary business and legal document of shippers.

Such a computing system exceeded the capabilities of the current state of the art, and few vendors could provide it. However, a Burroughs system was purchased in 1968. The system had far greater capacity than was immediately needed.

One problem was to gain acceptance of the new system, from POS staff as well as customers and freight agents. The software system was built in phases, program module by program module. The first module, on-line by July 1969, handled break-bulk cargo control, which was still 90 percent of the Port's business.

Since the first program module was developed for the more complicated task of handling break-bulk cargoes, it was an easier task to develop programs for mixed-load containers and fully unitized cargoes. During this time, POS was conducting trade negotiations, primarily with Japan. The success of these negotiations depended in part upon a properly working computer program for containerized cargoes. The final stages of this program were developed in less than 5 months, and it was ready by July 1970 when the first Japanese container cargoes began arriving.

Since timely service is the most important ingredient the Port can offer to both importers and exporters, real-time, on-line computer control is one of the most important capabilities the Port has developed. The POS keeps control of goods "almost at the retail level," from the time of shipment to ultimate delivery.

When a ship sails for POS, the steamship company sends the entire cargo manifest to the POS Director of Systems and Data Processing via landline, courier, or satellite. The sooner the cargo data are in the computer, the better preplanning the POS can do to expedite the shipments. Steamship companies receive a monthly letter recapitulating their performance as to completeness and timely arrival of cargo manifests.

In response to stated customer needs, POS tailors inventory control for as many as 15,000 importers, 300 of whom actually may have goods in POS warehouses at any one time.

Such a detailed control system provides shippers with many options. For example, an importer can defer decisions about freighting onward from Seattle until the shipment has arrived at POS.

Cargo and Transport Devices

The Port of Seattle's policy since the late 1960s has been to purchase latest model devices to provide for future growth. Three-high container stackers were purchased, rather than two-high.

The Port had to keep in mind its chief customer and traditional shipping partner, Alaska. Containerized barge loading facilities were developed simultaneously but separately from terminals designed for transocean vessels. Both roll-on/roll-off and load-on/load-off facilities were built for the Alaska market, as well as loading facilities for railroad barges to Alaska.

The POS has recently retained a consultant to advise and write bid specifications for a maintenance-monitoring system for container cranes. The system is to sense and computer-record key parameters such as motor amperages, pressure differentials, and voltage drops throughout the machinery to assist in diagnosing maintenance needs. The goal is to reduce repair costs and downtime of equipment.

Controlled and Planned Inspections

POS has designed warehouses and the Foreign Trade Zone yards for ease of customs clearance and inspection by shippers.

Environmental Control

The Port of Seattle has become aware (sometimes after the fact) of the need for pollution abatement. Dredge materials are now stockpiled and used by the Port or given away. The airborne dust associated with loading bulk grain is collected by a vacuum system and the material sold to the local animal feed industry. The wash water from the imported vehicle preparation area is recycled to recover and reuse the solvent. The Port provides oily waste pickup service to vessels at the berths.

Ship Handling, Mooring, and Docking

Vessels coming to the Port of Seattle traverse the deep and well-charted waters of the Strait of Juan de Fuca and Puget Sound. The U.S. Coast Guard operates a vessel traffic system with shore-based radar surveillance, and the ships are under the required guidance of a Puget Sound pilot.

The facility used to load railroad barges consists of a two-track ramp delivering cars to multiple track barges. Rather than an elaborate system of switches, the barges are moved laterally to align the ramp and barge tracks.

Use Planning of Berths, Equipment, Manpower

The Port of Seattle uses computer simulation modeling to identify future problems in ship and cargo handling, space, and manpower.

Many shippers solve their own space problem by leasing exclusive berths and space or by obtaining preferential berth assignments. In both cases, the Port retains secondary rights to the berths and spaces.

The Port fosters training of all personnel involved with the Port's longshore activities, whether Port employees or not, by providing classroom space and teaching aids. Stevedoring and longshoring firms and unions utilize these facilities.

MANAGEMENT

As shown above, Frankel's list of areas of new technology is important to the development of modern ports. However, technologies do not, in themselves, explain the growth of the Port of Seattle. Important as the new technologies of the freight business are, they do not, singularly or in concert, necessarily lead to a successful port. Whatever the hardware or technology, a port becomes successful through establishing goals, supporting the good management to achieve those goals, and developing an aggressive marketing effort to attract users.

CHRONOLOGY

A brief chronology of events will serve as an overview to POS development:

1851 First settlers arrived in Seattle (by ship); they came to trade rather than farm.

1893 Culminating many years of organized efforts, railroads came to Seattle, connecting waterfront to midwest and East Coast.

1895 Virgil Bogue, engineer, issued his first plan for development of Seattle's waterfront.

1898 Alaskan Gold Rush established Seattle as prime supplier and shipper to Alaska, a position POS holds to this day.

1911	Port District Act became law on June 8 after long civic debate. Washington State ports thereby became public and were empowered to plan development of port activity with related transportation systems.
1915	Headquarters building and pier on central waterfront, still used for POS offices today, were dedicated.
1918	Port of Seattle handled 40 percent of all U.S. trade with Japan.
1948	Business and citizen concern regarding post-World War II decline in Port of Seattle activity resulted in formation of Seattle Chamber of Commerce's Port Development and Maritime Committee.
1949	Seattle-Tacoma International Airport dedicated.
1950	Port participated in Trade Mission to Japan (first such U.S. mission to postwar Japan).
1951	Port participated in first postwar Japanese Trade Fair in United States held in Seattle.
1956	POS took major step in retaining consulting firm of Booz, Allen & Hamilton to do in-depth study; POS's further major decision was to make report public.
1956	"Ocean-Borne Commerce of the State of Washington," a port study, was published by Business Executives Research Committee, representing some of the community's most prominent businessmen. It was produced under the direction of Stanley H. Brewer, University of Washington Professor of Transportation, and showed an alarming economic decline in the State's ports.
1957	POS began policy of hiring trained professional staff, one of the first being J. Eldon Opheim as comptroller (later General Manager) with assignment to carry out 60 recommendations of Booz, Allen & Hamilton report. (Note: POS made all recommended changes with one exception; the Foreign Trade Zone was retained.)
1958	Chamber of Commerce sponsored citizens' Port Committee, with seven subcommittees to study

specific activities of POS. Issued memorandum on needs of POS.

1959	KING-TV produced "Lost Cargo," a documentary about the economic problems of the Port of Seattle. All the local media continued demanding POS changes until November 1960 election.
1960	In election, Port changed from three to five commissioners, to serve for $1.00 a year instead of salary, and bond issue was passed.
1960s	Ongoing through the 1960s were major capital improvements, purchase of needed backup land, construction of container terminals and berths, expansion of warehousing facilities, buying major equipment such as cranes and straddle carriers, simultaneous strengthening of marketing programs through POS offices in Tokyo, Hong Kong, Washington, D.C., New York, Chicago, Spokane, and Anchorage.
1962	POS began $30 million terminal building program for Duwamish Waterway.
1964	Sea-Land moved into Terminal 5.
1966	Decision was made to create computer system; management service firm hired to conduct feasibility study; decision made to separate data processing and computer systems from accounting department.
1966	Commissioners formally adopted statement of POS "Purposes & Objectives" on March 14, that revised statement adopted November 26, 1964.
1968	Aggressive sales program of POS facilities to overseas customers began, even before facilities were completed.
1970	POS signed agreement with six Japanese containership lines.
1970	New $13 million grain terminal opened at Pier 86 on 40-acre site. Facility could handle largest grain ships in the world.
1972	POS signed agreement with Port of Butte (Montana) for distribution and assembly facility.

1976 Piers 90 and 91, Seattle U.S. Navy Terminal, officially purchased by POS for $15.3 million following lengthy negotiations commencing in 1970. (Piers 90 and 91 had been POS property originally, appropriated by the U.S. Navy for World War II.) The purchase added 198 acres and twin half-mile piers to POS facilities.

POLICY DECISIONS

During the crucial decade beginning in the mid-1950s, the most important policy decision for the development of the Port of Seattle was the emphasis on customer services. Innovative management decisions made in those years are discussed below; they can be categorized as (a) political, (b) financial, and (c) personnel.

Political

Historically, the Port of Seattle has benefited from political involvement:

> The most successful port on the coast will be that port that can impress upon its citizens the financial benefits that a successful port will bring to all residents of its community.[5]

Public ports cannot function without some level of acceptance from the electorate. The people of Seattle and King County became concerned about their declining Port as early as 1948, when the Seattle Chamber of Commerce formed its Port Development and Maritime Committee, and in 1950, when the Seattle Municipal League conducted a study that showed the economic decline in Port activities. This led to the 1956 major study by Booz, Allen & Hamilton for the Port. It is to the credit of the Commissioners that the report, although critical, was made public.

These efforts were useful as thoughtful studies, but were equally useful in arousing public concern. The dailies, Seattle Post Intelligencer and Seattle Times, in both news articles and editorials, brought Port matters to the attention of their readers and called for implementation of the 60 recommendations in the Booz, Allen & Hamilton report. Local trade journals such as the west coast weekly Marine Digest kept Port issues before their readership.

The Chamber of Commerce formed seven subcommittees to look at Port problems. Their efforts were far from cursory, and many of these chamber activities are perpetuated by units of the modern Port organization.

In June 1959, the local broadcast station KING-TV produced the documentary "Lost Cargo," demonstrating the decline of the Port of Seattle.

The media kept the Port and its problems in the attention of the electorate until the November 1960 elections, when the voters changed the Commission from three to five members, serving at $1.00 per year instead of on salary, and provided a $10 million bond issue.

Financial

The concept of unitizing cargoes was not a new idea to Seattle. As early as 1928, Puget Sound Freight Lines (which serves outlying towns and islands) had used palletized cargo handling. Alaska Steamship Company had experimented with modular cargo boxes for freight containers to Alaska in the post-World War II years.

The Port purchased a few containers in the 1950s to introduce shippers to their use. However, small steps were not sufficient. The ports of the world were faced with many decisions in utilizing modern cargo technology. It was obvious that substantial amounts would have to be spent to modernize.

In the early 1960s, the bonded indebtedness of the Port of Seattle was less than $10 million. (The current issues of bonds amount to approximately $250 million.) The Port entered the era of technological change with large financial reserves. Of all the money spent by POS on facilities since 1911, two-thirds was spent during the decade 1960-1970.

The POS was willing to undertake financial risks. Equipment that was oversized for existing needs was purchased. The Port began demolishing old warehouses and surfacing storage yards at Pier 5 in 1960 before any new construction was designed and before there was any tenant interested in container shipments. In 1964, Pier 5 became the first location for Sea-Land activities in Seattle.

Personnel

The post-World War II studies of POS had included criticisms of the manner of operations, particularly the fact that the commissioners exercised too much responsibility for day-to-day matters.

The Booz, Allen & Hamilton report recommended that the commissioners devote their energies to policy matters and recruit a professional staff to assist the manager in day-to-day operations. Today, POS is operated by a staff organized into the following departments:

Executive Director

Senior Director, Facilities and Operations
Senior Director, Finance and Administration
Senior Director, Planning and Port Relations
Legal Officer

Director, Accounting and Port Auditor
Director, Aviation
Director, Engineering
Director, Marine Terminals
Director, Marketing
Director, Personnel and Industrial Relations
Director, Planning and Research
Director, Public Information
Director, Purchasing and Office Services
Director, Special Services
Director, Systems and Data Processing

To establish and maintain customer relations and to assure that the Port remains attuned to changing customer needs, regional managers operate from marketing offices in New York, Washington, D.C., Chicago, Spokane, Anchorage, Hong Kong, and Tokyo.

RESULTS

The POS has succeeded in becoming, once again, the effective economic force its post-World War II critics wanted. In each of the past 10 years, the POS has set records in operating revenues, cargo tonnage, and container traffic.

The Port has emerged as the container load center of the North Pacific, the number-two container port of the West

Coast, and the number-three container port in the nation. In 1976, 16 million short tons moved through POS and 2,470 ship arrivals were recorded. The 1976 direct disbursements to Seattle-registered longshoremen amounted to $24,180,378.

The Port now has 52 berths available at 18 terminals. Berth length ranges from 350 to 1000 feet, and depth alongside varies from 18 to 73 feet. Thirteen container cranes, 9 revolving cranes, and 25 three-high stackers are installed at 5 full-container terminals and 7 container freight stations.

Utilizing these facilities are 90 steamship agencies and 14 tug and barge lines. Three railroads, 33 truck lines, and 32 air cargo lines provide feeder service to the Port.

CONCLUSIONS

- The Port of Seattle recognized its comparatively poor standing among world ports and responded to public pressure for change and improvement.
- POS recognized that a port, particularly Seattle, is a way point in the total transportation system between supplier and consumer. Port operations are typically more time-consuming and costly than other segments of the total transportation network.
- POS recognized the need to reduce time spent in port by vessels and their cargoes in order to reduce the customers' total shipping costs.
- POS purchased and installed facilities, equipment, and control systems necessary to reduce time and costs. POS took financial risks to build for the emerging containerization trend and provide computerized integrated cargo tracking.
- POS reorganized itself in fundamental ways. POS changed its commissioners -- their number, remuneration and duties -- and it built a competent professional staff.

ACKNOWLEDGEMENTS

This study was conducted with the assistance of the Port of Seattle staff, Richard D. Ford, Executive Director. Members of the Port Commission during the time of the study were Merle D. Adlum, Jack S. Block, Paul S. Friedlander, Henry L. Kotkins, and Henry T. Simonson.

The valuable contributions of Patricia Baillargeon, Consultant, are acknowledged.

In addition to Commissioners and POS staff, the following persons were contacted: Miner H. Baker, Eric S. Bremner, Emory Bundy, Douglas K. Fleming, Denney Givens, Virgil E. Harder, John M. Haydon, Lewis R. Holcomb, Howard E. Lovejoy, Donald Mossman, J. Eldon Opheim, Don W. Page, Robert H. Pealy, and Fred H. Tolan.

REFERENCES

1. "Public Port Financing in the United States," U.S. Department of Commerce, Maritime Administration, June 1974.

2. E. G. Frankel, Port Planning and Development, Center for Transportation Studies, Massachusetts Institute of Technology, 1977.

3. A. D. Couper, The Geography of Sea Transport, Hutchinson & Co. Ltd., 1972.

4. Virgil Bogue, Plan of Seattle, City of Seattle, 1911.

5. Padraic Burke, A History of the Port of Seattle, Port of Seattle, 1976.

INNOVATION IN THE MARITIME INDUSTRY: LANDBRIDGE SERVICES

David L. Gorman

Innovation in the Maritime industry can take many forms ranging from new equipment to new uses for existing equipment. "Landbridge" services fall in the latter category.

Landbridge services are an innovation in the use of existing technologies. Even the physical form of the concept is as old as recorded history. Landbridges are simply overland links in a marine transportation system that allow the distance traveled to be shorter than it would be in an all-water service.

In the settlement of California, the wagon road that crossed the Isthmus of Panama prior to the construction of the canal was a landbridge. It permitted cargoes from the East Coast of the United States to be transshipped at the Isthmus, reloaded on ships on the Pacific Ocean side for final delivery in California. Earlier, the same road (or trail) linked the Spanish colonies on the West Coast of South America to the Atlantic. In both cases, the long trip around Cape Horn was avoided. An earlier landbridge existed for centuries at Suez, linking Europe with India.

Landbridges as a modern innovation, however, are based on a totally different motivation. Although they take advantage of geography (and are limited by it), the motivation is not simply to save time in transit, but rather to permit an operator to extend his range of competition for cargo. By making use of a land link across the United States, a ship operator whose all-water service is limited to the North Atlantic can serve the West Coast of the United States as well as the East Coast -- the former by a combination of water and rail service and the latter by all-water service.

In a similar manner, all-water feeder services could extend the same operator's competitive range from the North Atlantic to the Mediterranean, Baltic, or Caribbean Seas. For example, by operating a feeder service from Baltic ports to Rotterdam, a North Atlantic operator could serve those ports in addition to his basic North Atlantic itinerary. Similarly, a Mediterranean feeder service could extend the North Atlantic itinerary to Mediterranean ports. Therefore, we have included all-water feeder services as a subset of landbridges.

In both services, the innovation consists of using existing transportation systems in ways in which they have been used for centuries to achieve a totally new objective -- expansion of the competitive range of the individual ship operator.

It is for the innovator an essentially zero risk, zero investment proposition. It offers an improved product to the consumer with substantial benefit to the innovator. It is a relatively limited innovation in terms of its direct and indirect impacts, which, together with its rapid development, permits fairly complete evaluation of its growth and effect on marine transportation.

Bridge traffic has been defined, and perhaps over-defined, in more detail. "Landbridge" is a term sometimes used to describe a bridge service that involves a continental crossing between two water legs. Europe to Japan via the United States or the Soviet Union is an example. "Minibridge" is the most common term (for the most common service) and describes a service involving a water leg and a transcontinental leg. The U.S. East Coast to Japan through West Coast ports is an example. Finally, "microbridge" is occasionally used to define shorter land movements. Since all essentially are the same type of service, it is felt that bridge traffic is an adequate descriptor for all.

THE ENVIRONMENT

Two elements necessary for the evolution of bridge traffic to its current form developed relatively independently over the past decade. The first of these was containerization. Bridge traffic requires that cargo be handled at least once more than in an all-water service (at the point of transshipment from land to sea or sea to land) and in many cases twice more (when a bridge links two sea passages). While this could certainly be done with break-bulk cargo, it would be highly uneconomic. With the development of containerization, however, the additional costs associated with transshipments are much smaller relative to the total cost of shipment.

The second element is the unit train, which was originally developed by the railroads to move large quantities of bulk cargoes, such as coal, to a single destination. As containerization grew, railroads began quoting rates on container movements that were really extensions of existing rates for carrying trucks. Several plans -- trailer on flat-car (TOFC), container on flat-car (COFC), etc. -- were developed very early in response to a presumed demand for container and trailer transport by rail. However, such shipments were generally in small numbers of units, from each source to each destination, and were priced accordingly. Bridge service offered the potential of volume movements of containers to the account of a single owner (the ship operator) and a single origin and destination. Given a sufficient volume, the railroads could respond by offering unit train service at greatly reduced rates.

These two elements thus provided a low-cost transshipment procedure and, given sufficient volume, a low-cost land transportation mode. It is doubtful, however, that there would have been any incentive to take advantage of these if the general environment of liner shipping in the past decade had been different. In fact, assuming a reasonable level of prosperity for the liner companies during that period, there would have been a genuine disincentive to offering bridge services. The ship operator who offers such a service does so at the cost of sharing at least some of his revenue with the rail carrier. If he provides an all-water service to the same point as the bridge service (as is the case with operators who serve Japan from both the East and West Coasts of the United States), the bridge option represents a direct loss in revenue, competing with his own all-water service. If he does not provide an all-water service, he must still balance the payments to the rail service against his gains in utilization -- not always profitable, as is described in a later section.

In the late 1960s, containerization in a very few years was adopted on a massive scale in all major U.S. trades. Container tonnage was added rapidly, and by 1970 a condition of semi-permanent overcapacity was reached. This condition is the result of extensive addition of capacity by independent operators and national-flag fleets, made possible by the open conference system that exists in U.S.

trades. In other trades with closed conferences, entry is much more difficult, and as a result, the U.S. trades tend to attract surplus liner tonnage from all the world trades. While trade has grown since then, container capacity continues to be added, and there appears to be no reason to believe that the overcapacity situation will be remedied in the forseeable future.

Container system profits are particularly sensitive to utilization, as the slopes of the lines in Figure 1 indicate. These lines reflect estimated voyage profits on one trade route as a function of utilization of the ship's capacity. "A" is a small foreign-flag break-bulk ship; "B" is a large U.S.-flag break-bulk ship; and "C" is a U.S.-flag containership. Costs and revenues were developed with the assistance of operators in the trade.

It is evident from the slopes of the lines that the containership is much more profitable after it reaches its breakeven utilization than the break-bulk ships. It is equally evident that it loses money faster when utilization is below breakeven. Obviously all three owners have a great incentive to maintain utilization above the breakeven point, but that of the container operator is greater -- he has more to gain when he exceeds breakeven utilization and more to lose if he does not. As a result, the impulse toward marginal costing to improve utilization, common to all three, is even stronger for the containership operator.

Given the conditions of overcapacity on many container trades, there is a strong incentive to use whatever means are available to increase utilization. One obvious measure is rate competition, which has been endemic in the container trades in recent years. Ordinarily, rate competition is eliminated by the conference system, but with the overcapacity in the container trades the effectiveness of conference control was weakened, and legal and illegal rate cutting became common. Bridge traffic represents a different approach -- tapping other trade routes for additional cargo.

In the development of bridge traffic, then, the technological elements were in place, and a strong economic incentive existed.

THE GROWTH OF BRIDGE TRAFFIC

Data on the actual tonnage moving in bridge traffic are fragmentary. Census statistics do not identify bridge cargo

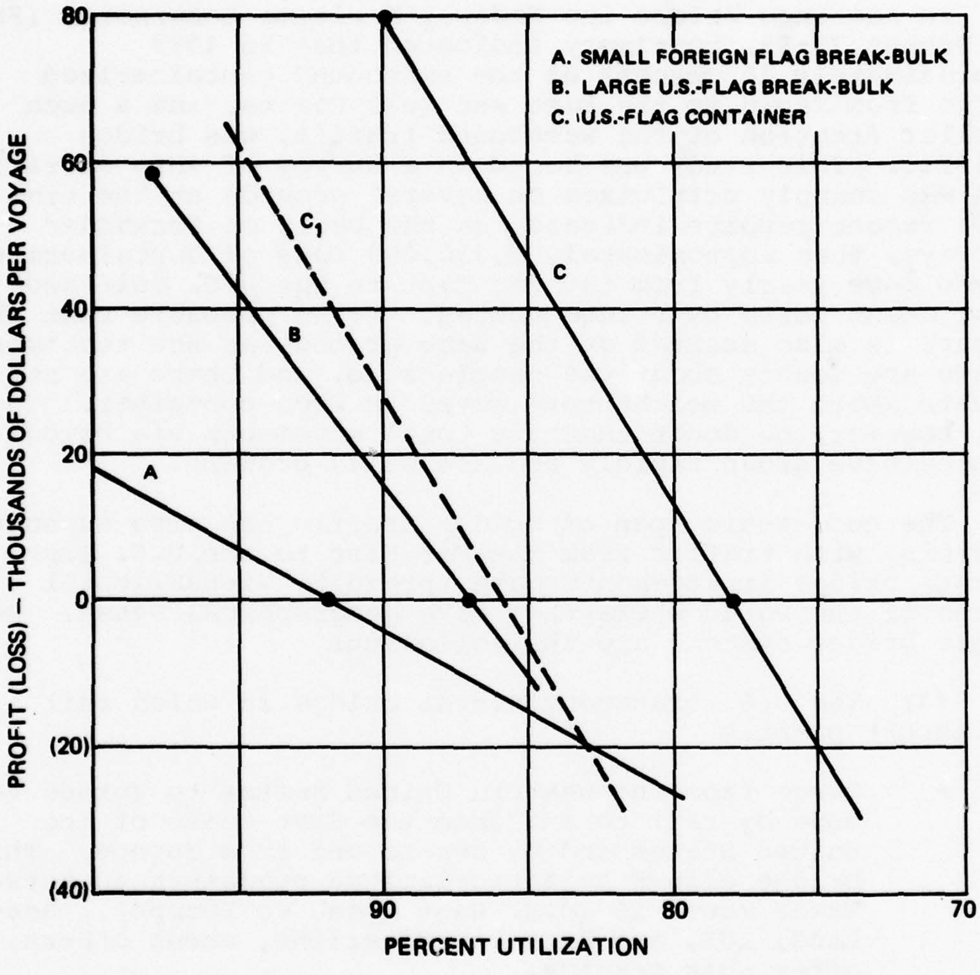


FIGURE 1

VOYAGE PROFITS AS A FUNCTION OF UTILIZATION as a separate entity. Bridge movements are simply grouped into the customs district where the commodity clears customs. As a result, commodities moving from Japan to the East Coast using the transcontinental bridge are classed as West Coast imports.

In hearings before the Federal Maritime Commission (FMC) in Docket 73-38, testimony indicated that in 1973 approximately 10 percent of the eastbound containerized cargo from Japan to the East and Gulf Coasts, and a much smaller fraction of the westbound traffic, was bridge traffic. This study was based on a survey of ship operators and was sharply criticized on several grounds at the time. More recent reports indicate, on the basis of forwarder surveys, that approximately 2,330,000 tons of containerized cargo move yearly from the Far East to the U.S. Gulf and East Coast ports by bridge routes. It is probable that this figure is also suspect on the same grounds as the testimony. There are doubts about the sample size, and there are strong doubts about the weight tons moved in each container. There is, however, no doubt that the total movements via bridge routes have grown rapidly and are still growing.

The geographic span of bridge traffic has also expanded. Starting with traffic from the Far East to the U.S. East Coast, bridge arrangements have spread to virtually all parts of the world where they make geographical sense. Some major bridge systems are the following:

(1) The U.S. transcontinental bridge in which rail transport permits

- Cargo from the western United States to Europe to move by rail to and from the East Coast of the United States and by sea to and from Europe. This bridge allows Atlantic-limited operators to serve Trade Route 26 (U.S. West Coast to Europe). Sea-Land, ACL, and Dart Containerline, among others, offer this service.

- Cargo from the East Coast of the United States to and from the Far East to move by rail to and from the West Coast and by sea to and from the Far East. This bridge allows Pacific operators to compete on Trade Route 12 (U.S. East Coast to the Far East). APL, States, Seatrain, the Japanese Consortia, and others are active here.

- Cargo from Europe to the Far East and the Far East to Europe to move by water to the United States and by rail across the country. This bridge allows lines in the U.S. trades to compete for cargo with the lines on the all-water route from Europe to Japan (via Suez). It also permits competition with the Soviet Trans-Asian bridge.

(2) The Gulf bridge in which inland rail connections permit

- Cargo from the Gulf Coast to Europe to move by rail to the southeastern Coast of the United States and by water to Europe. This bridge allows East Coast operators to serve Trade Routes 21 (Gulf to Europe) and 13 (Gulf to Mediterranean).
- Cargo from the Gulf Coast to the Far East to move by rail to the West Coast of the United States and by water to the Far East. This permits West Coast operators to serve Trade Routes 22 (Gulf to the Far East) and 17 (Gulf to Indonesia, Malaysia).

Both of these Gulf bridges are served by the same lines that offer the transcontinental bridge.

(3) The European bridge, in which inland European rail or truck connections permit cargo to and from the Mediterranean to move via European Atlantic ports to and from the United States. This allows North Atlantic operators to serve Trade Routes 10 (East Coast to the Mediterranean) and 13 (Gulf Coast to the Mediterranean) as well as, in connection with the U.S. bridge, West Coast to Mediterranean cargo.

(4) The Central American bridge service, in which inland truck connections from Panama permit cargo to and from Central America to move on the U.S. intercoastal trade via Panama. This allows intercoastal operators to serve in part on Trade Routes 4 (East Coast to the Caribbean), 23 (West Coast to the Caribbean), and 25 (West Coat to the West Coast of Central America).

The net effect of this spread of bridge traffc is to extend the competitive range of individual operators and conferences to the point where inter-operator competition and inter-conference competition is now almost worldwide. Coupled with all-water feeder services, many major ship operators, formerly constrained to a few routes, can now offer service practically on a worldwide basis.

For example, Seatrain, the originator of bridge traffic in the United States, formerly served only the North Atlantic and North Pacific trade routes. Through bridge traffic, it is now essentially serving the entire northern hemisphere.

THE ECONOMICS OF BRIDGE SERVICE

The economic incentive to the ship operator for the establishment of bridge traffic was discussed briefly in an earlier section. In an effort to further define and set limits on this incentive, costs of operation and freight rates were solicited from several operators. The intent is to show exactly what contribution to the owner's net revenue would be expected from adding or substituting bridge traffic for direct service.

In this analysis the trade route selected is that from Japan to the East Coast of the United States. The bridge operator serves with his own ships the leg from Japan to California, with service to the East Coast provided by transcontinental railroad. The costs are computed from the marine terminal in Japan to the rail terminal on the East Coast. In the case of the all-water competition, costs are from the marine terminal in Japan to the marine terminal in New York. The itineraries are also simplified for easier calculation -- direct services in all cases. Costs are representative of U.S.-flag unsubsidized operations.

The results are summarized in Table 1. Voyage costs are for a one-way voyage at 100 percent utilization and do not reflect overall voyage results, since outbound utilization is usually considerably lower than inbound in all three cases. The costs are, therefore, probably low. Voyage costs include wages and fringes, subsistence, insurance, maintenance and repair, fuel, overhead, capital charges, container lease fees, and port costs. Cargo-handling costs include both direct handling charges and an approximation of terminal and equipment costs. In the case of bridge traffic, cargo-handling costs are higher as a result of the additional transfer from marine to rail terminal on the West Coast.

Revenues are based on actual rates for three commodities currently moving in reasonable quantities from the Far East to the United States. Commodity "A" includes electrical and electronic equipment such as medical instrumentation and was selected as a high-rated commodity. Commodity "B", air conditioning equipment and parts, commands an intermediate

TABLE 1

RELATIVE COSTS–DIRECT AND BRIDGE SERVICE

21 Knot-1,000 TEU Vessel
20 Revenue Tons/TEU

	Japan-California Direct	Japan-East Coast Direct	Japan-East Coast Bridge Service
Voyage Cost/Unit	$ 194.00	$ 418.00	$ 194.00
Cargo Handling Cost/Unit	285.00	285.00	385.00
Rail Division			
Up to 20 20-Foot Units			588.00
TOTAL COST	$ 479.00	$ 703.00	$1,167.00
Revenue			
Commodity A	$2,020.00	$2,327.00	$2,327.00
Commodity B	1,200.00	1,570,00	1,570.00
Commodity C	1,040.00	1,270.00	1,270.00
Net Revenue			
Commodity A	$1,541.00	$1,624.00	$1,160.00
Commodity B	721.00	867.00	403.00
Commodity C	561.00	567.00	103.00

rate. Commodity "C", chinaware, was selected as a relatively low-rated commodity. Just as the cost estimates are probably low, the revenue estimates are probably high, since 20 revenue tons for a 20-foot container is a fairly high utilization. The numbers do, however, serve to illustrate the basic economics of bridge service, including some of the incentives and some of the barriers.

Referring back to Figure 1, suppose that the container operator, Line C, is operating close to his breakeven point. This is not a particularly healthy position, and there is an obvious incentive to increase utilization. Given the overcapacity that has existed on most container trades since 1970, it is also a not-uncommon position for container operators.

An obvious move for the container operator, if he is to increase his utilization, is to cut rates. The effect of an across-the-board rate cut of 15 percent by the container operator is shown in Figure 1 as curve C_1. He may gain cargo as a result of the rate cut, but his breakeven utilization is also increased substantially. Given a tightly competitive situation, the other lines in the trade can be expected to retaliate (very rapidly if the rate cut is made legally and sooner or later if it is made illegally).

Regardless of the revenue gains from increased utilization, a large portion of those gains must be paid for in reduced revenue for all cargo currently carried by the operator. Selective rate cutting (i.e., rate cuts on selected commodities only) may be more successful, but there is still a price to be paid in decreased revenue on cargo already being carried. Given the inevitable retaliation of the other competitors, rate cutting is not likely to be a profitable exercise, even though it has been the most common approach in the past few years.

Bridge service, however, offers a totally new source of cargo. Even with the additional handling cost and the payment to the railroad, the operator can still make a profit on the bridge containers. The profit is not as great as it would be if he carried the same commodities on his own all-water transpacific trade, but bridge cargoes comprise a very reasonable additional cargo. In effect, the highest rated bridge cargoes simply become somewhat more moderately rated cargo for the transpacific operator.

The operator can also be quite flexible in his pricing of bridge cargo. It is not his own rate structure that is being disturbed. Although bridge rates are usually set for competitive reasons at the same level as the all-water rates, the operator can easily set the rate below the all-water rate to attract more cargo. He can do this without some of the penalties associated with rate cutting in his own all-water trades.

The economic incentive to the operator to offer bridge service is clear -- increased utilization of his ships at essentially no cost to himself.

There is also a strong incentive for the shipper to use this service, if offered. The operator is providing the shipper with a potential (and very often, actual) reduction in transit time. From Japan to California, sea time is about 9 days. Transcontinental railroads using unit trains can generally maintain 6-day delivery to the East Coast. Allowing an extra day for transfer from the marine terminal to the rail terminal on the West Coast, total transit time is thus 16 days.

The all-water route takes 21 days from Japan to the East Coast, and, therefore, a saving of 5 days of transit time can be achieved by using this bridge. To some shippers this is an important incentive -- so important that some bridge opponents have insisted that bridge cargoes should carry a premium rate.

Bridge service thus offers a rather rare combination of incentives -- a better service to the customer coupled with a positive benefit to the operator. And somebody else pays the bill.

BARRIERS TO BRIDGE TRAFFIC

The barriers to bridge traffic have been essentially legal and raised by those who are actually or can be potentially damaged by its growth. There are four categories of victims, three actual and one potential.

The first, obviously, is the all-water carrier. It is his cargo that makes the bridge service feasible and attractive, and there is very little he can do about it. He really has only two alternatives. The first is to reduce rates to compete with the bridge traffic and hold on to his cargo. In a sense this is like starting a rate war with himself -- a war which he cannot win since the bridge operator can simply match his rate cuts and still improve his position, albeit by a lesser amount. Meanwhile the all-water carrier has reduced his revenue on all his carryings, and most probably has disrupted the conference system on the all-water trade.

The second alternative for the all-water carrier is to offer his own bridge service. Here, he moves into competition with himself, and a competition in which the more successful he is the worse off he is. In his high-rated cargo, Table 1, where his all-water service showed a profit of $1624 per container, he is now offering the identical service for a profit of only $1160. The lowest rated commodity, which paid him a respectable $567 on the all-water route, is now almost marginal at $103.

The all-water carrier is indeed hurt by bridge traffic, and hurt badly.

The conference in the all-water trade is also damaged, and in a very fundamental sense. The conference is organized to control rates and competition in the all-water trade, and suddenly it is faced with a competitor who is totally outside its control and, moreover, beyond its reach. The bridge carrier is a member of a totally different conference. The all-water conference, established to control competition, is now in competition with another conference.

A third victim of bridge traffic is the ports serving the all-water trade. Containers that were loaded and discharged in East Coast ports are now loaded and discharged on the West Coast. In principal, this loss could be made up by an equivalent bridge movement from the West Coast of the United States to Europe, but this trade is infinitesimal compared to the Far East trade from the East Coast ports. Every bridge container in this trade then represents a loss of work for East Coast longshoremen and a loss of custom for East Coast ports. Conversely, the West Coast ports and labor benefit. Given the complicated container royalty and work preservation provisions, including Guaranteed Annual Income of the East Coast labor agreements, the Far East bridge has displaced labor and increased costs for <u>all</u> operators using East Coast ports. Eventually, these cost increases will be reflected in increased freight rates practically everywhere in the world to and from East Coast ports.

Finally, the greatest potential victims of bridge service may be certain groups of shippers patronizing the all-water route. A glance at Table 1 is sufficient to establish the target of the bridge operator's marketing effort. The bridge operator will concentrate on the highest rated commodities since, with his higher costs and the railroad division, the lower rated commodities would be marginal at best -- and most probably would be unprofitable under most conditions.

The all-water rate structure, like all conference rate structures, is based on value of service. It costs the carrier no more to carry a container of commodity "A" than it does of commodity "C". The rates charged are set in such a way that the carrier profits on the mix of commodities in the trade. He obviously makes a high profit on commodity "A" and very much less on commodity "C".

With the bridge operator making substantial inroads on the higher rated commodities, the all-water operator's revenue structure will be depressed, not only by the loss of cargo but by the skewing of his revenue structure toward a lower average rate. As a result the all-water operator will eventually be forced to raise rates (probably across the board) on a now heavily low-rated cargo mix. These are precisely those commodities and those shippers that can least afford such an increase.

The barriers to bridge traffic, therefore, have been and are being raised by groups that are genuinely damaged by the new form of competition. Essentially, their only recourse is a legal one.

The exact extent of the damage suffered by the injured parties is extremely difficult to determine. This is principally the result of the difficulty in estimating the total number of containers moving on bridges. In the East Coast-Far East trade, for example, many containers listed as bridge containers by the conferences in the Far East to California trade formerly moved on Overland Common Point (OCP)[1] rates to the West Coast and are not a real diversion of cargo. Sharply varying estimates were cited in recent International Longshoremen's Association (ILA) negotiations, but essentially the exact quantities of cargo diverted cannot be estimated.

It is clear that most of the damage to others can be regarded as dislocation rather than injury and need not be permanent. Those injured, however, are difficult to convince.

THE STATUS OF BRIDGE TRAFFIC

The legal reaction to bridge traffic is embodied in FMC Docket 73-38 filed by CONASA (Council of North Atlantic Steamship Associations), the Ports of Boston and Philadelphia, and the ILA in 1973. The respondents were 14 steamship companies that were offering bridge services between the Far East and U.S. East Coast ports. It is known as the Far East Minibridge Case.

The basic charges raised were that bridge rates were "unreasonably low and detrimental to U.S. commerce" and that they were "discriminatory" and resulted in diversion of cargo from the ports' "naturally tributary regions." Following the protracted testimony, the FMC Administrative Law Judge made an initial decision in favor of bridge traffic in 1977. The decision essentially rejected the arguments of the complainants.

In the meantime, bridge traffic continued to grow and threatened the very existence of some conferences. The whole concept of conference control of rates and competition was called into question by the fact of this inter-conference competition. The response of the conferences has been to propose inter-conference agreements to control bridge rates and practices. In this they have been sharply opposed by the U.S. Department of Justice and by many shippers who feel that this type of "superconference" will eventually either forbid bridge traffic, force higher rates in bridge traffic, or otherwise reduce its effectiveness as an alternative service. Thus far, the opponents have been successful and no such agreements have been approved.

Bridge traffic has become a fixture in many trades and is unlikely, at this point, to disappear, although through conference activity its effectiveness may be constrained in the future. Three other factors may affect the scale of bridge traffic in the future. The first is increased Panama Canal tolls which favor the continued growth of bridge traffic. The second is a demand by the railroads for an increased share of the revenue. This appears to be occurring now and would, of course, adversely affect bridge traffic. Finally, the physical condition of the railroads may also be a limiting factor.

Bridge services are now offered by many carriers, and, to a certain extent, the same "overcapacity" that exists in the container trades now exists in bridge traffic. Rate competition in bridge traffic has somewhat reduced its appeal to operators, but, in self-defense, practically all operators use it. In the recent ILA strike on the East Coast, bridge traffic to the West Coast was an alternative available for the first time and was used on a vast scale to move cargo to and from the Far East. The effect of the strike on shippers was thus less than in previous strikes.

As an innovation, bridge traffic has been very successful. It usually offers the shipper an improved service and, provided rate levels are not depressed by overcompetition, promotes a new source of remunerative cargo to the operator.

Like most innovations, it is also thoroughly disruptive. Its cargo gains come at the expense of the all-water carrier. It shifts the demand for labor and port facilities from one coast to another, and it has made a strong contribution to the weakening of an already weak conference system in U.S. trades.

NOTE

1 OCP rates have existed for years and were developed to attract cargo from interior points in the United States to the West Coast. They are lower than rates from the West Coast to the Far East and are designed to compete with rates from the East and Gulf Coasts to the Far East.

HIGHLY SKEWED PROPELLER

Frank Dashnaw

Ship's hull vibration excited by propeller blade generated forces is one of the most unpredictable and damaging conditions that happen to a ship. The incidents of this condition have occurred more frequently as horsepower ranges have increased. Serious hull vibration can cause cracking of the hull, increased maintenance costs of all the equipment aboard ship, increased crew stress, breakage of steam lines and other piping, and may necessitate operating the ship at less than design speed to avoid serious damage. Numerous attempts to understand and correct this problem have been undertaken in the past.

The Maritime Administration sponsored the comprehensive research program that led to the successful test and evaluation of this first highly skewed propeller (HSP) (100 percent skew) on the ore-bulk-oil carrier (OBO) SS USTRASEA, owned by the Aries Marine Shipping Company. Aries Marine later ordered the manufacture of a similar HSP for another ship of the same class.

This extensive effort included model and strength tests, improvements in propeller design methodology, independent strength analyses, classification society review, and detailed, full-scale performance tests. Among those who contributed to the success were the David Taylor Naval Ship Research and Development Center; Hydronautics, Inc.; Aries Marine Shipping Company; Littleton Research & Engineering; and National Steel and Shipbuilding Company.

Subsequently, the Maritime Administration also provided an HSP (100 percent skew) for detailed test and evaluation on a different type vessel -- a roll-on/roll-off ship of the SEABRIDGE Class owned by American Export Lines. Ships of this class vibrate badly. This HSP dramatically decreased the propeller/wake-induced vibration levels, permitting the ship to resume operations at design speed.

Later, States Steamship Company ordered four six-bladed HSP's (50 percent skew) for their new MAINE Class ships to prevent an expected vibration problem. Now, Matson Navigation Company is having one four-bladed HSP (100 percent skew) manufactured to correct a hull vibration problem.

Each of the installed HSPs shows a sharp reduction in vibration levels, with the 100 percent skewed HSPs giving more dramatic reductions than those having 50 percent skew. An HSP is designed to smooth out the effects at the stern of a ship of the non-uniform water flow (wake) that would otherwise induce pulsating forces on each propeller blade of conventional design as it rotates through varying wake conditions.

The technical approach to this development of the HSP was based on the rationale that it would be much better to reduce sharply the driving forces that cause the vibration problems rather than attempt to modify the structure to withstand those forces. Previous attempts at correcting this problem through structural modifications (in cases where it could be done at all) were costly and often unsuccessful.

Economically, the HSP is quite attractive. The approximately 8 percent increase in propeller weight that is not required to ensure adequate strength represents the primary cost impact. The reported, slightly higher efficiency of the HSP in service may be due to either the observed reduction in cavitation erosion and/or a superior design.

This innovation could not have happened without the combined effort of a number of organizations -- David Taylor Model Basin, the owner of the vessel, the American Bureau of Shipping, the U.S. Coast Guard, National Steel and Shipbuilding Corp., and the Maritime Administration. However, the critical link was the owner of Aries Marine Shipping Company. Had the propeller failed, a substantial loss in revenue would have occurred. Conversely, when the propeller did succeed there was no immediate and balancing increase in revenue, although, there is no doubt that the propeller installation will pay for itself many times over the life of the ship in reduced maintenance costs.

This project seems to approach the threshold of risk that an operator is willing to undertake without a substantial opportunity for increased revenues and profits.

DEVELOPMENT OF GAS TURBINE PROPULSION: G.T.S. JOHN SERGEANT

Sterling A. Fielding

SCOPE

The JOHN SERGEANT was included in a program initiated in 1954 with the objective of exploring advanced concepts for propulsion systems for a fleet of merchant ships to replace the aging fleet built during World War II. The SERGEANT was claimed to be the first gas turbine, oceangoing vessel and to use the first new-type marine power plant to be introduced since the first diesel engine installed in 1903.

The controllable and reversible pitch propeller was an essential auxiliary for the gas turbine, inasmuch as the gas turbine is inherently uni-directional in rotation. Although the controllable pitch propeller idea dates back to about 1850, all actual installations developed and in service were in a low power range.

The simplicity of controlling the gas turbine influenced the decision to develop a single-lever bridge control as a step toward automated central control of ship propulsion.

ENVIRONMENT

Several factors contributed to the development of the JOHN SERGEANT. These include the following:

- Gas turbine propulsion had been discussed and studied extensively for more than a decade, and gas turbine power plants were in service for various land-based services;
- A large number of merchant ships built under the war program would need to be replaced within 10 to 15 years;

- There were about fourteen hundred 10-knot LIBERTY ships in the Reserve fleet. One objective was to evaluate alternate plans for upgrading these ships to a more economical 15-knot speed for possible future emergencies;

- Residual fuel oil (bunker "C") was considered the only economical fuel for ship propulsion; and

- Labor for ship operation was a high-cost item. The basic simplicity of controlling a gas turbine tended to be favorable for development of a centrally automated system.

HISTORY OF DEVELOPMENT

Under a $12,000,000 appropriation, the JOHN SERGEANT was one among four ships selected in August 1954 from the moth-ball fleet of war-built ships for experimental development of advanced propulsion concepts. The power plant consisted primarily of equipment produced by General Electric Company. The gas turbine was an open cycle, regenerative, two-shaft type, with an axial flow compressor, driven by a high pressure gas turbine, and with a separate load turbine in the same casing. The load turbine was designed to develop 6600 SHP (ship horsepower), and, through a reduction gear, to drive a controllable and reversible pitch propeller at 113 RPM (revolutions per minute).

The 6600 SHP rating was compatible with the objective of upgrading the LIBERTY ship from a 10-knot to a 15-knot ship, with the bow design being modified by the addition of 25 feet to the length. For new ships, two gas turbines could be connected to the same reduction gear to increase the power rating to the level being considered at that time for the smaller cargo ships.

The controllable pitch propeller system was designed and built by S. Morgan Smith Company in York, Pennsylvania. This company had extensive experience in controllable pitch propellers for hydraulic power plants. However, the propeller built for this ship incorporated a new concept for the blade attachment, for which the company was processing patents at the time. This new concept proved to be a weak link, and the problem persisted to the end of the three-year service period.

The economic necessity for burning bunker "C" fuel required an on-board fuel-washing system to reduce the percentage of impurities (sodium and vanadium) to an acceptable level, in order to prevent excessive buildup of chemicals on compressor and turbine blades. It was necessary that the fuel supply be obtained in certain ports where a fuel complying with a certain specification was available. The fuel-washing system on this ship never proved suitable for handling any and all sources of bunker "C" fuel. The fuel-washing operation involved extra labor, and the operation was not favorably adaptable to automated control; however, the overall crew requirement for the gas turbine system was less than that for a steam system at that time. The alternatives would be to use diesel fuel at a higher cost or have the fuel treated in a shore-side facility. For a fleet of ships, the second alternative could possibly be feasible.

The conversion of the ship and installation of the new propulsion system was completed by Newport News Shipbuilding & Dry Dock Company, Newport News, Virginia, in September 1956.

SEA TRIALS

Sea trials were conducted September 10-14, 1956. Trials were conducted on diesel fuel and on washed bunker "C" residual oil, alternately. The performance of the gas turbine power plant exceeded design predictions. Maximum power of 7514 SHP was developed at 113 RPM, with an ambient air temperature of 70°F (10°F lower than the design temperature of 80°F). The fuel economy was also better than design predictions and better than a modern steam plant in the same power range.

SERVICE EXPERIENCE

The ship was immediately put into service on North Atlantic voyages from U.S. East Coast ports to English, Dutch, and German ports. Since the gas turbine is inherently more efficient at lower air inlet temperatures, it was found the plant was capable of developing power output substantially above the 6600 SHP design value while operating in the North Atlantic climate.

Although the controllable pitch propeller functioned perfectly through the first year of service, a slight oil leakage from the hub was observed while in port. The ship was drydocked for propeller inspection. The propeller was dismantled, and it was found that all four sockets in which the blades were secured had developed fatigue cracks. Some design refinements were developed, and the sockets were replaced. Downtime was about six weeks.

At the end of the second year's service, the gas turbine system was still performing superbly, but the CP propeller had developed the same type failure as found previously. The blade sockets were redesigned to provide some "beefing-up" of the weak section. Again, a downtime of about six weeks was required for propeller repairs.

At the end of the third year, the propeller was examined and the same type failure had developed. Although the gas turbine was still performing satisfactorily with only a few minor repairs, the ship was taken out of service.

No further effort was exerted toward debugging the propeller design. It was the writer's opinion, based on experience with the Navy's CP propeller development, that the blade trunion, screwed into the socket would be a superior design for the higher power installations.

PROJECTED TRAJECTORY

Gas Turbine vs Steam Power

Fuel Economy. The gas turbine was competitive with steam power, with both systems using residual fuel. However, the gas turbine required washing of the fuel to remove pollutants.

Advanced Power Ratings. The gas turbine could be installed for 15,000 SHP per propeller without further development of gas turbine components. However, for power ratings 20,000 to 40,000 SHP per propeller, steam had a definite advantage, since this power range had already been developed.

Controllable Pitch Propeller (or Reversible Gearing). Failures of the controllable pitch propeller indicated that further development of a propeller of this type was essential even at the 7500 SHP level. CP propellers in the 20,000 to 40,000 SHP range are still not satisfactorily developed. Regarding the alternative, reverse gearing of the clutch type was installed on one gas turbine ship (G.T.S. CALLAGHAN) and a reverse gear of the planetary type has been shop tested. Details about these developments are not familiar to the writer.

Automation. The gas turbine power plant is favorably adaptable for automated central control. The JOHN SERGEANT was designed with a single-lever control on the bridge that would effect all maneuvering functions. However, the fuel-washing system was not readily adaptable to automation. Hence, a shore-side supply of ready-to-burn fuel would be essential for automated operation of the ship.

Summary. Extensive adoption of the gas turbine in lieu of steam for the merchant fleet would depend on the following developments:

- Development of gas turbine components for the higher power ratings required for modern ships;
- Development of either a reliable and feasible controllable pitch propeller or a reversible reduction gear unit for the desired power rating; and
- Availability of a shore-side supply of fuel in a ready-to-burn condition in compliance with the specifications required for the gas turbine system.

FACTORS THAT MAY HAVE AIDED THE DEVELOPMENT

A gas turbine propulsion system for a ship should be designed strength-wise for the highest economical power rating attainable at the lower ambient air temperatures prevailing on possible trade routes. For example, the JOHN SERGEANT, operating in the North Atlantic route, was capable of developing a shaft horsepower 20 to 25 percent above the design rating, which was based on an 80°F. ambient temperature. Noting that a SHP meter is not ordinarily included in shipboard instrumentation, operation at higher than design power rating could have contributed to the recurring mechanical failures.

HISTORY AND CURRENT STATE OF SHIPBOARD AUTOMATION

Donald H. Kern

It is the objective of this study to trace the development and introduction of shipboard automation as an innovation in the United States and foreign maritime industry. Factors that initiated and encouraged the development of automation technology and supported its installation aboard merchant ships are examined together with factors that have acted to inhibit progress in this field.

Any effort to explore the technical content of "shipboard automation" as an innovative concept immediately underscores the fact that the scope of innovation involved can range from automation of a single operational feature such as steering and course keeping, to automation of all major functions required for the operation of a modern seagoing ship. The concept normally has only one feature that can be identified as being common to all ships, independent of the level of automation employed, and that is the intelligent electronics that is provided to monitor and control the functions selected for automation.

It is not surprising to find, therefore, that the term "shipboard automation" is subject to wide variation in interpretation and considerable ambiguity as to meaning. For purposes of this study the term is intended to connote a highly integrated ship automation system that monitors and controls all or nearly all the major operational functions of the ship. Applying this basic definition, a modern automated merchant ship would include such features as:

- Automatic monitoring and control of main propulsion and auxiliary machinery systems, including alarming of out-of-limit conditions, automatic turndown and/or shutdown in casualty situations, auto start of standby units, and automatic logging of designated machinery performance parameters;

- Bridge systems that include such features as automatic steering and course keeping with the ability to pilot the ship over a relatively complex predetermined course, direct bridge control of main propulsion power, automatic navigation position fixing, anti-collision radar and anti-stranding, and sonar systems;

- Automatic cargo handling, cargo pumping, and auto load calculation with the capability of adjusting liquid ballast or cargo to maintain optimum ship trim and list for efficient propulsion and safe transit during hazardous weather conditions. A supporting subsystem includes hull stress monitoring;

- Hull monitoring; and

- Damage control systems that include automatic monitoring for fire and flooding conditions with the ability to initiate emergency actions such as fire sprinkling or smothering, closure of fire or watertight doors, and pumping to control flooding.

At this point in time, the "modern automated merchant ship" described by the above listing of many automated individual ship functions must be considered as hypothetical. No single ship, to the author's knowledge, incorporates all of the features cited above, although many ships operating today, particularly foreign-flag merchant ships, are referred to as highly automated since they are fitted with a majority of these features. The particular array of automated functions found on any one ship will vary depending upon the shipowner's desires, the influence of the ship designer and shipbuilder involved, and other factors such as the cargo carried, shipping routes, and classification society used.

The history of the innovative process that has led to wide acceptance of highly automated merchant ships might be considered to have its genesis just prior to World War II. During this period, automation was introduced to a few selected ship systems and machinery components. Examples include automated steering, that is, the so-called autopilot, automatic boiler control, and bridge control of propulsion power level. If one surveyed progress in this field, circa 1955, the findings would reveal continued use of these features with but few refinements and virtually no extension of automation to other ship functions.

It is significant to note that, while automation in the maritime industry was marking time, following World War II other industries were introducing innovative automation concepts at a rapid rate and, by so doing, were achieving impressive gains in productivity and improved manpower utilization. This progress is clearly evident if one examines the performance of the petrochemical, steel, electronic component manufacturing, and aerospace industries. Automation of important control functions in commercial aircraft, military aircraft, and space vehicles also became accepted practice during this same period.

It is submitted that few knowledgeable people would argue with an appraisal that set the early 1960s as a realistic milestone to mark the point when the maritime industry seriously embraced automation for ship control and operating functions. In so doing, the maritime industry was one of the last of the world's major industries to adopt automation technology.

The prime catalyst that fostered and supported the introduction of automation concepts in non-maritime industries and, ultimately, in the maritime industry was, beyond any question, the availability of intelligent electronics. The computer, the processor, sensing devices for pressure and velocity, and a myriad of other operating parameters together with associated control circuitry permitted the monitoring and control of complex functions. The further introduction of solid state components for the manufacture of intelligent electronics reduced the cost of systems and significantly improved system reliability. This latter technology certainly can be credited with a lion's share of the extraordinary growth in automated devices and systems that has been observed in all industries in recent years. The very real improvement in reliability offered by solid state devices has been particularly attractive to the maritime industry, since automated shipboard systems must perform at sea for extended periods in a relatively hostile environment, isolated from specialized repair personnel and facilities.

Today, one must conclude that the availability of reliable intelligent electronics and shipboard automation design know-how fully support any major maritime nation putting to sea a highly automated merchant ship offering the potential for improved overall performance, enhanced efficiency of operation, and, most importantly, improved profitability. With these tools available, some countries have achieved significant results; others, notably the United States, have failed to aggressively pursue the introduction of automation to their merchant fleet. Why does this situation prevail? A brief examination of the history of the development and introduction of automation, or the lack thereof, in certain key maritime countries provides some answers to that question and, more importantly for the United States, highlights actions we must take if we are to improve the competitive position of the American-flag fleet in world maritime trade.

In 1961, Japan announced to the maritime world that it had demonstrated the operation of the first automated seagoing ship. The ship, KINKASAN MARU, was fitted with bridge control of her main propulsion plant and a centralized control system for all engine room machinery. By our current definition, the KINKASAN MARU might not qualify as a highly automated merchant ship. The sea trials of this ship did, however, provide an important automation milestone, since they represented the culmination of a coordinated and concentrated Japanese effort to produce a model ship that could demonstrate at sea the practical application of automatic and remote control of ship systems. The program had been started in March 1959, when the Japanese Ministry of Transportation requested that the Shipbuilding Technical Council study the "technical problems involved in the automated operation of ships and possible solutions to them". The Council set up sub-committees to handle specific subjects, and instituted a joint effort by shipping, shipbuilding; related industries to assist in the program; and, with the Ship Bureau of the Ministry of Transportation, coordinated the project's research activities.

Japan's position as a major shipbuilder, supplying a large percentage of the world's merchant ship tonnage to an international market, is well documented. Progress toward increasing the automation features incorporated in these ships continued through the 1960s and, in 1967, the Ministry of Transportation established an ambitious program to further advance automation technology in Japanese-built ships. To lead this effort, the Ship Bureau of the Ministry brought together representatives of the shipbuilding industry, shipowners, component suppliers, industry and university research activities, and classification societies who functioned as members of the "Joint Research Committee on Advanced Integrated Control Systems for Ships".

The cooperative efforts of this group were instrumental in producing a series of highly automated merchant ships during the period 1969 to 1973. It is pertinent to note that the main thrust of the Japanese automation program was directed at a reduction in shipboard manpower requirements. The ability to operate large oceangoing ships, particularly VLCCs (very large crude carriers), on more or less fixed shipping routes with fewer personnel presented an attractive feature to foreign-flag fleets and to the Japanese shipowners who were facing a severe shortage of qualified seagoing manpower. The Research Committee mounted a major effort in the early 1970s and produced a prototype design for a highly automated VLCC that was capable of being operated with a nine-man crew.

World events in the mid-1970s, however, overtook the Japanese programs. The slump in demand in new ship construction and a depressed world shipping situation in the mid-1970s acted to discourage further Japanese effort in the field of automation. Coordinated and cooperative programs such as those that produced KINKASAN MARU and the highly automated ships delivered in the 1969 to 1973 period have not been continued, and it is doubtful at this time if the prototype designs for low-manned (i.e., nine-man crew) ships will find a market. The world shipping situation coupled with extensive leasing of Japanese-owned ships has caused the Japanese Maritime Union to strongly oppose any further action aimed at reducing shipboard manning.

Norway and Sweden have been in the forefront of development programs that have successfully introduced innovative automation concepts to very nearly all of the operating functions of modern seagoing ships. Although the method of achieving the unique success that these two countries enjoy in the area of shipboard automation varies in certain details, the fundamental approach employed is remarkably similar.

Major and readily identifiable effort directed toward the development of practical shipboard automated systems was initiated in both of these Scandinavian countries in the late 1960s. From the outset, it was recognized that automation could have a serious impact on nearly all aspects of the maritime industry; that both the cost of introducing seagoing hardware and the risks involved would be high; and, that, if they were successful in their efforts, the ultimate payback to the entire industry would be extremely attractive. Having identified the magnitude of the task and the potential benefits that could accrue from a successful program, both countries were able to secure the cooperation and active support of all the major players that could contribute to, or would be affected by, the introduction of automation to their merchant fleets. The programs drew support from shipowners, shipbuilders, maritime unions, government, classification societies, and universities and industry research facilities.

Norway's program involved a significantly broader base of support than did the automation effort in Sweden. Close to a hundred maritime-oriented companies in Norway now contribute funds and provide active support of personnel to the effort. A full-time project group was established in 1970, referred to as "Projects or System for Management and Control of Shipping" (SDS), for the purpose of coordinating projects relating to the maritime industry. Automation tasks are included as part of this group's responsibility. Financial support for the group is derived in equal shares from the government (National Research Council) and the participating industries.

Sweden's program, although fundamentally similar to Norway's, draws its cooperative support from the same range of maritime-oriented activities; however, the total number of activities participating from the shipowner, component supplier, and shipbuilder segments of the industry are far fewer than in the Norwegian case. In point of fact, Sweden's Salen Shipping, as the shipowner, and Kokums Shipyards, as the shipbuilder and ship design activity, have been the dominant force in this arena and must be awarded the principal share of the credit for the highly successful automation performance found in the Swedish merchant service.

Norwegian and Swedish highly automated merchant ships have now logged well over 100 ship years of at-sea operations with an enviable record of reliability and safety. The most notable group of ships contributing significantly to this record is the eleven ships of Salen's SEA SERPENT Class. Operation of these ships with unmanned engine rooms for over 40 hours on weekends (1200 Saturday to 0700 Monday) and 14 hours on weekdays (1700 to 0700) has become an accepted and routine practice.

An opinion presented earlier in this study noted that Japanese automation efforts concentrated principally on achieving a reduction in shipboard manpower requirements, with other potential benefits being accepted as welcome but incidental by-products. The Scandinavian countries, on the other hand, have placed the emphasis of their automation program on achieving improved operating efficiencies, reducing maintenance costs, reducing unscheduled repairs and ship off-line time, improving crew job satisfaction, and increasing safety. Although some reduction in crew size has resulted from automation, many of their automated ships are not operated at the minimum crew levels authorized by statutory rules and regulations. This situation is not driven by union demands, but rather by shipowners electing to retain personnel onboard above the minimum allowed levels to carry out planned maintenance programs that, in the long run, provide greater economic pay-off than could be achieved by reducing crew size. It is clear that from the outset Norway and Sweden placed great importance on the sociological aspects of automation, and their studies and development efforts have been carried forward on a sociotechnical basis rather than pursuing a purely technical approach. Like the Japanese, they have been concerned about the future availability of qualified personnel to take their ships to sea and have recognized the increasing disparity, in a negative sense, with which the seagoing manpower pool viewed life at sea as compared with shore-side job opportunities and working conditions. Automation was seen, and was used primarily as a means of improving the attractiveness of a seagoing career and, secondarily, as affording some potential for a reduction in shipboard manpower needs.

Other European countries have been actively engaged, to varying degrees, in shipboard automation, but the overall impact of their effort on the world maritime industry would have to be categorized as minimal as compared to the influence of the Japanese, Norwegian, and Swedish accomplishments in this field. However, worthwhile technical developments have evolved from limited automation programs in Denmark, West Germany, Spain, Italy, France, Great Britain, and the Netherlands. In most instances, these developments have been associated with particular items of machinery, cargo handling, or navigation systems. To cite an example, the work of Bermeister and Wain in Denmark provided for unmanned operation of their large diesel engines which are used extensively throughout the world as main propulsion elements for seagoing ships. The inability of certain of these maritime nations, most notably Great Britain, to assemble an effective cooperative team of maritime industry, government, union, and university players appears to be the prime missing ingredient that has prevented or hampered these countries from acquiring a leadership role in the ship automation marketplace.

The United States' situation presents itself as an incongruous conundrum. Most certainly, this country has been in the forefront with regard to the development, manufacturing, and marketing of intelligent electronics, the common denominator and basic ingredient of nearly all modern automated systems. There is little question that we are retaining a leadership role in this field by dint of continuing developments. Advanced microcomputers, microprocessors, microcontrollers, and complex sensors provide examples of U.S. capabilities in this area. Accomplishments in the petrochemical, steel, aerospace, electronic component manufacturing industries, and other industries have, for many years, clearly demonstrated an ability to innovate, develop, and produce automatic controls for complex processes. Control, navigation, and anti-collision systems associated with U.S. commercial aircraft, military aircraft, and space vehicles provide prime examples of sophisticated automated concepts.

In the light of the demonstrated technological capabilities cited above, there can be no doubt that there exists within the United States all of the fundamental tools, hardware, facilities, and human talent necessary to produce, in rapid fashion, automated shipboard systems superior to those now available in the world marketplace.

To further heighten the conundrum associated with the U.S. automation situation, it has been the author's personal observation of at-sea operations of automated foreign ships that the basic technology being used in these ships is derived directly from American developments; that the sensors, actuators, amplifiers, and other components used as system building blocks are of U.S. design and manufacture or are often foreign built under a licensing arrangement; that the intelligent electronics such as computers and processors are mainly of U.S. manufacture or utilize basic U.S. design concepts.

Given this set of circumstances, which clearly identifies the relatively massive U.S. technological capability, it is difficult to rationalize the very limited progress that has been achieved by the United States in developing advanced automation systems for marine services and in applying these systems to American-flag ships.

Certainly, one would think that our continued adherence to the philosophy of free enterprise, coupled with the aggressiveness with which U.S. industry pursues the development and introduction of innovations that offer promise of improved profitability, even in the face of relatively high-risk situations, would have acted to encourage shipboard automation developments. Further, it is noteworthy that, although we have fallen far behind other maritime nations in the area of automation, the root cause for our lethargy in this specific area cannot be attributed to a general or overall lack of a progressive attitude within our maritime community. Quite to the contrary, the United States has held a highly visible position in the world maritime industry as innovators and achievers, due principally to the introduction of novel ship design concepts such as roll-on/roll-off, LASH (Lighter Aboard Ships), and containerization. These American developments had a significant impact on world shipping, and today are widely imitated. Their time frame for gestation coincided very closely with the development and application of automation to European and Japanese ships. In light of this situation, it appears worthwhile to (1) scrutinize carefully those factors that lead certain maritime nations to adopt automation and to continue to expand their shipboard application and (2) review those barriers that have inhibited the introduction of automation in the U.S. merchant fleet.

FACTORS AIDING THE INTRODUCTION OF AUTOMATED SHIP SYSTEMS

The factors that have aided the introduction of automation and have continued to encourage shipowners and operators to employ the technology in the merchant ships of the world can be identified from a review of technical literature on the subject. The library of data is extensive, and it is important to note that a significant portion of the information now available is based on at-sea operating experience with these systems. Reports of performance of actual hardware in the ocean environment and expressed opinions of shipowners and operators who have been associated with the operation of highly automated ships were used wherever possible to identify those factors that have been supportive to shipboard automation. A summary of the factors follows:

Improved Profitability

From the point of view of the shipowner or operator, improved profits is, of course, the fundamental objective behind the introduction of any new concept to their ships or to their method of operating their particular segment of the ocean-shipping industry. Investment of capital, therefore, in a new system is, of course, expected to produce a reasonable return on investment during the operating life of the ship. An innovation that does not produce a reasonable return will soon die on the vine. This latter phenomenon has not prevailed in the case of automated ships operated by aggressive and competitive shipping companies in the Scandinavian countries and Japan. These companies have, over the years, increased the level of automation applied to their ships, indicating that their investment was attractive in that they were able to exploit automation to their economic advantage.

At the outset of this paper, the term "shipboard automation" was defined as a highly integrated system, monitoring and controlling all major operational functions of a modern merchant ship. The integrated system was described as consisting of five major functional elements or subsystems, namely:

- Machinery system;
- Bridge system;
- Cargo system;
- Hull monitoring system; and
- Damage control system.

Depending on the type of ship and the many variations in voyage patterns that are possible, the contribution of any one of the five subsystems to improved profitability can vary significantly. No attempt will be made here to examine the full matrix of alternatives; however, a qualitative identification of the major contributors is presented in the following summary of factors that bear directly on ship operation profitability.

- Improved shipboard manpower utilization has provided increased crew productivity in automated ships. This benefit has been achieved principally through automation of machinery systems which eliminated the need for watchstanders and data recording duty assignments, thereby allowing the conversion of these personnel to machinery maintainers, a highly productive role as compared to the nonproductive duties of watchstanding and data recording. Engine room personnel in an automated machinery space can be utilized, therefore, to conduct, on a continuous basis, a well-planned and organized preventive maintenance program. The investment of manpower in such a program acts to reduce shore-based maintenance requirements, reduce ship off-line time for maintenance, and maintain the machinery systems closer to their designed operating condition (as compared to leaving all maintenance for accomplishment by shore-based facilities at widely spaced intervals).

It is of interest to note that some Scandinavian shipping companies operating highly automated ships with engine rooms certified for Unattended Machinery Space (UMS) operation have made only slight reductions or no reductions in engine room manning levels, electing instead to retrain and use the available manpower for maintenance. Where this approach has been followed, the shipping companies have considered it essential that, concurrent with the installation of automated machinery systems, a detailed, planned maintenance program be developed and placed in operation immediately upon delivery of the ship. The Chief Engineer of an automated ship has as one of his primary duties the management and administration of the ship's planned maintenance program.

An improvement in manpower utilization has also been realized, but to a much lesser extent than that noted for machinery automation, through the use of automated damage control systems. Fire and smoke sensors, bilge level sensors, automatic sprinkling and smothering, auto door closing, auto pumping, etc., have eliminated the need for roving watches, allowing this manpower to be put to a more productive use.

- Certainly, reductions in shipboard manpower requirements through automation have been an attractive incentive to shipowners and operators. Unfortunately, this aspect of automation has been overemphasized and misidentified as a principal benefit, thereby acting as a catalyst to precipitate strong union resistance to all facets of automation. There is no question that automation, when examined on a worldwide basis, has resulted in a reduction in crew size. This result was achieved primarily in the early years of automation during a period that saw severe shortages in the available pool of seagoing manpower. At that time, government and union action toward crew reductions was passive and, in some instances, cooperative.

The subsystems that have demonstrated a potential for manning reduction are automated bridge, machinery, cargo handling, and damage control systems. There is obviously a lower limit for total ship manning that is dictated by safety consideration, special evolution such as cargo transfer and mooring, emergency requirements due to equipment breakdown, etc. The lower limit relating to these factors, particularly safety, is established normally by the requirements of classification societies and government regulating bodies or is established artificially by union resistance as a matter of job preservation.

Manning levels as low as nine have been seriously proposed for a major ship (200,000 dwt). Although it is extremely doubtful that such a crew size should be accepted, it is of interest to note that competent engineers and naval architects have devised techniques and systems that, in their judgment, would provide for the safe operation of such a ship. It is generally recognized that a movement toward significant manning reductions will ultimately require the development of dual or multi-rated personnel. Such personnel will be needed to provide sufficient flexibility in crew assignments to satisfy all possible ship operating evolutions and to ensure proper handling of emergency situations.

It is the author's opinion that, starting with today's ship manning levels, crew reduction is not the major benefit to be sought after through automation; rather, one should carefully examine the alternative of retaining and reorienting shipboard manpower to improve manpower utilization and productivity.

- Reduction in plant and equipment casualties and malfunctions has been demonstrated as one of the important benefits that can be expected from automated machinery plant operation, as opposed to manual operation of a similar plant. Consistent and reliable plant performance can, of course, provide a significant reduction in ship operating costs by eliminating the need for costly, unscheduled shore-based repairs, by avoiding loss of operating revenue situations due to removal of a ship from planned voyages, and by avoiding customer dissatisfaction generated by ship operating schedule delays. Review of at-sea operating records from automated ships indicates a distinctive and surprisingly uniform pattern with respect to casualty or fault incidence rate. For a period of 2 to 3 years following delivery of a new automated lead ship design, aggressive and active debugging of the system is required. By the end of the third year and beyond, the incident rate settles down to approximately 6 faults per month and continues at this level. Follow ships built to the same design, having the benefit of lead ship debugging, experience a much reduced initial fault incident rate, and at the end of two years of operation reach the steady state rate of approximately 6 faults per month on the average of one true alarm every 5 days.

A fault or true alarm for purposes of this discussion refers to situations where the services of the duty engineer were required to investigate and take corrective action. Examples of such alarm situations are

- Loss of main condenser vacuum;
- L.O. purifier failure;
- Superheated steam temperature high;
- Boiler flame failure; and
- Forced-draft fan high oil temperature.

It is, of course, possible that well-groomed, manually operated steam turbine driven ships are being operated at a similar low rate of fault incidence. Shipowners, however, operating ships with both automated and manually controlled machinery plants have reported consistently improved reliability of operation, on average, of the automated plant as compared to the manually controlled plant.

A long-term low-fault incident rate has contributed significant savings in ship operating costs. However, a feature of even greater importance with respect to operating costs is the ability of modern automated machinery systems to rapidly identify and alarm out-of-limit conditions, and to control the fault by stopping, turning down, or isolating the problem component or subsystem. These automatic actions prevent damage to the unit initially involved and avoid cascading casualties which have the potential of generating major damage that could lead to a total loss of ship propulsion power.

Additionally, automated machinery systems have demonstrated a capability to quickly and consistently start stand-by units following isolation of a malfunctioning component or subsystem. This allows the ship to maintain propulsion or auxiliary power until such time as the fault can be investigated and corrected. The potential for operating cost reduction by minimizing or totally avoiding damage to components or systems, by preventing cascading casualties, and by minimizing loss-of-power situations that could hazard the safety of the ship is obvious. One operator of automated ships has estimated that continuous control of the machinery plants by intelligent electronics has prevented one major machinery of ship operating casualty per year per ship. A conservative estimate of the average cost of a major machinery plant casualty (or resultant ship operating casualty, considering loss of operating revenue, etc.) would be in the neighborhood of $150,000.

Reduction of casualties and ship operating accidents can also be achieved through the use of

- Automated cargo control systems to ensure safe loading and distribution of cargo and ballast;
- Hull monitoring systems to avoid damage to hull structure due to overstressing during heavy weather operation; and
- Anti-collision and grounding systems together with harbor navigation and docking systems to avoid costly operating casualties.

Although the casualty incidence rate in the aforementioned areas is, fortunately, far less frequent than is normally encountered in the operation of the propulsion and auxiliary machinery systems, the ultimate effect on ship operating cost of a grounding, collision, failure of hull structure, etc., is many orders of magnitude larger than the average machinery casualty.

A secondary effect that has been observed as an outgrowth of improved machinery plant reliability is a reduced usage rate of on-board spare parts. The automated ship can, therefore, affect an operating cost reduction as compared to its non-automated counterpart in that a lower inventory level of on-board spare parts is required, and, over the life of the ship, fewer spare parts will be used.

In all the areas noted above, a well-trained and expert crew man, using manual operating techniques, might provide adequate casualty avoidance, control, and recovery actions if he were in the right place at the right time, responded rapidly, and was able to maintain his composure throughout the duration of the casualty situation. Experience has repeatedly shown, however, that, with modern sophisticated ships, requiring such consistent error-free performance from the average crew member is expecting more than can be delivered.

- The dramatic rise in the cost of fuel in recent years has directed ship operators' attention to finding ways and means of reducing fuel use without degrading overall ship operating performance. Automation of a number of ship operating functions has produced attractive results in this regard. Specifically, fuel use has been reduced by the following methods:

  - The use of improved navigation systems that provide frequent and accurate update of a ship's position, when combined with autopilot systems, permits the steering of an optimum course with respect to distance sailed, currents, winds, navigation hazards, etc., to minimize fuel burned in transiting from port to port;

  - Navigation systems, acting in combination with automated machinery systems, allow a determination of optimum speeds (power levels) for purposes of fuel use to meet scheduled in-port arrival times;

- Autopilot systems that control ship steering have demonstrated a superior capability in maintaining a desired course, eliminating excessive use of rudder, and minimizing track wander, all of which act to reduce fuel use; and

- Automation of machinery systems can maintain control of plant functions to within very close tolerance of design operating points on a continuous basis. This continuous monitoring and control provides more efficient plant operation relative to fuel consumptions, and it is generally accepted that an automated steam turbine plant can produce savings in the range of 2 to 3 percent as compared to a manually operated propulsion plant. For diesel propulsion, automation can only be expected to provide something less than a 1 percent fuel savings.

• From an economic viewpoint, hull monitoring and cargo control systems can provide an advantage in that both systems permit more effective use of ship operating time. The hull monitoring system allows the ship master to make a more refined judgment regarding maximum safe operating speed during periods of bad weather. The speed selected by this means is normally higher than is usually determined by applying rules of thumb and "seaman's eye"; thus, the ship is able to decrease transit time. Similarly, the automatic cargo control system can transfer cargoes at a faster rate than was possible with manual operation which reduces in-port turn-around time.

• Finally, automated damage control systems can offer significant economic incentives by acting to minimize the destructive results of fire and flooding. Smoke, fire, and flooding detection devices quickly alert personnel to hazardous situations, and selective and rapid automated actuation of sprinkling, smothering, compartment closure devices, etc., can minimize damage resulting from these hazards. These systems increase in importance where ship operators elect to reduce crew size, thereby decreasing the number of men available for fire fighting and other damage control functions.

Sociotechnical Improvements

There is no question that a prime objective of the Scandinavian countries, acting to encourage their rapid introduction of automation, was improved profitability and the potential of obtaining a larger share of world oceangoing trade. There is also little question that the success of the Scandinavian automation effort was due in large measure to their early recognition of the sociological impact of these new concepts. Their initial development efforts carefully examined the sociological facets of the concept as well as the technical aspects involved. The Scandinavian solution to the severe shortage of seagoing manpower that faced most maritime nations in the 1960s was not simply to automate and reduce the number of onboard personnel required to operate their ship. They attacked the problem by finding ways and means to improve the attractiveness and rewards of a career at sea. That they found an answer is quite evident if one examines the quality of personnel manning their automated ships. Personal interviews conducted by the author with crew members of an automated Swedish ship clearly indicated that there was a uniformly high level of job satisfaction and general acceptance that a lifetime seagoing career offered adequate long-term rewards and provided acceptable living conditions both while at home and at sea.

Based on extensive at-sea operations of Scandinavian merchants ships, one can document the sociotechnical benefits that can be expected from highly automated ship systems. Benefits that accrue can be categorized in general terms -- improved job satisfaction, job enrichment and acceptable lifetime career rewards. Furthermore, the specific factors that contributed to these benefits are briefly summarized below.

- Boring, highly repetitive and routine watchstanding functions can be very nearly eliminated from shipboard duties and the work routine by the use of automated systems. Any man who has been required to stand a 4-hour engine room throttle watch or a bridge wheel watch during steady state at-sea steaming is painfully aware of the boredom and the total lack of job satisfaction associated with such a task. Unfortunately, a large percentage of a merchant ship's operating time is spent under steady-state steaming conditions, and traditional rotation of watchstanding duties among crew members means that a majority of the crew will be afflicted with these boring tasks. Other routine watches such as engine room data logging, bridge lookout, refrigeration plant watch, and pump room watch are only slightly less boring and repetitive. With automation, these boring and repetitive tasks can be assigned to the computer and its supporting intelligent electronic systems.

The man previously required for nonproductive watchstanding is now available to undertake various types of productive work throughout the ship. Accomplishing ship's maintenance and repair tasks is significantly more rewarding to the individual than watchstanding. This obvious fact was recognized early by the Scandinavians, and it was determined essential that the introduction of automated systems, particularly in the machinery area, must be accompanied by a thoroughly planned and documented preventive maintenance system, coupled with a detailed schedule for testing of automatic system alarms and fault control features to ensure their proper operation when required. When manhour requirements were estimated for the conduct of the planned maintenance to handle unscheduled repair work, it was determined that the manning requirements in the propulsion and machinery area approached those required for a non-automated ship.

This has led to relatively slight reductions in crew size with the principal action being the reorientation of crew training and work assignments. The end result of this has shown that crew members find their daily shipboard work life sufficiently rewarding and challenging to continue with a seagoing career, and shipowners have found they are able to attract higher quality and more talented personnel, and they now benefit from much lower personnel turnover rate.

- With automation, the change in crew work assignments from watchstanding-type duties to a varied array of ship work tasks allowed all shipboard personnel, other than bridge watchstanders, to adopt a normal eight-hour work day and forty or forty-four hour work week. This has introduced a more attractive daily shipboard life. Crew members can more readily meet for social purposes or recreation after work on weekdays and on weekends than was possible in non-automated ships, where the crew necessarily had to be split into watches over a 24-hour period, allowing only limited association between personnel assigned different watch periods.

- Reliance on automated systems for continuous operation of major ship functions and the demonstrated reliable performance of these systems at sea has developed a level of confidence that has encouraged the use of multiple crew concepts. For example, three crews for two ships or seven crews for five ships might be utilized, with more or less total crew turnover at a selected port. This permits crew members to schedule and plan their periods ashore and at home well in advance, and allows a more acceptable portion of a man's total time to be spent at home. This concept is possible today since nearly all major world shipping ports offer high speed jet airline service that makes crew interchange arrangements relatively convenient and inexpensive.

Improved Safety in Ships Operations

Safety of ship operation is a matter of serious concern to nearly all segments of the maritime industry. Certainly the shipowner and operator, the maritime unions, the ship's crew, and the customer who desires his cargo to be delivered on time and undamaged all have a very real interest in ship safety. Government agencies, classification societies, the Coast Guard, and maritime insurance agencies have, over the years, generated a myriad of rules, regulations, and requirements that dictate required ship design features, methods of operation, rules of the road, etc., that must be incorporated or followed before a ship can be insured or allowed to operated. Automation of certain ship functions has acted to enhance the safety of ship operations. Automated features and operating modes using automated concepts such as reduced bridge manning and unattended machinery spaces have been reviewed and accepted by the various regulatory activities. In fact, recent actions of regulatory activities have been directed toward requiring and/or encouraging the use of certain automated features such as collision avoidance radar, improved automatic fire detection and smothering features, etc. The following automation features can be identified as contributing to improved safety of ship operations.

- Automatic pre-programmed turndown or shutdown of machinery systems or components when out-of-limit conditions are sensed acts to avoid casualties that could ultimately generate fire and/or explosions if not quickly identified and proper corrective action taken.

- Loss of propulsion power or steering when operating in confined or high-density traffic areas is certainly one of the most serious of undesirable casualty situations that can face the ship operator. Automatic start-up of standby units that can rapidly restore or avoid loss of power situations in critical main propulsion and steering systems can significantly enhance the safety of ship operation in these circumstances as compared to dependence on manual actions to provide the necessary correct and timely response.

- The benefits that can accrue from the use of bridge anti-collision systems are thoroughly and extensively documented. A number of systems that have been proven at sea are available for shipboard installation as standard production equipment. These systems can offer a very real reduction in the potential for collision, even with reduced bridge manning, in fog and low visibility situations, in areas involving high-density ship traffic, and/or in waters restricted by navigational hazards.

- Automatic navigation positioning and piloting systems provide position determination with a relatively high degree of accuracy and reliability for open-ocean transit, coastal piloting, harbor or restricted water passage, docking, and anchoring. The advent of the VLCC with its limited maneuvering and stopping capabilities has greatly emphasized the importance of and need for such automated navigation equipment, particularly for the last three navigational situations identified above.

- Anti-stranding sonar systems are under development and have experienced some at-sea testing with mixed results. Continued development and refinement of these systems can ultimately offer improved safety of operation in areas of the ocean that are sparsely charted or in restricted waters that present significant submerged navigational hazards, particularly those waters that are plagued with a high percentage of fog and low visibility weather.

- Large displacement ships such as VLCCs require very long stopping distance (up to 3 miles) which can obviously generate critical and dangerous situations. It is important, therefore, that time to stop and stopping distance be minimized and accomplished in a safe fashion without overstressing and endangering the propulsion machinery, main shafting propeller, rudder, etc. Automatic bridge-activated emergency stop systems that accomplish this task in a reliable, safe, and consistant fashion have been developed and are in service. Orders to the propulsion plant controlling power level, and direction of shaft rotation for emergency stop are pre-programmed into the computer, based on previously conducted at-sea testing. The bridge watch can initiate a safe emergency backing maneuver by activating a single pushbutton or lever.

  The potential benefits to safety that can be derived from automatic fire and flooding sensing and control devices are obvious and have essentially become a required part of a modern merchant ship's basic safety features.

Improved Environmental Situation

The news media of the world has, in recent years, lavished attention on all incidents of ship groundings, collisions, or fires, particularly where the accident has resulted in oil spillage or has involved a dangerous cargo that has posed a hazard to population centers. We have become supersensitive to matters having an adverse impact on our environment, and the maritime industry most assuredly has become sensitive to the need to take action to avoid major ship casualties that place them in the spotlight of adverse world publicity.

Certainly, as we design and put to sea larger and larger ships that are difficult to maneuver, as the cargo-carrying capacity of individual ships increases many fold as compared to recent past practice, as ships that carry large quantities of hazardous cargo such as liquefied natural gas are introduced, and as we introduce higher speed ships, not only do we increase the magnitude of the disaster that can result from a grounding or collision, but we also increase the potential for such a casualty to occur. The consequences of such disasters in terms of adverse publicity, actual costs to the shipowner for cleanup and payment of damage claims, increased insurance premiums, etc., have led to the introduction of training programs, equipment, systems, and new operating techniques intended to minimize the occurrence of these critical casualty situations. There is no question that the pressures generated by these conditions have expedited the development and introduction of certain innovative automation features previously discussed. The more important of these automated features aimed at improving this situation are briefly identified below:

- Anti-collision bridge systems to minimize the potential for collisions;
- Automatic navigation positioning and piloting systems and anti-stranding sonar systems that can act to avoid groundings;
- Machinery casualty control and recovery systems that can serve to minimize the potential of loss of propulsion power and steering and can also reduce the potential of fires and/or explosions that could be initiated by power plant casualties; and
- Bridge-activated automatic emergency stopping systems to minimize the potential for collisions or groundings.

An additional environmental feature that has not been exposed to a significant level of public attention, but with today's concern for the environment is one that should be accorded consideration, is stack gas or diesel exhaust pollution generated by ship power plants. Pollution from this source should only cause serious concern where large concentrations of ships occur, such as in the major shipping ports of the world. In these areas or cities, the products of combustion introduced by shipping activity do deserve attention to ensure that unnecessary pollution is minimized. Automatic control of propulsion plants, both oil-fired steam and diesel, with its ability to continuously monitor and control combustion efficiency can materially aid in maintaining clean combustion, thereby minimizing pollution problems.

BARRIERS INHIBITING THE INTRODUCTION OF AUTOMATED SHIP SYSTEMS

The foregoing discussion has attempted to identify and highlight those factors that have led certain maritime nations to adopt automation and to continue to expand the application of automation to new ships joining their flag fleet. If one considers evidence such as the successful shipboard automation programs that have been carried forward by foreign nations, the significant number of ship-years of at-sea operating experience with highly automated foreign merchant ships that is now a matter of history and for which there is extensively documented performance data, the availability of automation technology, and the demonstrated ability to apply this technology within the United States, the obvious question then becomes, "What are the factors and barriers that have inhibited the introduction of automation in the U.S. merchant fleet?"

It is equally obvious, that, in response to this question, one could be offered a wide variation in the specifics, emphases, and flavor of answers, depending on the particular niche within the maritime family of individuals addressed. Based on having participated in various ship automation studies sponsored by both the U.S. Navy and the Maritime Administration, having participated in international ship automation symposiums and conferences, and having had the opportunity to spend time at sea on a variety of foreign- and U.S.-flag ships with varying degrees of automation, the following is offered as the author's response to the question of barriers.

Labor Union Opposition

Opposition, actively and aggressively applied by the three major U.S. maritime unions, must be cited as one of the primary deterrents to the introduction of automated features to U.S. merchant ships. Briefly, the unions' position appears to embrace the following philosophy.

- Opposition to any action that would reduce shipboard manning and thereby reduce the total number of jobs available in the U.S. merchant service. This position is understandable and certainly strong resistance must be expected from the unions when actions are proposed that will directly threaten a seaman's source of livelihood.

- Unions have resisted and apparently will continue to resist changes to job descriptions that require changes in traditional work assignments. Strong objection has been voiced against any proposal that suggests the introduction of a dual rating system for shipboard personnel (i.e., one man capable of performing both deck and engineering duties). This position is less understandable, particularly where no reduction in shipboard manning level is proposed. Apparently, it stems from the jealously guarded jurisdictional control exercised by the three major unions (Deck Officers', Engineers', and Seamens'). Changes in job descriptions and/or action to create dual ratings for personnel could have an impact on the balance of jurisdictional control between the three unions and is, therefore, opposed by the union(s) that stand to lose ground.

- Union management has expressed serious concern that automation will degrade shipboard jobs, that shipboard duties that require meaningful mental and physical effort will be eliminated, and that, with no real duties to perform in an automated ship, the minds and reflexes of the crew will degenerate. The union's philosophy in this regard is difficult to accept and offers evidence that, within the unions, there is a lack of understanding and knowledge of the sociotechnical advantages that can accrue from the automation of shipboard functions.

Certainly, at-sea experience with automated ships that have carefully planned and executed the integration of crew work assignments with automated features has shown significant gains in crew job satisfaction, improved morale, and the ability to acquire and retain higher quality personnel as compared to the situation found on manually operated ships where the primary crew duties are simple watchstanding tasks, such as throttle watch or bridge wheel watch, and data recording.

- Control by U.S. maritime unions of crew members' vacation periods, assignment of individuals to ships, and, in general, the very close control maintained by the unions over all aspects of the individual's job assignments and duties is currently accepted practice in the U.S. maritime service. This situation does introduce difficulties if the shipowner attempts to take advantage of an investment in automation by utilizing multi-crew concepts for his fleet of ships. Transfer of the entire crew, or large segments of the crew, on a pre-determined schedule to optimize the shipowner's operating schedules and overall manpower costs would indeed require adjustments in traditional union/management methods of operating with respect to responsibility for crew assignments, vacation periods, etc.

- On the positive side, it is apparent that the maritime unions recognize to a certain degree that automation of U.S. ships could make the merchant fleet more competitive in the world shipping market, and thus in the long-run could create additional jobs for their union members. Quite correctly, the plea of the unions is that the shipowners, shipbuilders, and ship designers recognize and take into account the sociotechnical aspects, the human consequences of automation, and not limit their view to the technical aspects alone.

U.S. Shipowners and Operators Lack of Action

The active and energetic pursuit of automation innovations by Norwegian, Swedish, and Japanese ship operators has been clearly evident over the past decade. Their continued willingness to invest capital in extensively automated ships, particularly VLCC- and ULCC-type merchant ships having high acquisition and annual operating costs, indeed indicates that they have developed confidence that automated ships can produce a reasonable return on investment and can improve their operating profitability. By comparison, during the same time frame and continuing today, their U.S. counterparts appear to have a very limited interest in investing capital in automation features for their ships. The following factors appear to contribute to this lethargic atmosphere with respect to U.S. ship automation efforts.

161

- Discussions with U.S. shipowners and operators have, on a number of occasions, left the very clear impression that there is a lack of understanding and knowledge concerning the high level of automation currently existing in competitive foreign-flag ships, the number of these automated ships operating, and the large number of ship-years of reliable at-sea operation that has been recorded to date. Further, there appears to be a very limited knowledge of, or an attitude that seriously discounts, benefits that have been demonstrated as a result of automation, such as

  - Improved crew morale and crew job satisfaction with attendant reduction in personnel turnover and the ability to attract higher quality personnel;

  - Improved propulsion plant operating efficiency and a reduction in plant casualty incident rate and down-time; and

  - Reduction in crew training and requalification requirements.

- Shipowners and operators are acutely aware of the roadblocks thrown up in the path of shipboard automation by the expressed position and actions taken by the maritime unions. Attempts to overcome union opposition to automation have proved costly and time consuming. No doubt much of management's lethargy toward automation is due to a lack of confidence that they could obtain union cooperation or even achieve a quiescent union attitude on the subject, or worse, a fear that forcing automation on ships would generate a drastic union reaction. Admittedly, much of the union opposition stems from a rather significant overemphasis by management on incorporation of automation for the purpose of reducing shipboard manning levels.

- Shipowners who are dependent upon maritime subsidy programs for support of their new ship construction requirements have found that these same subsidy programs offer no encouragement or financial benefits to the shipowner who adopts automation features in his new ships. In fact, automation features that reduce crew size may act to reduce subsidy payments during the operating life of the ship.

Lack of a U.S. Market for Automated Ship Systems

Traditionally, in our free enterprise system, if a worthwhile market develops for a particular product or service, and the technology and skills exist that can supply that market need, then U.S. industry has rapidly moved to fill the void. In the case of shipboard automation, the technology, skills, and productive capacity required to develop and produce the needed components and systems is readily available. U.S. industry has emphatically demonstrated this capability as witness to the variety of successful and sophisticated automated systems that are currently functioning and fulfilling the needs of the petrochemical, steel, electronic, aerospace, and other industries in this country and throughout the world. The missing ingredient insofar as developing and supplying effective and competitive automated systems for the U.S. maritime industry appears to be the lack of a basic and worthwhile market. This is due to

- The low rate of ship construction in the U.S.;

  (Construction at the level experienced in recent years has not been sufficient to generate a market that warrants the investment of risk capital to develop and produce the sophisticated automated systems required for shipboard use at a competitive price.)

- The fact that the foreign market for ship automation systems is already thoroughly saturated with proven equipments of foreign manufacture;

  (Therefore, the possibility of creating a market by combining potential U.S. and foreign customers to generate the demand threshold necessary to encourage U.S. manufacturers to participate and produce competitive systems does not appear likely.)

- The establishment of sales and manufacturing facilities within the United States by foreign suppliers of ship automation systems; and

(This action makes the foreign systems more readily available and enables the supplier to offer timely technical and spare parts support to the shipbuilder during construction and to the shipowner following delivery of the ship. It has been noted that advertising copy for these foreign systems, aimed at the U.S. market, emphasizes that they are offering fully developed at-sea proven automated systems and components.)

- The inordinate cost of backfitting automated systems into existing ships.

  (With the exception of bridge systems, which in most instances can be accommodated within the existing bridge arrangement or can be readily interchanged with existing components, the cost of backfitting other automated functions, particularly those involving engine room systems, cannot be justified by the shipowner due to the low rate of return on the required investment for these installations.)

<u>Lack of Team Effort</u>

Discussions earlier in this paper highlighted the point that a large measure of the success now enjoyed by foreign operators of automated merchant ships resulted from the cooperative development and application effort of teams drawn from all the principal segments of their maritime industries and cognizant government activities. In certain instances, these programs had the benefit of participation by maritime unions and universities. The teams were afforded a high level of visibility throughout industry and government as to the aims of the program and the potential benefits that could accrue to all concerned if they developed a successful end-product.

Insofar as is known, no similar cooperative team effort has been attempted or considered for implementation in the United States. The United States effort in this field has, for the most part, been sporadic. Component and equipment manufacturers have developed, quite independently, individual items or subsystems that have found a limited market with shipowners. Shipowners, ship design activities, and shipbuilders have accepted and introduced automation features to certain ship functions. The U.S. Maritime Administration has funded and sponsored a variety of research and development projects aimed at providing some form of technical improvement, including automated features, for all major ship functions. Almost without exception, however, these have been independently conducted projects as to scope and with regard to the participants. There has been little visible evidence that the various players involved in these projects have been required to engage in inter-project information exchanges, or that the individual projects are being coordinated with the aim of achieving a fully integrated ship automation system with due consideration given to both the sociological and technical factors.

Similar comments can be directed at the U.S. Navy's automation effort. It is pertinent to note also that there exist numerous areas of common interest between MarAd and Navy automation projects. Unfortunately, there is little evidence available that a cooperative information and data exchange program has been instituted between these two organizations for the purpose of gaining maximum benefit, for both military and maritime applications, from the investments being made in the various individual projects.

Customs and Traditions within the Maritime
Community Slow the Introduction of Automation

It is well recognized that the introduction of automation features to various shipboard functions will, in almost every instance, have an impact on long established customs and traditions relating to the ship's crew. The inertia of these customs can be significant and can impede or even prevent the adoptions of automation innovations that appear highly attractive from the point of view of technical and/or profit payback potential. Certainly, many conflicts that are generated are minor in nature and can be readily resolved; however, there do exist major issues, in addition to the obvious issue of crew reduction, that have impeded and will continue to impede the introduction of automation in U.S. merchant ships. Briefly, these are

- Inflexibility of the unions, and in some instances management, toward modifying long-standing crew work assignments and/or instituting changes to the division of work assignments between segments of the crew such as "deck" and "engine room"; and

- Resistance to adoption of relatively radical changes such as the use of multi-crew concepts that propose total crew changeovers at pre-planned locations and present times. Dual ratings for individual crew members is also a radical departure from the norm that generates serious objections. Failure to create dual ratings significantly degrades benefits that might be gained from the location of machinery plant control center in the vicinity of the bridge allowing a dual rated (deck/engineer) officer to monitor both bridge and machinery functions where the latter functions are automated to the extend of qualifying for unattended operation.

Laws and Regulations That Block the Adoption of Automation Concepts

Fast moving technology has, at times, overrun the ability of regulatory agencies to react in a timely fashion reviewing, accepting, and incorporating in their regulations and rules proposed automation features that are developed as a result of new technology. The overall effect of such occasional restrictions on automation progress has been relatively minor as compared to the impact of other inhibiting factors that have been discussed previously. In point of fact, on balance, world regulatory agencies and maritime classification societies have adopted, within acceptable time frames, regulations, controls, and design and construction requirements that permit and even encourage incorporation of automation concepts.

APPROACHES TO ENHANCE AND EXPEDITE INTRODUCTION OF AUTOMATION CONCEPTS IN THE U.S. MARITIME INDUSTRY

The ever-widening gap between the intensive application of ship automation technology by major world maritime nations and the stagnation of U.S. ship applications should be a matter of serious concern to the American maritime community. Our concern should be directed at the competitive advantage that is being achieved and documented as automated foreign-flag ships accumulate a significant amount of reliable, at-sea performance time. As has been repeatedly demonstrated, survival of any industry in the free world is quite dependent on that industry's embracing new technology required to stay ahead or, as a minimum, abreast of the competition. Subsidies used for the primary purpose of avoiding a negative bottom line in the profit and loss column of our shipping industry are a short-term and nearsighted panacea at best. Ways and means must be found to improve the competitive posture of our merchant marine industry in the world marketplace if we are to avoid having it relegated to a law protected, coastwise trade position.

It is not suggested that an infusion of automation technology will act as a total panacea. It is suggested, however, that it is one avenue that should be aggressively pursued, since the facts currently available clearly indicate that the application of advanced American technology to this task could act to improve our competitive position. Re-examination of those factors that have aided the introduction of automation in foreign-flag ships, and those that have inhibited the adoption of this technology in U.S. ships leads to the following offering of recommendations as to approaches that could enhance and expedite the introduction of automation concepts.

- Encourage the formation of cooperative teams of ship operators, ship designers, shipbuilders, maritime unions, and hardware manufacturers to share the risks and benefits involved in developing and producing advanced, fully integrated automated ship systems. Certainly, the U.S. Maritime Administration, the U.S. Coast Guard, and the American Bureau of Shipping should play an active role in encouraging and supporting this effort both morally and with funds.

- A program aim should be established that clearly sets a goal to use to the fullest extent possible the most advanced American innovations in intelligent electronics to produce a fully integrated automated system encompassing all major ship functions. It is suggested that we not attempt to mimic existing foreign subsystems, but rather that our advanced computer and processor technology be applied to develop a fully integrated ship system which, when compared to available foreign systems, is capable of providing

    - Improved overall system reliability and safety;

    - Improved efficiency of operation through system integration; and

    - Reduced system acquisition costs and a reduction in overall ship life-cycle costs.

- A second program aim should be established to thoroughly examine the sociological aspects of any proposed changes to a ship's physical plant or method of operating that are introduced as a result of automation. This objective should be accorded a priority position and a high level of visibility to ensure that it receives attention equivalent to that given to the technological aim. In this area, there is a very real need to develop communication links between the maritime unions and the shipowners and technical communities such that union needs and concerns can be addressed and a forum is available that allows the ship operator to expound on the need to produce a shipping system that can survive in the highly competitive world marketplace.

- Ensure recognition of the need for a significant at-sea prototype system evaluation and debugging period following delivery of an automated ship. Experience has shown that it is essential that design/engineering technicians accompany the ship to sea for the purpose of continuing crew training and to carry out repairs or make modifications to the automated systems. It can be anticipated that this at-sea proving period for the prototype system can extend over a one year period, and during this period primary responsibility for performance of the automated system should rest with design/engineering technician rather than the ship's crew. The goal should be to have the system performing reliably and have the crew fully capable of operating the system at the conclusion of this one year period.

- Consideration should be given to affording U.S. crews the opportunity, at the earliest possible time, to become familiar with, and gain the necessary level of confidence in, the performance of a fully automated unattended machinery plant. For this purpose, it is suggested that foreign automation systems, providing an UMS capability that has been proven at sea, be installed in U.S. ships, and that appropriate preventive maintenance systems be instituted in these ships such that current engine room manning levels are retained, but that engine room personnel are utilized in preventive maintenance work vice watchstanding.

This approach is suggested since it has been found that from three to six years are required before ship's personnel are sufficiently indoctrinated and are willing to accept and rely upon fully automated plant operation. Early indoctrination of personnel in UMS operation would provide a pool of experienced personnel that could be drawn upon to man ships sailing with prototype, U.S.-developed automation systems.

- U.S. Maritime Administration (MarAd) research and development programs should be reviewed and reoriented wherever necessary to ensure that the investment now being made in support of various individual automation technologies will ultimately support a totally integrated ship system. It is suggested also that MarAd examine ship subsidy programs with a view toward reorienting these funds for the purpose of encouraging or requiring the development, design, and installation of automated features in U.S.-flag ships.

BIBLIOGRAPHY

1. Hamada, N., "Ship Automation in Japan and What Comes After Automation"; Report of Ship Bureau, Ministry of Transportation; Tokyo, Japan; April 1966.

2. Tam, N.K.H.; Milano, G.J.; Kern, D.H., "The Application of Microprocessors to Direct Digital Control of a Marine Boiler"; Paper presented at the Second International Symposium for Ship Operation Automation; Washington, D.C.; August 30 to September 2, 1976.

3. Mericas, E.C., "A Retrospect on Automation in Marine Engineering"; Naval Engineers Journal; October 1967.

4. Halverstadt, D.A.; Kern, D.H.; Williams, T.J., "A Bibliography of the Field of Ship Automation"; Report No. 58, Purdue Laboratory for Applied Industrial Control; December 1973.

5. Chavanet, L., "Unattended Machinery Spaces in Steam Turbine Tankers"; Paper presented at the Joint Conference of The Institute of Marine Engineers and the Nautical Institute; London, England; March 6, 1974.

6. Crvikshank, J.M.; Mar, F.I., "Unattended Operation of Turbine Driven Vessels"; Paper presented at the Joint Conference of The Institute of Marine Engineers and the Nautical Institute; London, England; March 6, 1974.

7. Johansson, L., "The Application of Electronic Systems in Ships' Engine Rooms"; Paper presented at the Joint Conference of The Institute of Marine Engineers and the Nautical Institute; London, England; March 6, 1974.

8. Shishko, R., "The Economics of Naval Ship Automation: An Analysis of Proposed Automation of the DE-1052 -- Executive Summary"; Report prepared for Defense Advanced Research Projects Agency; R-1790/1-ARPA; November 1975.

9. Baylis, J.R.; Kern, D.H., "A Proposed Project Plan for Research and Development Effort in the Area of Naval Surface Ship Optimum Manning"; prepared for Naval Ship Systems Command; NAVSEA - 03222; November 1977.

10. Halverstadt, D.A.; Kern, D.H.; Williams, T.J., "A Plan for the Automation of the DE 1052 Class of Naval Surface

Ships"; Report No. 61; Purdue Laboratory for Applied Industrial Control; March 1, 1974 - May 15, 1974.

11. Scott, M.T.; Kern, D.H.; Williams, T.J.; "An Analysis of Personnel Effects and Naval Regulation Considerations in the Automation of Naval Surface Ships"; Report No. 60; Purdue Laboratory for Applied Industrial Control; December 2, 1973 - March 1, 1974.

12. Kern, D.H.; Williams, T.J., "Some Reports on the State-of-the-Art in Automation of Modern Merchant Shipping, Volume II - Conferences and Visits"; Report No. 55; Purdue Laboratory for Applied Industrial Control; May 16, 1973 - August 15, 1973.

13. Kern, D.H.; Williams, T.J., "Some Reports on the State-of-the-Art in Automation of Modern Merchant Shipping, Volume I - T/T SEA SERPENT"; Report No. 55; Purdue Laboratory for Applied Industrial Control; May 16, 1973 - August 15, 1973.

CONTRA-ROTATING PROPULSION SYSTEMS FOR U.S.-FLAG MERCHANT SHIPS

Francis X. Critelli

U.S. merchant ships predominantly use steam turbine propulsion systems, utilizing the two-heater/steam air heater/economizer cycle almost exclusively. From a fuel utilization (energy conservation) point of view, this cycle is the most inefficient compared to more exotic (high-pressure/high-temperature/reheat) steam cycles and/or medium- or low-speed diesel propulsion systems. This preference for the inefficient cycle continues today, even in view of the very high cost of bunker "C", marine residual fuel oil. There is a very high probability that steam turbine propulsion will continue to be the predominant propulsion system for U.S.-flag merchant ships, even until the year 2000. For a high-speed container ship utilizing this inefficient cycle, the 1976 fuel costs are estimated at approximately $3,200,000 to $4,000,000, depending on the number of days at sea. The estimated 1982 fuel cost for this vessel ranges between $6,300,000 and $8,000,000, or 55 percent of the vessel's annual voyage costs.

REDUCING FUEL CONSUMPTION

The primary avenue for reducing fuel consumption lies in educating both management and labor in the area of energy conservation. Management needs to develop rational techniques and methods for maximizing vessel utilization (increasing cargo) and optimizing fleet movement. The ship's workforce needs to concentrate on efforts to maintain the equipment aboard ship such that it is operating at maximum efficiency.

The function of the marine power plant or any power plant is to convert a basic form of energy (coal, oil, etc.) into some form of useful and usable work (power). This, in most instances, takes place in two separate and distinct processes -- energy conversion and power transmission. Efficiency improvements can be made in both processes.

The future price and availability of residual fuel oil is influenced by many supply (foreign and domestic) and demand factors as well as domestic political and environmental policies. Because the U.S. economy is basically distillate oriented, it is expected that the quality of residual oil will further deteriorate. Efficient use of low-quality residual oils in power generation equipment, through the energy conversion process, is being pursued aggressively by both industry and government. These aggressive research efforts in the energy conversion process will produce efficiency improvements that can be directly applied to the power plants aboard U.S.-flag merchant ships. These improvements include fluidized-bed boilers, residual-burning gas turbines, more efficient "combined" (dual) cycles, and so on.

The marine industry differs substantially from the industrial/utility industry in the method for transmitting power and energy into useful work. The marine industry utilizes large-diameter, low-speed shafting and bearing systems to drive propellers, while the utility industry utilizes small diameter, high-speed shafting to drive electrical generators or motors. Thus, research in the power transmission area (e.g., shafting, bearings, gearing, propellers, maneuvering rudders, and steering gear) must be undertaken by the maritime community, if efficiency improvements are to be realized in the power transmission area.

There are many areas of research worth pursuing in the power transmission process for improving efficiency and reducing fuel consumption. Indeed, today there is sufficient evidence to indicate that the most rational research investment should relate to the eventual widespread application of contra-rotating propulsion systems to U.S.-flag, steam turbine propelled merchant ships. This is a system totally unique to the marine environment, for which there is no commercial/industrial base to draw upon from a technology transfer point of view.

CONTRA-ROTATING PROPULSION

Extensive studies undertaken in both the United States (David Taylor Model Basin) and Europe (Holland) on a series of high-speed container ship hull forms have shown that contra-rotating propulsion provides on the order of eight to twelve percent improvement in the hydrodynamic performance of the ship. This corresponds to a direct reduction in fuel consumption of equivalent percentages. In principal, contra-rotating propulsion utilizes two propellers, one behind the other, rotating in opposite direction at approximately the same RPM, but slightly different torques. The aft propeller is designed to capture the wake from the forward propeller, and in so doing, generate additional thrust. In other words, for the same disc area, one standard propeller compared with two contra-rotating propellers, the CRP generates more thrust and the same ship speed is obtained with less horsepower. For the container ship referenced above, the savings in fuel costs would amount to approximately $320,000 per year (1976) or $600,000 per year (1982).

The technological and economic constraints that existed prior to 1970, and that prevented this form of power transmission system from being developed and implemented, do not exist today. For example:

- Fuel prices have risen to the point where the savings in annual fuel costs due to contra-rotating propulsion systems justifies the additional investment costs for the system;
- Planetary-type transmission systems have been developed and tested such that the original conventional gear problems (costs, weight, cubic, etc.) no longer exist; and
- The U.S. Navy has utilized contra-rotating propulsion systems on submarines. Hence, some of the hardware-related problems with seals, bearings, etc., for contra-rotating shafting have been resolved.

The primary constraint today lies in the fact that the propulsion system needs to be demonstrated and shown to be reliable in commercial U.S.-flag merchant ship applications.

NEED FOR DEMONSTRATION

U.S.-flag merchant ships are very costly investments, averaging approximately $50,000,000 per ship. Any improvement or change that could adversely impact the profitability of the ship during its economic life must be viewed with apprehension. A major casualty in the power transmission system generally requires an extensive time out-of-service for repairs as well as extensive repair and/or replacement costs. Recent casualties to ships' transmission systems (Waterman, Delta, and Lykes) have shown that these repairs can cost in excess of $1,000,000 and involve out-of-service time in excess of ninety days. Thus, if technological improvements are to be applied and made available to the maritime industry, their performance and reliability must be demonstrated. Likewise, methods must be developed to minimize the risks associated with demonstrating this technology in cooperation with industry.

When the risks are minimal, the maritime industry is generally quite cooperative in permitting their vessels to be used to demonstrate new technological improvements. However, when the risks are great, irrespective of the potential economic return, the maritime industry cannot afford to offer its vessels to demonstrate new technology -- unless some form of insurance or assurance is provided that removes the economic penalty associated with the risks.

RISK INSURANCE

Various methods, schemes, and procedures have been proposed to minimize the risks associated with demonstrating new technology aboard U.S.-flag merchant ships. However, none appears more promising than risk insurance. To some degree, it is quite similar to product liability insurance; however, the former would be limited to cover only the economic (dollar) loss directly borne by the ship operator, and it would be limited. Such a form of risk insurance would provide the necessary vehicle for the Maritime Administration to implement many of the research and development results of its aggressive program to improve the competitiveness and productivity of the U.S. maritime industry.

HYDROFOILS IN THE U.S. MARITIME INDUSTRY

Robert J. Johnston

Over the past decade, a number of hydrofoils have been introduced to the United States shipowners and operators. Yet, in March 1978, there was not a single U.S.-built commercial hydrofoil operating in U.S. waters. The big question is why? The question becomes even more interesting when one looks around the world and sees U.S.-built hydrofoils (Boeing Jetfoils) now operating in Japan, Hong Kong, Venezuela, and across the English Channel from London to Belgium.

There have been at least five U.S. companies that have produced and demonstrated a commercially viable hydrofoil. Today, only the Boeing Company is actively marketing a commercial hydrofoil product. In Europe, an Italian builder, Naval Tecnica (formerly Cantieri Rodriquez) has been a profitable hydrofoil producer for more than ten years. Japan is reported to be sustaining a commercial hydrofoil enterprise. One must surmise from the duration of their industry, that the Russian have had favorable experience. So the question remains, What is wrong in the United States?

The following discussion will explore some of the probable answers to that question and indicate where the government could facilitate the commercial acceptance of hydrofoils.

The lack of United States involvement in commercial hydrofoil operation is directly reflective of the estimated profit potential. Several factors contribute to the estimated base, including

- Size of potential market

  -- Geographical situations;
  -- Climate conditions; and
  -- Export opportunities.

- Cost of development

  -- Lack of government developmental support;
  -- Reluctance of industry to become involved; and
  -- Regulating requirements.

- Cost of ownership

  -- Requirements;
  -- Insurance;
  -- Crew costs;
  -- Port facilities;
  -- Introductory expense;
  -- Maintenance; and
  -- Utilization.

SIZE OF POTENTIAL MARKET

Every company that has considered building or has built commercial hydrofoils has prepared a market survey. In addition, independent studies have been conducted evaluating potential routes and markets. The resulting number of potential sales is sizable and has been of interest to certain companies. However, that number of potential sales is a small fraction of the size that would be considered sufficient to support entry in most other vehicle development programs. For a particular size hydrofoil, market estimates vary from 50 to 250 units. To enter a market for a particular size aircraft would generally require a market potential several times this size. This narrows the interest in speculation. The following are some of the factors that affect the hydrofoil market size.

<u>Geography</u>

Hydrofoils are attractive for the transport of people and high-priority cargo over water routes extending from 20 miles to about 200 miles. The length of the route of interest depends upon other available or potential means of transportation. When surveying U.S. potential hydrofoil routes, the availability of an excellent highway system, in many cases, provides a desirable alternative means of travel by private automobile. This is not the case in much of Europe and other locations where hydrofoils have proven profitable. In fact, one of the limiting features of hydrofoil route expansion in Europe is a strong desire of travelers to bring along the family car. This is forcing foreign consideration of larger hydrofoils capable of carrying a combination of cars and passengers. In summary, the pure geography of the U.S. mainland coastline does not offer many interesting passenger routes. Conversely, routes covering the Hawaiian Islands, the Virgin Islands, and other Caribbean Islands are most attractive.

Commuter-type traffic is another issue. Here, other factors besides the automobile competition become a consideration. The desirability of avoiding driving in congested areas, the availability of alternate commuting methods, and the resulting time savings become matters of consideration. Conversely, commuter-type traffic is heavy for only a few hours per day. Other off-peak uses of the craft should be considered for improving the utilization.

The hydrofoil also offers an attractive alternative to more conventional crew boats used in offshore operations. This particular use has not developed much interest to date. The capability to carry a crew change along with cargo appears attractive. Traditionally, transporters for this operation have been boat or helicopter operators not drilling platform owners. These transporters are reluctant to try new equipment without loss shelters. Here, a challenge exists to encourage additional marine transportation methods.

Climatic Conditions

Certain routes in the United States that might be attractive are in regions where ice, snow, or fog conditions that would limit the operating hours per year. Like aircraft, hydrofoils require a high utilization (2000 to 3000 hours per year). If a major portion of the operating year is lost because of weather conditions, the only solution is to find a complementary route in southern climes. By working both routes during their respectively favorable weather and, hopefully, high traffic periods, the combination could provide adequate utilization.

A U.S. manufacturer must appraise his export possibilities. In a high technology product, the United

States has export advantages. Hydrofoils fit this category, and it has been demonstrated that U.S. hydrofoils can be exported successfully and profitably. On the counter side, other countries have laws similar to the U.S.'s Jones Act. These countries, like the United States, require that the ship's bottom be built in-country to carry their country's flag. Where we can export, the ability of the importing country's economy to support a hydrofoil line is a consideration. Many lesser-developed and emerging countries simply cannot afford the acquisition price or passenger fares required to sustain a hydrofoil operation. Expanding the use of in-country employment by long-term financing, by utilization of a licensing agreement, by including at least some assembly or constructive effort, and by training are ways to expand the U.S. export market. Of course, any growth in the true export market lowers the series-built acquisition price and makes the product more viable in the U.S. economy.

One of the ways that government can assist in expanding the market potential is to play an active role in expanding exports. For example, the government could provide long-term financing or other inducements to make craft attractive to countries with a need for fast waterborne transportation.

COST OF DEVELOPMENT

Recognizing that the market potential is somewhat limited, the cost of development becomes a major consideration. Many generations of commercial aircraft were a direct outgrowth of military predecessors, and a major portion of the development cost was covered by the military. At one time, this path was visualized for developing commercial hydrofoils. In fact, during the several military development cycles, a substantial technical base has been made available for the design of new commercial vehicles. At the same time, it must be recognized that each new design will create its own problems. Unfortunately, the limited military procurement of hydrofoils has resulted in a struggle for any company to maintain technical continuity. The Boeing Company, which has had the most success, has on occasion debated the economic wisdom of sustaining its effort.

Government Developmental Support

It further must be recognized that to produce a viable commercial hydrofoil with the level of reliability required to make it profitable requires a major investment. One of the reasons that aircraft companies have been the developers of hydrofoils is the unwillingness of the shipbuilding industry to make the required level of financial and technical commitment. If the government is interested in expanding the high technology aspects of the maritime industry, then consideration should be given to subsidizing or assisting in the amortization of the developmental costs.

Industry Support of Development

Another approach to sharing the developmental costs is for industries to form teams. Traditionally, this approach has been used in the introduction of a new aircraft. Based on market surveys, an estimate is made of the number of units that need to be produced to break even. Other industrial organizations are then invited to participate with the prime producer by sharing the investment needed to cover the breakeven quantity. All take the risk that a sufficient number of vehicles will be produced and sold to realize an ultimate profit.

To date, the experience of U.S. industry in sharing hydrofoil development costs has been bad. A notable example was the Maritime Administration's DENISON program. A number of companies participated in this effort, sharing a major portion of the developmental cost. Practically every participant was disappointed in not realizing any economic return from such cooperation. The Grumman DOLPHIN program is another example in which all joint participants in the development sustained losses. As a result, a reluctance exists for industry to team for the purpose of spreading the developmental burden.

Regulatory Impact

Initially, faced with the problem of regulating a new vehicle, confusion existed over which agency had the responsibility. Was a hydrofoil a vehicle over which the Federal Aviation Administration should have jurisdiction, or should it be under the purview of the U.S. Coast Guard? This issue is now settled in the United States with Coast Guard having the responsibility. Other countries have solved the issue differently. Cooperative effort under SOLAS (Safety of Life at Sea) and IMCO (Intergovernmental Maritime Consultative Organization) is continuing to clarify and take cognizance of advance craft characteristics.

The early regulatory requirements were rather rigid because they applied conventional marine standards to high performance vehicles. With the experience gained by documenting several hydrofoil designs, these problems are more in hand. However, a substantial investment is required to meet these applied regulations. This fact has made it particularly difficult to utilize foreign designs to penetrate the U.S. market.

Over the past few years, several companies have attempted to capitalize on the SUPRAMAR success in other parts of the world. Licensing agreements have been established for U.S. manufacturers to produce and market these proven designs. In every instance, the regulatory requirements necessitated a redesign to meet U.S. standards. In order to use the SUPRAMAR design, it was recognized that waivers would have to be granted. The expense and risk associated with these requirements stalled all efforts to build a U.S. industrial hydrofoil base from the SUPRAMAR design.

The introduction of a new vehicle by the licensing method is certainly a way to reduce developmental costs. To stimulate a new industry, some consideration must be given to U.S. acceptance of foreign practices that have been proven acceptable by experience and have been approved by foreign certifying agencies.

COST OF OWNERSHIP

Requirements

So far, this paper has looked at the problems associated with the vehicle producer. Now, the considerations of the buyer will be addressed. No producer is going to be successful unless the vehicle can make money for the operator. To assure that the operator makes money requires a complex program that starts with basic design considerations. For example, a debate that has not been resolved is the question of what increase in ticket price will a passenger pay for more speed or more ride comfort. Speed and comfort improvements are related to larger acquisition costs. A resolution that will define a hydrofoil with a proper balance between performance requirements and costs to ensure that operators can make money over the planned routes is required.

The requirement for size is most critical. The producer is strongly motivated to provide a passenger seating capacity representing the needs of the most number of potential owners. Usually, a breakeven load factor is around 50 percent. The owner must be quite critical in assessing the realism of achieving that factor over the planned route.

Insurance

Insurance costs for hydrofoils are relatively high and can be the source of a major operating expense. The data base for U.S. hydrofoils is low, and the experience factor has been poor. There have been grounding incidents and whale and log impacts. When looked at over a worldwide base, the incidence of accidents is low. Also, the human casualty and injury rate is remarkably low. In fact, hydrofoils have the best experience regarding lack of fatalities of any transportation mode. No one had ever been killed on a free-world hydrofoil until this last year. However, insurance rates in the United States have been driven up by a very few incidents.

To avoid whale, log, or debris impact, studies are now underway to provide detection devices. The outstanding maneuverability characteristics of hydrofoils provide ample time to avoid impact if the object can be detected. The provision of such a device might well be paid for by the reflected savings in insurance premiums. Also, the government could share the risk of loss or damage during the introduction period of a hydrofoil route to help stimulate the industry. From worldwide experience, the premium rate should be comparable to other marine vehicles carrying the same number of passengers.

Crew Requirements

When it is mandatory to carry a U.S. crew, increased operating costs result. The problem is well understood in the maritime industry. The issues are related to salary, required crew size, and overtime. Probably, the most helpful benefit that could be derived would be from minimizing overtime. The crew is in a stand-by basis during a portion of any given operating day. If an agreement could be reached to count only the operating hours for pay purposes, the actual number of crews could be reduced.

Port Facilities

One of the major areas where government or municipal agencies can assist is by providing port facilities. Any improvement in marine transportation has an ancillary benefit to the communities served. Hydrofoils do not require elaborate arrangements for embarking and disembarking. Generally, a dockside location with sufficient water depth, the provision of a camel wide enough to protect the foil overhang, and an adequate gangway to provide a suitable berthing arrangement are sufficient. The location of the passenger terminal convenient to connecting ground transportation would complete the port facility requirements. Alleviating the need for the operator to invest in such facilities would certainly help the operator get started.

Introductory Expense

Initially, any new hydrofoil route will operate at a loss until sufficient passengers are attracted. If the route is for commuters, they must become convinced that they can depend upon this new mode of transportation. Travelers have to find out about the new routes, and publicity takes time. Here again, a government subsidy covering part of the initial operating expenses would stimulate operators to become involved. Other means of government stimulation could include providing for the vessel to carry mail, buying a fixed portion of the daily seats for government personnel use, or agreeing to use a daily amount of high-priority cargo space. Probably, the most tenuous period for formulating a new route is during the start. Here, any form of sharing the burden could be of great assistance in encouraging participation in the venture.

Maintenance and Utilization Factor

Once underway, the major variables in making a profit are the cost of maintenance and the hours of utilization. The objective must be to reduce missed departure times and unscheduled outages. Nothing kills passenger acceptance quicker than unscheduled outages. One operation demonstrated that a single missed day of operation immediately reduced the load factor to less than breakeven. It then required three weeks of sustained operation to recover a profitable load of passengers.

The criticality of the operation requires careful planning and analysis to be certain that planned preventive and corrective maintenance are undertaken only during scheduled downtimes. Lessons can be learned from the aviation industry which has successfully dealt with similar problems. A plan for maintenance must be available. Needed repair parts must be identified and stocked to be available when needed. The operator should not have to stock all these parts. Here, the producer must share the burden of supply and investment or utilize the assets of the vehicle's major equipment vendors. The larger the vehicle base, the easier the solution to the problem becomes. One gas turbine powered hydrofoil operation with no spare turbines is a no-win situation. Even a routine overhaul can remove the boat from service for a month or longer. Multiple-unit operation would make this problem less severe. A one-vehicle operation, whether bus or hydrofoil, is difficult to sustain profitably. The maintenance plan must recognize and deal with these situations.

Hydrofoil maintenance requires a higher degree of sophistication than for a conventional ferry boat. A maintenance crew must be staffed, trained, and sustained if the operation is to be successful. Both the producer and the owner must ensure that this happens if the route is to be profitable.

The on-board equipment requires monitoring to ensure that the need for maintenance or replacement is identified prior to failure. A monitoring plan and proper instrumentation are required to ensure that this is understood and accomplished. Here again, the producer must build the capability into the boat, and the crew must understand what is required to keep the boat operational.

All of this is aimed at ensuring that the hours of utilization are high. Earlier in this paper, route selection and its effect on utilization was discussed. If the adequacy of the maintenance plan is added to those considerations, the realism of the profit potential can be assessed.

What can a government agency do about the utilization factor? If an agency is to provide support to help the U.S. hydrofoil industry get started -- by subsidy, by backing a loan, or by some other means -- then government should be as concerned as the owner that the venture be reasonable. In assessing whether or not the venture is reasonable, as much concern must be given to the plan for maintenance as on the adequacy of the design.

In summarizing this paper, it must be stated that the intention is not to scare off possible investors. It is hoped that some of the difficulties mentioned in getting a hydrofoil business off-the-ground will, rather, be food for thought for a producer and an operator. Most hopefully, some of the content of this discussion will be provocative to those government planners who are concerned with expanding marine transportation.

AIR CUSHION VEHICLES

William Ellsworth

The objective of this brief case review is to identify some of the more important factors that facilitate or hinder the development and commerial success of the air cushion vehicle (ACV) in the U.S. maritime industry. The factors that facilitate the commercial acceptance of the ACV include those that demonstrate its ability to outperform its competitors in the eyes of the customer, whether the customer is a ferry passenger, an oil company ready to do seismic exploration, or a civil engineering company laying a pipeline. The customer's assessment will relate performance and potential revenue, i.e., the price of a ticket or charter. Judgment will be based on demonstrations, and the potential AVC charter customer will keep an eye on what is happening in other parts of the world and on other forms of transportation. So far, it appears that the U.S. ferry customer has seen little to encourage the market for the ACV. Compared to Europe, there are few well-travelled U.S. water crossings that have not been bridged, and demonstrations of the craft in the United States have been decidedly negative. More encouraging ACV results have been shown in heavy load-carrying and surveying tasks.

The potential commercial ACV operator in the United States has seen low reliability, high operating costs, high first costs, and the need for highly skilled pilots. Hydrofoils offer close competition to ACVs, as there have been several examples of successful hydrofoil operations in European and Russian waters. Although there are now successful ACV operations in Europe, the previously mentioned problems still act as inhibitors to United States ACV operations.

A U.S. ACV technology is being developed under military leadership, and the writer believes there are several possible routes in the country that are better suited to ACVs than any other type of craft. Increasing success and profits are being demonstrated abroad. In time, these factors could lead to a modest U.S. ACV industry.

PROFIT OPPORTUNITY

The fact that profits can be made from ACV operations has been demonstrated amply by Hoverlloyd Ltd., operating SRN.4s across the Dover Straits. Hoverlloyd realized a profit of between $950,000 and $1,400,000 (based on an exchange rate of $1.9/£) for 1977, and the carrying figures showed a 25 percent increase in the month of August 1977 compared to August 1976. Reliability had increased to the point where only 1 percent of the scheduled flights had to be cancelled because of unserviceability.[1] Seaspeed also offers cross-channel and Isle of Wight ferry services.

Profitability depends on specific conditions of the route including:

- Existence of a viable demand for a "ferry-type" operation; (Hovercraft can compete successfully with conventional ferry-boats)
- Lack of competition by a bridge or tunnel;
- Lack of competition by road, even if the trip time is longer by road; (Hovercraft cannot compete with the automobile)
- A large enough market to support the capital investment for the right craft for the route; and
- Availability of a craft large enough for the weather conditions on the route (i.e. the "right craft").

These conditions were met for the Solent with a craft of the SRN.6 size, and the cross-channel routes became successful when a larger craft of the SRN.4 type became available, bringing the weather cancellation rate down to 3 percent. A still larger craft would be subject to an even lower cancellation rate.

Profit opportunity should be an equally strong incentive in the United States, provided the right conditions can be found.

USER DEMAND

User demand for ferry-type services is dependent on comfort, such as might be determined by noise level and motion characteristics; on convenience, such as that defined by frequency of service and ease of loading and unloading; and on competition and speed.

Comparative noise level data was not available for this review; but, from the writer's experience in several craft, the SRN.4 is very different, and, when underway, the internal noise was no more objectional than that of a propeller-driven aircraft.

The effect of motion on SRN.4 passengers in different sea states is given in Table 1, and a comparison of accelerations in various forms of transport is given in Figure 1. These data show that, although current ACV travel involves some passenger discomfort, the SRN.4 compares favorably with other forms of transport.

The principal convenience of ACV service relative to other forms of marine transportation is the extreme simplicity of "docking" and "undocking" maneuvers.

Some additional incentives for the U.S. operators and builders of ACVs can be seen in the Canadian tests by the Coast Guard for search and rescue operations, and in the Canadian government's tests of the VIKING and VOYAGEUR craft.

The ACV is capable of competing effectively against conventional displacement ferry service only when conditions such as length of trip, weather conditions, potential of demand, and size of ACV combine favorably. This occurs in the English Channel where the demand is high, and where it has been possible to build a craft sufficiently large and seaworthy to operate in Channel weather 97 percent of the time.

In many cases where ferry services exist in the United States, there is a potential for the ACV to provide effective competition because of its high speed and, in some cases, its ability to shorten the route by disregarding shallows and sandbanks. Generally, the ACV cannot compete with the automobile, particularly with conveniently placed bridges and highways. On the other hand, the ACV can often compete with hydrofoils and fast-planing craft on the basis of reduced vulnerability to floating debris; ability to

TABLE 1 Effect of Craft Motion on Passengers

Wave Height Feet	Operations No. Trips	Operations No. Passengers	Seasick Occurrence No. Trips	Seasick Occurrence No. Passengers	Percent of Passengers Seasick
0-0.9	43	3,524	2	2	0.05
1-1.9	59	4,779	0	0	0
2-2.9	20	1,983	2	22	1.10
3-3.9	11	899	1	2	0.22
4-4.9	22	2,043	3	11	0.54
5 ft and above	28	2,333	17	240	10.30
Total	183	15,561	25	277	1.78
Total (below 5 ft seas)	155	13,228	8	37	0.27

TABLE 2 Relative Frequency of Trips versus Overall Duration

Duration (hours)	Frequency Index	Duration (hours)	Frequency Index
1.00	100.00	3.50	6.45
1.25	67.30	3.75	5.17
1.50	46.60	4.00	4.40
1.75	34.10	4.25	3.76
2.00	25.20	4.50	3.18
2.25	19.30	4.75	2.70
2.50	15.10	5.00	2.35
2.75	11.70	5.25	2.00
3.00	9.50	5.50	1.74
3.25	7.82		

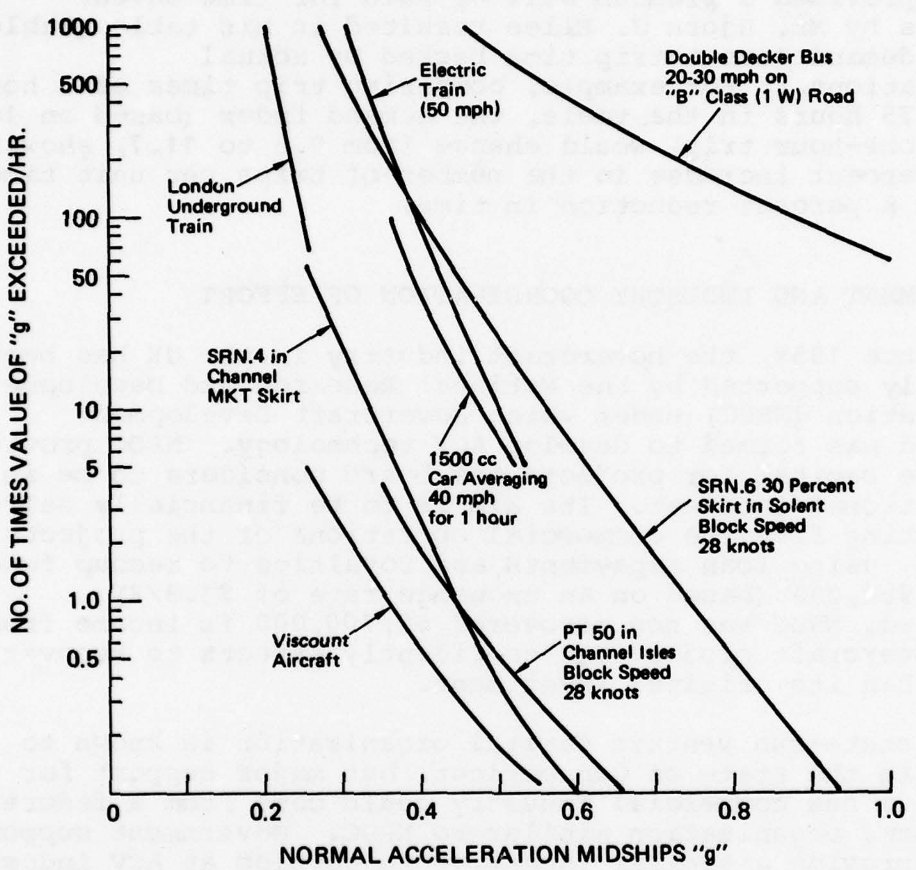


FIGURE 1

COMPARATIVE ACCELEROMETER READINGS

(various transports)

traverse land, ice, swamp, and shallow water; and generally higher speed.

Speed has a strong influence on demand, and the relatively high speed of the ACV is a good incentive to the user, provided a premium will be paid for time saved. Studies by Mr. Bjorn J. Ellee resulted in his table (Table 2) of demand versus trip time backed by actual observations.[2] For example, comparing trip times of 3 hours and 2.75 hours in the table, the demand index (based on 100 for a one-hour trip) would change from 9.5 to 11.7, showing a 23 percent increase in the number of trips per unit time for an 8 percent reduction in time.

GOVERNMENT AND INDUSTRY COORDINATION OF EFFORT

Since 1959, the hovercraft industry in the UK has been strongly supported by the National Research and Development Corporation (NRDC) under which Hovercraft Development Limited was formed to develop ACV technology. NRDC provides venture capital for projects the board considers to be in the national interest. Its aim is to be financially self-supporting from the commercial operations of the projects funded, using loan repayments and royalties to recoup funds. Of \$9,500,000 (based on an exchange rate of \$1.9/£) invested, NRDC has now recovered \$5,700,000 in income from the hovercraft project and confidently expects to recover more than its original investment.

A state-run venture capital organization is known to exist in the State of Connecticut, but major support for the ACV as a new commercial industry could come from a federally sponsored organization similar to NRDC. Government support could provide a similar incentive to develop an ACV industry in the United States.

TESTING AND DEMONSTRATIONS

ACVs have not received the degree of publicity in the United States that they have in Europe. The U.S. ACVs suffered some early setbacks because of the capsizing that occurred with small craft -- significantly one in San Francisco -- and because of the problems encountered with the San Francisco demonstration of the SRN.5. This history is likely to continue to have an inhibiting effect long after the technical problems have been solved and economical operation is proven elsewhere.

INTERNATIONAL COOPERATIVE AGREEMENTS

One of the most significant incentives for ACV development in the United States has been the industry-level agreement between Bell Aerospace Corporation and the British Hovercraft Corporation. As the result of this agreement, technology on hovercraft developed in Britain was made available for exploitation here, and several years of independent parallel development have been saved. The saving in financial terms would be difficult to estimate, since it is linked to Bell's turnover attributable to ACVs. This has been largely exploratory to date.

A secondary effect of the Bell-British Hovercraft agreement has been the encouragement of competitors in the military field, such as Aerojet General Corporation and Rohr Corporation, who might some day enter the commercial market.

SUBSIDIES, TARIFFS

If tariffs on imported ACVs could be suspended, it would give an incentive to U.S. companies wishing to establish ACV commercial operations. Once this type of craft was accepted through successful operations, and once demand was built up and U.S. builders were ready, tariffs could be imposed to increase the U.S. share of the ACV construction market. Bell is ready to build the SK-5 now, although the craft is noisy and obsolete.

Subsidies would have an encouraging effect for operators and builders of ACVs as they do for the U.S. shipbuilding industry. However, it would seem more likely that the government would let the industry stand or fall on its own economic merits, since, unlike the ship-related industries, there is no established employment group to be protected.

REGULATORY BODIES

In the United States, ACVs have been classed as vessels, and, as such, they come under the U.S. Coast Guard for regulation of their operations. Permits were obtained for the demonstration of the SRN.5 in San Francisco, but at the time of writing, USCG regulations do not distinguish materially between ACVs and hydrofoils, and in some cases, such as firefighting, requirements do not distinguish between ACVs and displacement vessels.[3] Thus, there may be some inhibition of ACVs due to USCG regulations that do not

AD-A077 202 NATIONAL RESEARCH COUNCIL WASHINGTON D C MARITIME TRA--ETC F/G 13/10
INNOVATION IN THE MARITIME INDUSTRY.(U)
MAY 79 N00014-75-C-0711

UNCLASSIFIED NL

3 OF 3
ADA
077202

END
DATE
FILMED
12-79
DDC

END
DATE
FILMED
12-79
DDC

fully recognize the weight sensitivity of this class of craft.

In addition to firefighting regulations, the following characteristics are subject to USCG regulation:

- Stability;
- Life Boats;
- Subdivisions;
- Structural Fire Protection; and
- Personal Licensing.

Regulations for some of these areas have been restrictive, especially where additional weight has been imposed. However, consideration is currently being given by the Coast Guard to SOLAS (Safety of Life at Sea) and IMCO (Intergovernmental Maritime Consultative Organization) regulations for novel and dynamically supported craft that may avoid some of the weight penalizing problems.

There are, of course, many other regulatory bodies that have been known to impede the establishment of commercial ACV operations, particularly those governing the local community and environmental acceptance. A 1977 attempt to establish a Hovermarine HM.2 operation in New York took considerable time to overcome regulatory restrictions. Some background to the governmental jurisdiction and regulation that has existed for ACVs is given in Reference 4.

PROTECTED TRADES

The Jones Act will have (and may already have had) a restricting influence on the development of ACV commercial operations in this country by prohibiting foreign commercial operations of hovercraft or surface effect ships (SES) from one U.S. port to another (see Reference 4 for example). The intent of the Act is to prevent the control and financing of such projects with foreign capital. It could be argued that commercial ACV exploitation might have been further advanced in the United States if a foreign company such as Hovertravel Ltd. had been encouraged to establish one or more ferry services in the country. Terms might have been agreed upon whereby control would be handed over to U.S. investment after a prescribed number of years. Successful operation in the country would be an incentive for U.S. firms to provide ACV services on other routes.

The Buy American Act restricts any federal agency from establishing a demonstration service using fully developed British, French, or Japanese craft. The purpose of this type of service would be to encourage U.S. firms to build and operate air cushion craft, thus getting the industry on its feet. Some states have their own Buy American Act or equivalent, and legislation presently on The Hill would restrict the purchase of foreign equivalent for projects partly funded by the federal government.

LEVEL OF EFFORT AND PLANNING

The level of effort in U.S. ACV technology is relatively high in military but low in commercial applications. A greater level of effort in commercial R&D spending could result in the capture of a share of the ACV market for U.S. companies, as new designs with greater capacity, better performance, and lower operating costs are developed. Such a process would be similar to the expansion of the U.S. aircraft industry, which has had a spectacular success.

The military capabilities of the ACV and SES and the strong military support for the craft are presently the greatest incentives for developing the technology of the craft in the United States. Characteristics such as speed, disposable load ratio, ride, noise, reliability, maintainability, navigation, handling, and fuel economy are important both for military and commercial purposes.

REFERENCES

1. "UKHS Bulletin", Published by the United Kingdom Hovercraft Society, January 1978.

2. Lucking, A.J. "Longest Queues are for the Fastest Journeys", Flight International, June 26, 1969.

3. A.W. Fowler telecon with Lt. McCord, Office of Merchant Vessel Inspection, U.S. Coast Guard, Washington, D. C., March 1978.

4. Lambert, J.L. "ACV Mass Transportation Project", Port of Oakland, CAL-MTD-3, April 1967.

BIBLIOGRAPHY

1. Abelson, Philip H.; "The Federal Government and Innovation"; SCIENCE; Vol. 201; No. 4355; August 11, 1978.

2. AN ANALYSIS OF FEDERAL R&D FUNDING BY FUNCTION: FISCAL YEARS 1969-1977; Survey of Science Resource Series; National Science Foundation; Washington, DC; 1978.

3. APPLICATIONS OF R&D IN THE CIVIL SECTOR - THE OPPORTUNITY PROVIDED BY THE FEDERAL GRANT AND COOPERATIVE AGREEMENT ACT OF 1977; Congress of the United States; Office of Technology Assessment; Washington, DC; June 1978; 42 pp.

4. Baer, Walter S., et al; ANALYSIS OF FEDERALLY FUNDED DEMONSTRATION PROJECTS: VOLUME 2, FINAL REPORT; "Supporting Case Studies"; U.S. Department of Commerce, National Bureau of Standards, prepared for Experimental Technology Incentives Program by Rand, Santa Monica, CA; April 1976; pp. 11-12, 18-58, 91-95, 106-108, 185-188.

   Beyond research and development (R&D) activities, federally supported "demonstrations" of innovations such as nuclear power reactors, personal rapid transit vehicles, and desalination plants have been designed to speed their commercialization. The results have been mixed. Some demonstrations have met their objectives, while others have not. As a result, many questions arise about what can be learned from this experience to enhance the effectiveness of federally funded demonstrations in the future. The purposes of the Rand study are (a) to identify major factors associated with successful and with unsuccessful project outcomes, and (b) to formulate guidelines for federal agencies in improving the planning, implementation,

monitoring, evaluation, and dissemination of results of future demonstration projects.

This study involved analysis of 24 past demonstration projects spanning a wide range of federal agencies, technologies, and project characteristics.

5. Baer, Walter S., et al; ANALYSIS OF FEDERALLY FUNDED DEMONSTRATION PROJECTS: VOLUME 3, FINAL REPORT; "Supporting Case Studies -- NS SAVANNAH"; U.S. Department of Commerce, National Bureau of Standards, prepared for Experimental Technology Incentives Program by Rand, Santa Monica, CA; April 1976; pp. iii-v, and Appendix A.

   In 1955, the Eisenhower Administration advanced a plan to build the world's first nuclear-powered merchant ship as a part of the U.S. Atoms for Peace program. This ship was later called the NS SAVANNAH after the first steam-powered ship to cross the Atlantic Ocean. Like its steam-powered predecessor, the NS SAVANNAH was delivered later than planned and no sooner were the shakedown cruises completed than it had to be laid up in port for another year because of a union dispute.

   Success finally came in a series of demonstration voyages over the next two years to ports around the world. But, when Congress subsequently forced this demonstration ship into cargo service as a general cargo ship, the ship cost considerably more to operate than could be earned in revenues, casting doubt on the idea that nuclear-powered merchant ships could be commercially successful. The nuclear merchant ship project developed in the late 1950s as part of the enthusiastic effort to diffuse the military's nuclear success into the commercial sector. This also fit nicely with President Eisenhower's Atoms for Peace initiatives; and, the efforts of a substantial number of Congressmen to "rebuild" the merchant marine based on nuclear power.

   The project team was seriously handicapped in their efforts by interference with many programs -- shipbuilders, suppliers, vendors, etc. Lack of union cooperation and inter-union rivalry provided a social/economic stumbling block that was never fully overcome.

The ship was designed to be a public demonstration of nuclear power. Both technically and as an international demonstration, the NS SAVANNAH was a tremendous success; it was only when Congress insisted that the ship haul cargo that there was no hope for success, for the ship was not designed for that service.

Most of the technical team believed that, had they been permitted to build a large crude oil tanker as had been originally planned, the ship would have been a reasonable economic success and would still be in operation. There is a split in the group's opinion as to whether additional ships would have or should have been built. The economics seems to be marginal and the regulatory hurdles seem more formidable every day.

6. Baer, Walter S., et al; ANALYSIS OF FEDERALLY FUNDED DEMONSTRATION PROJECTS: VOLUME 3, FINAL REPORT; "Supporting Case Studies -- Shipbuilding"; U.S. Department of Commerce; National Bureau of Standards; prepared for Experimental Technology Incentives Program by Rand, Santa Monica, CA; April 1976; pp. iii-v, and Appendix E.

   The National Shipbuilding Research Program was formed in 1969-70 as a joint government-industry effort to improve technology development and dissemination within the shipbuilding industry. The work program is developed and funded on a cost-shared basis, with government and industry acting as equal partners.

   The program has completed or has in process approximately 100 projects; there have been good successes and some failures. The organization and techniques utilized have been able to maximize the successes through wide industry diffusion and have recognized the failures in time to avoid large expenditures of resources.

   The technique of developing research needs from the standpoint of the immediate user has proven to be a very effective means of involving the shipbuilding community in raising the level of innovation, technology, and communication for their mutual benefit. Independent evaluations of the program have rated it is as being one of the most successful within government.

There are several very good reasons that the innovation is succeeding:

- Participation by users for the research product on an industry-wide basis;
- Rising expectations throughout the industry;
- Cost sharing among the parties; and
- A rare, honest partnership between government and industry.

Deterrents to success were

- Industry distrust of government projects and project personnel;
- Industry worries over government antitrust activities;
- Industry practices of non-cooperation with each other; and
- Government's inability to make long-term commitments.

7. "Balloons to Move Cargo Ship-to-Shore"; AVIATION WEEK & SPACE TECHNOLOGY; July 4, 1977.

8. Benford, Harry; "Of Ships and Shipping, 2000 A.D."; Special Lecture; The University of Michigan; November 14, 1975; 12 pp.

The principal theme of the paper is that ship technology is undergoing rapid change and is likely to continue to do so. It is, therefore, important to be ready for change, even though we can but dimly see what the future may hold. "The net result will be to render obsolete those individuals and organizations that cannot adapt to change. The secret of survival lies in continuing, aggressive research and development spurred by more and better educated engineers and managers who have been taught to teach themselves."

Those are the principal conclusions of this paper. The underlying justification comes from the author's reflecting back to the postwar period (1947) and comparing maritime crystal ball work of that day with what has actually transpired:

- Seven predicted developments actually came into being;

- Six predicted developments fell by the wayside; and
- Forty-one developments that were not in the crystal ball have come into being.

Having established the rapid growth of marine technology, as well as its unpredictability, Benford goes on to hazard some guesses about technological improvements that can be expected simply because they are so obviously needed:

- Better mooring systems;
- Elimination of corrosion and barnacles;
- Elimination of groundings and collisions; and
- Better fleet management to eliminate port delays, and so forth.

9. Benford, Harry; "On the Genesis of Shipboard Automation"; Working Paper prepared for the National Academy of Sciences, Committee on Innovation and Technology Transfer in the Maritime Industry; Washington, DC; April 14, 1978.

10. Benford, Harry; "The Role of Education"; Working Paper prepared for the National Academy of Sciences, Committee on Innovation and Technology Transfer in the Maritime Industry; Washington, DC; April 11, 1978; 3 pp.

Benford cites several authorities who state that this nation's world leadership in industrial production has its roots in education. In general, our private industry is manned by large numbers of well-educated engineers and business managers -- much more so than in most foreign nations -- and this explains our high productivity, which allows our high hourly wage rates. In the shipbuilding industry, however, the situation is reversed. Here we find U.S. shipyards lagging far behind foreign yards in attracting well-educated technical talent. Our ability to innovate thus suffers by comparison.

11. Best, Roger J.; "An Experiment in Delphi Estimation in Marketing Decision Making"; JOURNAL OF MARKETING RESEARCH; November 1974; pp. 448-452.

12. "Big Shippers Speak Their Mind About Closed Conferences: 'We May Need You, But It's Only A

Marriage of Convenience'"; AMERICAN SHIPPER; June 1977; pp. 4-5, 8 & 44.

13. Blackman, A. Wade; U.S. OCEAN SHIPPING TECHNOLOGY FORECAST AND ASSESSMENT; United Aircraft Research Laboratories, for U.S. Department of Commerce; Maritime Administration; July 1974; Volumes 1-5.

14. Blackwell, Robert J.; Assistant Secretary for Maritime Affairs; U.S. Department of Commerce; Maritime Administration; presentation made to Merchant Marine Subcommittee of the House Merchant Marine and Fisheries Committee in Support of Fiscal Year 1979 Authorization; Washington, DC; February 7, 1978; 12 pp.

15. Booz-Allen Applied Research; "Transfer of Aerospace Technology to Public Transportation - LNG Tanker Case Study"; October 14, 1975; 25 pp.

16. Boucher, Wayne I.; Mark Anderson; Sarah Beckett; Lloyd Culbertson; Pritchard Strong; FEDERAL INCENTIVES FOR INNOVATION: THE IMPACT OF EPA ADMINISTRATIVE PRACTICE ON THE INNOVATION PROCESS IN U.S. COMPANIES: A CASE STUDY OF REGULATORY BARRIERS TO INNOVATION; National Science Foundation; Experimental R&D Incentives Program; Denver Research Institute; University of Denver; January 1976; 192 pp.

17. Bradbury, F.R.; "Constraints to Innovation"; CHEMTECH; January 1977; pp. 23-27.

18. Bright, James R.; "Evaluating Signals of Technological Change"; HARVARD BUSINESS REVIEW; January/February 1970; pp. 62-70.

The author contends that major technological innovations provide many signals that the alert manager can discern. However, there are also false signals.

The author assumes that a manager who is forewarned of changes will take advantage of the changes. To obtain this forewarning he suggests

- Searching the environment for signals that may be forerunners of significant technological change;
- Identifying the possible consequences (assuming that these signals are not

false and the trends that they suggest persist);

- Choosing the parameters, policies, events, and decisions that should be observed and followed to verify the true speed and direction of technology and the effects of employing it; and
- Presenting the data from the foregoing steps in a timely and appropriate manner for management's use in decisions about the organization's reaction.

19. Carey, William D.; "The Relationship Between Federal, State, and Local Government Support for Research and Development"; Joint Committee Print; PRIORITIES AND EFFICIENCY IN FEDERAL RESEARCH AND DEVELOPMENT; A COMPENDIUM OF PAPERS; Washington, DC; October 29, 1976; pp. 65-84.

Public supported R&D is essentially all at the federal level. No one has considered a shared approach where the federal, state, and local governments would jointly direct an R&D laboratory.

There are now three worlds of R&D -- federal, industry, and university/non-profit. A fourth world would be the state and local governments.

The solution is not necessarily matching funds, but rather "these jurisdictions could participate with low cost and zero risk in the early and middle stages of federal R&D program formulation and project design, with expectations of results that are keyed to their adoption and benefit."

The point is emphasized that the state and local governments need "technical capacity" and "informed capacity in order to participate."

"In political terms the NSF RANN program has not built a state-local constituency with sufficient conviction and self-interest to force the federal government toward a reorientation of its R&D arrangements."

20. "Cargo Preference, A Shippers' Guide to Current Worldwide Preference Practices"; CONTAINER NEWS; May 1977; pp. 48-49 & 51.

21. "Chase Manhattan Loses Interest in Ships for U.S. Liner Trades"; AMERICAN SHIPPER; April 1978; pg. 20.

22. Chirillo, L.D.; "Improving Shipbuilding Productivity"; MARITIME REPORTER/ENGINEERING NEWS; November 1, 1977; pp. 14-17.

23. Committee on Mineral Technology; TECHNOLOGICAL INNOVATION AND FORCES FOR CHANGE IN THE MINERAL INDUSTRY; National Academy of Sciences; Washington, DC; 1978; 62 pp.

24. "Communications: MARISAT Satellite System Provides Clear Reception Around the World"; MARINE ENGINEERING/LOG; July 1977; pp. 26-27.

25. Connors, Thomas G.; "Update: Domestic LNG Vessel Construction"; MARINE TECHNOLOGY; Vol. 15, No. 1; January 1978; pp. 1-13.

26. Creighton, J.W.; "The President's Interns and Their Perceived Value in the Technology Transfer Process"; TECHNOLOGY TRANSFER IN RESEARCH AND DEVELOPMENT; Naval Postgraduate School; Monterey, CA; 1975; pp. 49-60.

This article is a discussion of the effectiveness of a technology transfer program where technically trained engineers and scientists from the airframe industry were placed in government and private sector laboratories that had quite different missions. Did the mere transfer of engineers and scientists cause technology transfer? In many cases the answer was "yes". There were, however, problems such as

- The one year program was too short;
- Performance is a value judgment of the supervisor -- many supervisors do not strongly support the introduction of change; and
- There was some misunderstanding as to the objective of the program and the role of the newly assigned engineers and scientists.

27. Critelli, Francis X.; "Contra-Rotating Propulsion Systems for U.S.-Flag Merchant Ships"; Case Study prepared for the National Academy of Sciences, Committee on Innovation and Technology Transfer in the Maritime Industry; Washington, DC; 1978; 4 pp.

(see Appendix of this report for reprint)

This case study describes contra-rotating propulsion which utilizes two propellers, one behind the other, rotating in opposite directions, on internal and external shafts, at approximately the same RPM but slightly different torques. Significant fuel savings (on the order of 10 percent for fast container ships -- corresponding to 5 percent of annual voyage costs) can be realized through use of this innovation.

Lack of demonstrated reliability was a deterrent to this innovation's acceptance. An innovation such as this, that could, in the event of casualty, adversely impact profitability, is viewed with apprehension due to the tremendous cost of time out-of-service and extensive repair or replacement.

When financial risks are great, the maritime industry cannot afford to offer its vessels to demonstrate new technology unless insurance is provided to remove the feared, possible economic penalty. The author suggests a form of "risk insurance" that would cover only the possible loss directly borne by the ship operator, and he believes this would provide the necessary vehicle for the Maritime Administration to implement this possibly worthwhile innovation.

28. Cushing, Charles R.; INNOVATION AND PRODUCTIVITY IN THE LINER INDUSTRY; Northwestern University Transportation Forum; New York, NY; March 13, 1978.

29. Daschbach, Honorable Richard J.; Chairman, Federal Maritime Commission; presentation made before the Propeller Club of the United States, Port of Washington, DC; February 23, 1978; 6 pp.

The innovation in question is a revision to the shipping statutes of the United States to update them from the Shipping Act of 1916 and the Merchant Marine Act of 1936. Mr. Daschbach emerges as the champion of the innovation. Throughout the speech, he promotes the concept that leadership in the revision of the Act will reside in the Federal Maritime Commission. He states that the time has come, and his reason is that the not-invented-here attitude is a non-problem because the inventors are all dead.

The reason the 1916 Act must be redone is that it is obsolete. The 1916 Act did not contemplate containerization, intermodalism, landbridge, or the developing nations' demands (which will require new trading arrangements and codes of conduct). Also, new domestic problems exist because of multiple agency conflicts, as contrasted with the need for a single national voice in international shipping.

Mr. Daschbach indicates that the 1916 Act was generated in a world dominated by commercialism. He considers that the big reason for the Act's obsolescence is the emergence of a "national interest factor" reflecting national politics that have been added to the original, simple commercialism perspective. An example of this new factor is the increased emphasis on cargo preference.

The embedment problems are being anticipated and what might be called an antideterrent is being generated. Mr. Daschbach is ready to address problems raised by the public and to anticipate their grievances. He views public rejection of the revision as a risk. His solution is to solicit industry comments.

30. Dashnaw, Frank; "Highly Skewed Propeller"; Case Study prepared for the National Academy of Sciences, Committee on Innovation and Technology Transfer in the Maritime Industry; Washington, DC; March 1978; 2 pp.

(see Appendix of this report for reprint)

The highly skewed propeller turned out to be an excellent technical solution to a pressing problem -- badly vibrating ships. The innovation was inspired by practical necessity, but might never have come to fruition if the Maritime Administration had not taken initiative in not only fostering the research (at Taylor Model Basin), but also in obtaining the cooperation of a shipowner, a shipyard, the classification society, and concerned federal agencies. The report does not say whether MarAd bore any of the risk involved in case the trial propeller were to fail.

31. Davidson, G.C.; "Heavy Oil Engines for Marine Propulsion"; SOCIETY OF NAVAL ARCHITECTS AND MARINE ENGINEERS TRANSACTIONS; 1911.

32. Denver Research Institute; FEDERAL INCENTIVES FOR INNOVATION - WHY INNOVATIONS FALTER AND FAIL: A STUDY OF 200 CASES; report prepared for the National Science Foundation; January 1976; 77 pp.

This report does not deal with the marine industry, but has relevance to the broad subject of innovation. Several important conclusions were drawn in the report.

- The dominant reason for failures of government innovation was the technology;
- The dominant reason for failures of profit-making organizations' innovations was management;
- Without risk, one does not innovate;
- The private sector believes government has several roles in innovation: (1) sharing the burden of high risk, particularly where the innovation is in the public interest, and (2) providing technological assistance;
- "Don't fight the market"; and
- For success, one must not only provide success factors, but must also avoid a separate set of failure factors.

33. Dermody, John; "Port of Seattle Growth Through Modern Customer Services"; CASE STUDIES IN MARITIME INNOVATION; National Academy of Sciences; Washington, DC; May 1978; pp. 89-104.

(see Appendix of this report for reprint)

The argument is presented that the port concept has changed. The author states: "The function of a port is to provide for efficient and least cost inter and intramodal transfer, inspection, storage, form change, and control of cargo."

The economic importance of a port in the total shipping cost is illustrated. One example will emphasize this point: On the Australian trade, conventional cargo liners spend 50 percent of

their time in port, container ships spend only 12 percent of their time in port activities.

A port must see its opportunities and make appropriate commitments: "The prosperity of a port is not dependent on natural advantages as much as a systematic development of the broadest lines to attract foreign and domestic commerce."

This concept was truly exploited by the Port of Seattle. One illustration is "The Port of Seattle's tariff specialists advise shippers on the advantages, if any, to be gained in changing the form, packaging, and parcel size of goods during their transshipment through Seattle.

A second example: "The Port of Seattle keeps control of goods -- almost at the retail level -- from the time of shipment to ultimate delivery." (Through use of a well designed, computerized data processing system.)

A further example: The Port of Seattle has installed the most modern cargo transport devices and planned for and utilizes advanced concepts in environmental control, ship handling, mooring, docking, etc.

The importance of management is made clear by this statement: "Important as the new technologies of the freight business are, they do not, singularly or in concert, necessarily lead to a successful port. Whatever the hardware of technology, a port becomes successful through establishing goals, supporting the good management to achieve those goals, - - -."

The conclusion summarized by listing these several points:

- The Port of Seattle had a comparatively poor standing among world ports;
- There was public pressure to change;
- The total port concept was changed;
- The most important economic gain was through reduced port time for the vessel and cargo;
- Financial risks were necessary to accomplish a significant technological advancement; and

- Reorganization -- the Port Authority Commissioners and the line management were changed and upgraded in order to build a competent professional staff.

34. Devanney, John W. III; MARINE DECISIONS UNDER UNCERTAINTY; Massachusetts Institute of Technology; Sea Grant Program; Cornell Maritime Press, Inc.; Cambridge, MD; 1971; 203 pp.

35. "Diesel Engines"; SHIPBUILDING CYCLOPEDIA; 1920.

36. "Diesel Propulsion"; MARINE ENGINEERING; Vol. 1; 1962.

37. Early, E.H.; "Measuring the Effectiveness of a Rapid Response Technology Transfer Program," TECHNOLOGY TRANSFER IN RESEARCH AND DEVELOPMENT; Naval Postgraduate School; Monterey, CA; 1975; pp. 61-80.

    A special office was established at the Navy's Civil Engineering Laboratory to link the user requests for information with the appropriate scientist or engineer in the laboratory and to assure that the scientist or engineer responded to the request for information. The effectiveness of this "linker service" office was monitored over several years. This paper reports on the details of the organizational arrangement and on the measurement of the effectiveness of the office. A model was devised and is described where probabilities are assigned to the perceived benefit in order to realistically evaluate the dollar benefit to the Navy. Through this means, it was shown that the Navy benefits $2.72 for every dollar spent in promoting the utilization of R&D output from its Civil Engineering Laboratory.

38. Ebel, Francis G.; "Evolution of the Concept and Adoption of the Marine and Intermodal Container"; CASE STUDIES IN MARITIME INNOVATION; National Academy of Sciences; Washington, DC; May 1978; pp. 1-27.

    (see Appendix of this report for reprint)

    The case describes the successful development and implementation of the container as a means to improve service and lower unit cost of ocean transportation of commodities. It encompasses the initial experience in the mid-1950s through the subsequent maturing during the next twenty years.

Factors that helped speed the development were

- Decreasing productivity of longshore labor with conventional methods;
- Increased ship speeds resulting in port time's assuming a larger portion of the total transit time and port cost's accounting for 60 percent or more of the total cost;
- The development by the U.S. Army of an extensive container transport system that was used in the Korean War;
- Malcom McLean's experiments from which the favorable economics of the container-based system were evident; and
- Financial losses in Matson's traditional Hawaiian trade that required a drastic remedy to avoid bankruptcy.

Factors that helped the implementation/diffusion of the innovation were

- The Mechanization and Modernization Agreement on the West Coast removed ILWU opposition to labor-saving devices that permitted the introduction of containers and container-handling equipment on the West Coast without union opposition;
- Standardization in container sizes and fittings led to the development of container leasing;
- Entry of Sea-Land (an unsubsidized carrier) into the North Atlantic caused subsidized carriers to obtain container ships and offer container service; and
- Government-sponsored research demonstrated the potential savings available from containerization.

Factors that deterred the implementation/diffusion of the innovation included

- Union opposition to mechanization or labor-saving devices that would reduce employment;
- The functional elements comprising the ocean transportation movement of cargo (the ship, the stevedore, and the terminal) were controlled by separate and independent organizations;

- The managements of steamship companies were heavily tradition-bound;
- The large existing fleet of cargo ships could not efficiently accommodate containers; and
- The subsidized operators in the foreign trades did not have the economic incentives to innovate because construction and operating subsidies put U.S.-flag carriers on an equal cost basis with foreign operators, and the steamship conferences eliminated competition by pooling cargo and fixing rates.

39. ECONOMIC IMPLICATIONS OF THE U.S. MERCHANT MARINE AND SHIPBUILDING INDUSTRY: AN INPUT OUTPUT ANALYSIS; U.S. Department of Commerce; Maritime Administration; Washngton, DC; May 1977.

40. Ellsworth, William; "Air Cushion Vehicles"; Case Study prepared for the National Academy of Sciences, Committee on Innovation and Technology Transfer in the Maritime Industry; Washington, DC; 1978; 7 pp.

(see Appendix of this report for reprint)

This brief case study reviews some of the more important incentives and deterrents to the adoption of the surface effect ships (SES) in the U.S. maritime industry. Prospective customers include ferry passengers, oil companies doing seismic exploration, and, perhaps, the engineering/construction firm laying a pipeline. The incentives for adoption are demonstrations of ability to outperform competitors and foreign alternatives in the competition. In either instance, the customer will be relating the price of the ticket to the quality of the performance rendered.

So far, there has been little incentive for U.S. ferry customers to demand SES caliber service. Compared to Europe, there are few well-travelled U.S. water crossings that have not been bridged. In the few promising routes, the demonstration runs have been frought with mishaps that have marred the SES public image. On the other hand, heavy load-carrying duties and surveying promise to provide attractive early service opportunities for the SES in the United States.

Prospective U.S. SES operators have been witnessing demonstrations of high first cost, high operating costs, low reliability, and the need for highly skilled pilots. These are all deterrents to adoption. For some routes, the prospective operators view the hydrofoil as a winning competitor because of its successful operations in Europe and USSR.

U.S. SES technology is advancing under military sponsorship. Increasingly successful and profitable operations are being demonstrated abroad. There are several promising routes in the United States, so there is a probability that the SES will see wider U.S. use in the future.

41. Essoglou, M.E.; "The Linker Role in the Technology Transfer Process"; TECHNOLOGY TRANSFER IN RESEARCH AND DEVELOPMENT; Naval Postgraduate School; Monterey, CA; 1975; pp. 1-15.

This paper reports on several studies at the Naval Postgraduate School, Monterey, CA. The studies deal with the methodology of technology transfer and are related to a model that considers a source of technology, a transfer mechanism, and a user or receiver of the knowledge. The nine factors discussed that influence the movement of technology from the source to the user are as follows:

- Documentation -- the format, the organization, the language;
- Distribution -- the physical channels used to distribute the information -- the entry, the exit, the plan, redundancy;
- Organization -- the power structure, the nature of the business, the management style, resources, attitudes, bureaucratic tendencies, and state of equilibrium;
- Project selection -- who initiates, approves, authorizes, monitors, and is consulted about the project;
- Capacity -- the characteristics of individuals in the user organization

that are described by terms like venturesomeness, wealth, power, education, experience, age, self-confidence, etc.;

- The Linker -- the individual or group of individuals that does exactly what the term implies, i.e., links. It is probably the single most important factor, because these people link the source to the application;
- Credibility -- the information that is being transferred must emanate from a source that is at least credible according to the perception of the recipient or the potential user;
- Rewards -- the consequences of applying technology that is new to the receiving organization imposed by management are crucial. Namely, if a man is to get penalized more than rewarded, he will most certainly be disinclined to import a new piece of technology, idea, or approach which is untried within his particular organization; and
- Willingness -- a person who is going to make use of a piece of technical information must be willing to receive the message and must be willing to implement it.

42. Ferguson, Allen R., et al; THE ECONOMIC VALUE OF THE UNITED STATES MERCHANT MARINE; Transportation Center at Northwestern University; Evanston, IL; 1961.

43. Fielding, Sterling A.; "Development of Gas Turbine Propulsion -- G.T.S. JOHN SERGEANT"; Case Study prepared for the National Academy of Sciences, Committee on Innovation and Technology Transfer in the Maritime Industry; Washington, DC; 1978; 5 pp.

(see Appendix of this report for reprint)

44. Frutkin, Susan; "The Technology Transfer Process - The Case of the LNG Tanker"; OCEAN 75 RECORD (Ocean 75 is combined meeting of 1975 IEEE Conference on Engineering in the Ocean Environment and Eleventh Annual Meeting of the Marine Technology Society); San Diego, CA; September 22-25, 1975; pp. 855-859.

The LNG Tanker Case is presented to show the major factors influencing the innovation process. The incentive enhancers include people, financial support, demanding performance specifications or design criteria, identified need, and conscious attempts to change.

The barriers are economics, environment, inertia, and institutions.

LNG posed a fantastic advantage to transportation because of its 618 to 1 volume ratio of natural gas to LNG. The thrust for development of LNG tankers was largely due to circumstances of the times: the energy crisis, U.S. shipbuilding capacity losing ground to foreign yards, the push for cleaner environments, and technological advances in the cryogenic industry. However, the circumstances were critical since tankers form only a portion of the total transportation system of natural gas.

With the transport of LNG came ever stricter safety and control measures than with less sophisticated or hazardous materials.

The most significant technology transfer factor is probably the people associated with the technology; whereas, the greatest inhibitor is probably the economics -- the cheaper the innovation, the more it is employed.

Final advice is that not all technology is susceptible to transfer, and many persons fail to understand the technology transfer process.

45. Fusfeld, Alan R.; "How to Put Technology into Corporate Planning"; TECHNOLOGY REVIEW; May 1978; pp. 51-55.

46. Gamarra, Nancy T.; ERRONEOUS PREDICTIONS AND NEGATIVE COMMENTS CONCERNING EXPLORATION, TERRITORIAL EXPANSION, SCIENTIFIC AND TECHNOLOGICAL DEVELOPMENT; Library of Congress; Legislative Reference Service; Washington, DC; May 29, 1969; revised; 48 pp.

47. Garrison, W.L.; TRANSPORTATION TECHNOLOGY NEEDS AND THE PROCESSES BY WHICH THEY ARE FILLED; prepared for the National Academy of Sciences, Transportation Research Board Annual Meeting; Washington, DC; January 17, 1978; 21 pp.

48. Gartner, Joseph; and Charles S. Naiman; "Making Technology Transfer Happen"; RESEARCH MANAGEMENT; May 1978; pp. 34-38.

49. Gilpin, Robert; "The Government's Role in Fostering Technological Innovation"; TECHNOLOGICAL INNOVATIONS AND ECONOMIC DEVELOPMENT: HAS THE U.S. LOST THE INITIATIVE?; Proceedings of a Symposium on Technological Innovation; Washington, DC; April 19-20, 1976; pp. 167-180.

This paper discusses the government's role in fostering technological innovation, but does not consider the maritime industry specifically except for some discussion following the paper.

Gilpin identifies several changes that will act as incentives to innovation.

- New technology and market demand should be coupled in the private sector;
- Government should help to finance basic and applied long-term research and development, but should not enter into commercial development; and
- New knowledge required for innovation should continue to be generated within universities rather than by government-sponsored labs.

Gilpin states that uncertainty is the greatest deterrent to innovation. The problem of uncertainty causes firms to invest in short-term, low-risk innovations. Uncertainty falls into three categories:

- General business uncertainty;
- Technical uncertainty with respect to performance and cost of a product; and
- Market uncertainty - who will buy the product or service?

Gilpin believes that government can play a definite role in promoting technical innovation, particularly by supporting basic research. However, this effort should not extend into commercial development.

50. Gorman, David L.; "Innovation in the Maritime Industry: Landbridge Services"; CASE STUDIES IN MARITIME

INNOVATION; National Academy of Sciences; Washington, DC; pp. 105-120.

(see Appendix of this report for reprint)

Case study describes landbridge service, a successful marketing innovation that was implemented without changing the existing technology.

Factors that were incentives to innovate were

- No new technology was needed; both marine containerization and unit trains had already been developed;
- Both railroads and containerships had unused capacity;
- Both railroads and containership operators were having financial difficulties;
- Although regulatory parties were involved in considering the legality of these services, no governmental action was taken to stop the services;
- Value of service pricing allows the "overpriced" high value goods to be diverted;
- Geography permits shorter combined land/water trade route distances than all-water routes;
- Efficient land/water cargo handling and operations permit reduced transit times for shippers (at no extra cost due to pricing strategy); and
- Landbridge services allow expansion at the competitive range of the individual ship operator.

The aspects of landbridge that deterred innovation include:

- Alleged injury to certain parties by the new service (i.e., particularly the Council of North Atlantic Steamship Associations, The Ports of Boston and Philadelphia, and the International Longshoremen's Association have taken legal action to stop the landbridge service without success);

- As volume grows, the railroads have desired a larger division of the revenues shared with the containerships; and
- The steamship conferences on the U.S. Atlantic and Pacific may get together to jointly determine landbridge services.

Apparently this marketing innovation could have been implemented at an earlier date on a larger scale. It seems that the financial difficulties of the companies involved was the factor that finally speeded the process.

51. GOVERNMENT CONTRACTING FOR RESEARCH AND DEVELOPMENT; Executive Office of the President; Bureau of the Budget; Report to the President from seven government agencies; 1962.

52. "Government Favors the Giants in Handing Out R&D Funds"; THE WASHINGTON STAR; July 1, 1978; pg. B-6.

53. GOVERNMENT INVOLVEMENT IN THE INNOVATION PROCESS - A CONTRACTORS REPORT TO THE OFFICE OF TECHNOLOGY ASSESSMENT; Congress of the United States; Office of Technology Assessment; Washington, DC; August 1978; 69 pp.

54. Graham, Bradley; "Waning of Innovation Is Seen"; THE WASHINGTON POST; November 16, 1978.

55. Gribbin, Joseph A.; AN ANALYSIS OF CYCLICAL AND OTHER FLUCTUATIONS IN COMMERCIAL SHIPBUILIDNG IN THE UNITED STATES, 1950 - 1974; U.S. Department of Commerce; Maritime Administration; Washington, DC; 1977; 211 pp.

56. Halmos, Paul R.; "Innovations in Mathematics"; SCIENTIFIC AMERICAN; September 1958.

57. Hannay, N.B.; "Technological Innovation and National Priorities"; THE NATIONAL RESEARCH COUNCIL IN 1978; National Academy of Sciences; Washington, DC; pp. 63-76.

58. Hearings Before the Subcommittee of the Committee on the Department of Defense; U.S. House of Representatives; Committee on Appropriations for Fiscal Year 1978; March 22, 1977.

59. Heine, Irwin M.; THE UNITED STATES MERCHANT MARINE - A NATIONAL ASSET; National Maritime Council; Washington, DC; July 1976; 205 pp.

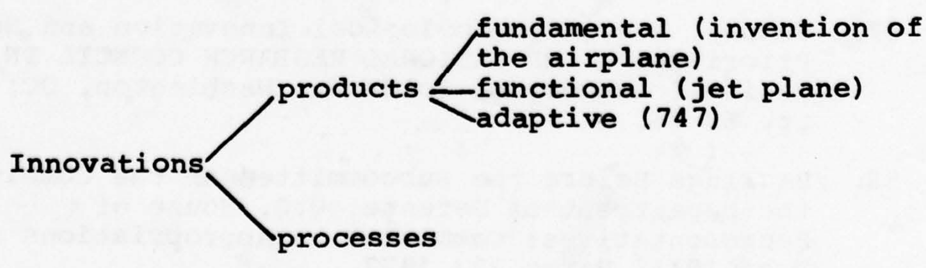
60. HISTORY - LOCKS AND DAM 26 (REPLACEMENT) SINCE LAWSUIT; handout; Lock 26; Alton, IL.

The innovation here is the levying of fees in return for use of federally funded lock and dam projects on the inland-waterway system. Twenty-one railroads have teamed to halt construction of a replacement project by the U.S. Army Corps of Engineers, unless a lockage fee is charged. The charge is to be related to the utilization-benefit of the waterway system to the traffic through this particular lock, because this lock allows access to the entire upper Mississippi system. An alternate that has been suggested is a federal tax on diesel oil throughout the entire inland-waterway system. The railroads argue that they have had to provide all of the facilities at their own cost, whereas waterway facilities are provided by the taxpayer. The railroads claim this has been an unfair subsidy to the waterway operators.

61. House, Peter W.; David W. Jones; "Innovation in the Private Sector"; GETTING IT OFF THE SHELF; University of California; Berkeley, CA; 1977; pp. 53-107.

This book is subtitled "A Methodology for Implementing Federal Research." Although it is not directed at any specific industry, there are, in the third chapter, conclusions that may well apply to the U.S. maritime industry.

The introductory parts of the chapter engage in some good analysis of the different kinds of innovation:



We must realize that, as we move from fundamental innovation to adaptive "innovation", we move from a position of high-risk and expense, with potentially high returns to one of low-risk and less expense, with probably marginal returns.

A section on the importance of innovation claims great things for R&D. In 1968, 75 percent of U.S. growth in sales came from new products; industry earns a 30 percent rate of return on R&D; etc. They state that U.S. private industries invest about 2 percent of sales in R&D.

There is a good section on why some innovations fail. The most important cause is that users' needs are not understood.

FACTORS ENCOURAGING INNOVATION AND DIFFUSION

Middle-sized firms are most likely to innovate. Small firms often lack the required financial resources and managerial talent. Large firms are often too bureaucratic and too self-satisfied.

An innovation will be most quickly adopted throughout an industry if it is (a) highly profitable, (b) low risk, and (c) cheap. Rate of diffusion is also influenced by the attitudes of the people affected and by the level of industrial activity. Firms operating at about 75 percent capacity are in the best position to adopt an innovation.

BARRIERS TO INNOVATION

Barriers can be divided into four categories: market, organization, technical, and environmental.

- Market barriers: A new product or service must be of value as perceived by the customer. Moreover, the advantage of any innovation must be high relative to the status quo. The market must be large enough to justify cost of development;
- Financial barriers: This section mentions many factors that must be considered when managers are considering the financial aspects of an innovation.

Of particular interest to the marine industry are the cyclic characteristics of the business;

- Organizational barriers: Many innovations require changes in organization, that bring all manner of human problems, hence resistance;
- Environmental barriers: These are constraints that are outside the firm's control: economic conditions, legal and political bounds, social conditions, etc.

62. House, Peter W.; David W. Jones; "Technological Innovation in the Public Sector"; GETTING IT OFF THE SHELF; University of California; Berkeley, CA; 1977; pp. 108-165.

63. "How to Make a Technology Assessment"; CHEMICAL AND ENGINEERING NEWS; March 28, 1977.

64. "Innovation Recession"; TIME; October 2, 1978; pp. 57 & 63.

65. INNOVATORS AND ENTREPRENEURS - AN ENDANGERED SPECIES?; presentations at the Technical Session; 13th Annual Meeting; National Academy of Engineering; National Academy of Sciences; Washington, DC; November 10, 1977; 40 pp.

66. Iseman, Peter A.; "The Arabian Ethos"; HARPERS; February 1977.

67. "The Japanese Worker vs. the British: A Horror Story"; THE WAYLAND-WESTON TOWN CRIER; January 12, 1978; pg. 15.

68. Jenstrom, Linda L.; "The National Shipbuilding Research Program: A Case Study of Innovation in the Maritime Industry"; CASE STUDIES IN MARITIME INNOVATION; National Academy of Sciences; Washington, DC; 1978; pp. 37-64.

(see Appendix of this report for reprint)

69. Johnston, Robert J.; "Hydrofoils in the U.S. Maritime Industry"; Case Study prepared for the National Academy of Sciences, Committee on Innovation and Technology Transfer in the Maritime Industry; Washington, DC; 1978; 9 pp.

(see Appendix of this report for reprint)

Hydrofoil equipped vessels are in common use throughout the world for military and commercial purposes. They provide a unique, high-speed, comfortable mode of marine transport suitable for relatively short distances of between 20 and 200 miles. However, in spite of the fact that five U.S. companies have produced and demonstrated commercially viable hydrofoil craft, only the Boeing Company is actively marketing commerical vessels, and those are for export. There is not a single commercial craft in operation in the United States today.

The development of hydrofoil vessels is very slow in the United States. Primary emphasis seems to be on military craft and some commercial vessels for export. The technology seems to be mature and well in hand, and stems from the basic technology data base of the aerospace industry. It would appear that a commercially viable hydrofoil vessel operating industry will be delayed into the future. The market is too weak, and social acceptance too uncertain.

Initial success of the SUPARMAR hydrofoil vessels in Europe plus the major storehouse of technology residing in the U.S. aerospace companies must have been the dominant forces driving the innovation. Two obvious forces worked tc deter the acceptance of hydrofoil craft in the United States -- lack of sufficient finances, and a weak perceived-market forecast. Two factors that may also be important, though not so obvious, have to do with various government regulations and a lack of social acceptance.

Hydrofoil vessels may become useful in the United States at some time in the future, perhaps first as military vessels, and later as commercial craft; however, attitudes may need to change substantially before that situation occurs.

70. Jolly, J.A.; "A Study of the Technology Transfer Capability of Eleven Organizations"; TECHNOLOGY TRANSFER IN RESEARCH AND DEVELOPMENT; Naval Postgraduate School; Monterey, CA; 1975.

An attempt was made to make a macro-evaluation of an organization's ability to transfer technology. The thrust of the study was to investigate the perception of individuals in eleven separate and independent organizations. Specifically, a series of questions dealing with nine factors that could influence the rate and magnitude of either the utilization (introduction) and/or the movement of technology were used to construct a questionnaire. The questionnaire was then administered to a sample of engineers in each of the eleven selected organizations. Details of the construction of the questions are reported in the paper. The paper seems to support the idea that "for profit" organizations are more highly motivated and more favorably organized to utilize (introduce) and/or encourage the movement of (new) technology than government-supported activities.

71. Jolly, J.A.; J.W. Creighton; Peter A. George; TECHNOLOGY TRANSFER PROCESS MODEL AND ANNOTATED SELECTED BIBLIOGRAPHY; Sacramento, CA; August 1977; 59 pp.

72. THE JOURNAL OF TECHNOLOGY TRANSFER; Technology Transfer Society; Los Angeles, CA; Vol. 2, No. 1; Fall 1977; 84 pp.

73. Kavanagh, Gary Lee; THE UNITED STATES SHIPBUILDING INDUSTRY, AND INFLUENCES OF CONGLOMERATES; Masters' Thesis; Massachusetts Institute of Technology; May 1977; 202 pp.

74. Kelly, Patrick; Melvin Kranzberg; TECHNOLOGICAL INNOVATION: A CRITICAL REVIEW OF CURRENT KNOWLEDGE; VOLUME I: "The Ecology of Innovation"; Georgia Institute of Technology, prepared for National Science Foundation; February 1975; 466 pp.

75. Kelly, Patrick; Melvin Kranzberg; TECHNOLOGICAL INNOVATION: A CRITICAL REVIEW OF CURRENT KNOWLEDGE; VOLUME II: "Aspects of Technological Innovation"; Georgia Institute of Technology; prepared for National Science Foundation; February 1975; 521 pp.

76. Kern, Donald; "History and Current State of Shipboard Automation"; Case Study prepared for the National Academy of Sciences, Committee on Innovation and Technology Transfer in the Maritime Industry; Washington, DC; 1978; 34 pp.

(see Appendix of this report for reprint)

77. King, Thomas A.; "The Value of Shipping to the U.S. Economy"; MARITIME POLICY MANAGEMENT; Vol. 4; 1977; pp. 163-166.

This article attempts to build the case for the U.S.-flag carriers on grounds other than defense.

The article does not address innovation except to assert that the U.S. maritime industry has been a leader in technological improvement. It does argue that foreign trade creates employment and a U.S.-flag presence is required to assure access to foreign markets, hence national economic security, thus subsidies are justified.

78. Lawrence, Samuel A.; UNITED STATES MERCHANT SHIPPING POLICIES AND POLITICS; The Brookings Institution; Washington, DC; 1966.

79. Leopold, Reuven; "Innovation Adoption in Naval Ship Design," NAVAL ENGINEERS JOURNAL; December 1977; pp. 35-42.

As a start, Leopold cites previous unsuccessful attempts to correlate certain factors that were thought essential to innovative success. The non-correlating factors include:

- Percentage of funds spent in R&D relative to total acquisition cost;
- Number of patents applied for in the organization; and
- Number of PhDs on laboratory staffs.

Leopold examines two case studies in which the U.S. Navy failed to innovate and concludes that the following inhibitions are to blame:

- Navy executives will not approve a new concept unless it can be shown to be cost-effective in its initial installation. Other navies, on the other hand, are willing to look on the initial installation of a new concept as an investment that may pay off in second or third generation applications.

- The U.S. Navy lacks a good conduit betwen researchers and designers. In some instances, poor ideas for innovation are kept alive too long and R&D dollars are wasted as a consequence. In other cases, good ideas are not accepted soon enough and R&D dollars are then wasted in excessive continuance of paper studies. The relative autonomy of naval labs deprives the researchers of a knowledge of real-world needs, so that much research is devoted to answering the wrong questions.

- Officers in charge of naval ship procurement are exremely conscious of costs and delivery schedules. In their eagerness to carry out their responsibilities, they have sympathy for innovative suggestions. Innovation, in their eyes, may bring minor benefits in the final product, but will also disrupt schedules and escalate costs.

- The U.S. Navy suffers from a shortage of engineers. In 1951 and 1952 BUSHIPS hired 250 young engineers. In 1977, it hired only 50.

80. Levinson, Harold M.; Charles M. Remus; Joseph P. Goldberg; Mark L. Kahn; "Modernization in the Maritime Industry: Labor-Management Adjustments to Technological Change -- Conclusions and Prospects"; COLLECTIVE BARGAINING AND TECHNOLOGICAL CHANGE IN AMERICAN TRANSPORTATION; The Transportation Center at Northwestern University; Evanston, IL; 1971; pp. 403-419.

    This is a detailed report on collective bargaining and technological change in the maritime industry with its intense competition and declining job opportunities in shipyard, longshore, and seagoing activity. "The labor force has been organized, entry limited, retirement eased and liberalized, and flexible utilization increased. These and additional factors have made for assurance of work opportunities and earnings, even in the face of immediate dislocation and possible future decline in jobs.

"The bases for mutual accommodation and continuing approaches to change have been laid. There will need to be a continuing education of the work force regarding the problems that face this industry, as well as for agreement on the union policies and restructuring necessary to foster the industry while maintaining maximum feasible worker security. Responsible union leadership and aware management are capable of meeting such a challenge: they have already shown their ability to meet the complexities of adjustment to modernization and mechanization."

81. Levy, Howard A.; "The Future of the Conference System Under the Antitrust Laws"; TRANSPORT 2000; November/December 1976; pp. 20-25.

The article is an agreement in favor of the conference system. The article asserts that the conference system is the only viable arrangement that will provide uninterrupted liner service. Despite the title, it does not address the future of the conference system.

82. Lingwood, D.A.; "A Study of Research Utilization in the U.S. Forest Service"; TECHNOLOGY TRANSFER IN RESEARCH AND DEVELOPMENT; Naval Postgraduate School; Monterey, CA; 1975; pp. 37-48.

This paper reports on a study of the incentives and barriers in the U.S. Forest Service (USFS) that offset the utilization of research and development output from the USFS laboratories. Major points discussed are

- Strong need for "self-starting" individuals;
- Need cognitively complex individual;
- Need good scientific information exchange environment;
- Need inter-project and inter-disciplinary collaboration;
- Must have clear reward system;
- Turnaround time, i.e., time between need and solution, must be reasonable;
- High familiarity between source and user;
- Overt effort by user as well as source; and

* Stability of management (avoid "musical chairs" concept).

83. Little, Arthur D. Inc.; BARRIERS TO INNOVATION IN INDUSTRY; Washington, DC; 1973; 161 pp.

84. Little, Blair; Robert G. Cooper; "The Role of Marketing Research in New Technology Ventures"; RESEARCH MANAGEMENT; May 1977; pp. 20-25.

The article deals with the need to perform market research when planning the introduction of new technology. With proper market research, an innovator can be more nearly sure that his product fits a consumer's need. In addition, by planning his marketing promotion ahead of time, he can better reach the consumer. Many potential innovators fail to do any market research, or at least not as much as they should, because they feel that market research will produce the wrong answers, vague and inconclusive answers, or no answers.

The major conclusion reached is that more market research would increase the probability of successful implementation of innovations. A method is proposed for determining approximately the right amount of market research to do.

85. "Litton Ships Systems, Ingalls Shipbuilding Division of Litton Industries, and Metal Trades Council, Office and Professional Employees International Union, International Brotherhood of Electrical Workers, Watchmen and Guards Independent Unions"; DIRECTORY OF LABOR-MANAGEMENT COMMITTEES, 2nd Edition; Spring 1978.

86. Lones, Trevor; "Fast and Reliable Ship Communications -- at a Price"; SEATRADE; May 1977; pp. 133-134.

87. Long, T. Dixon; "Japan's Technological Policy: Challenge or Warning?"; TECHNOLOGICAL INNOVATIONS AND ECONOMIC DEVELOPMENT: HAS THE U.S. LOST THE INITIATIVE?; Proceedings of a Technical Symposium on Technological Innovation; Washington, DC; April 19-20, 1976; pp. 153-166.

This paper discusses Japan's technological policy and how it contributed to innovation in that country.

The following actions tend to encourage innovation in Japan:

- An advisory apparatus exists to bring technological policy questions to the attention of the Prime Minister and other top officials;
- A substantial government budget exists to aggregate all expenditures for research and development;
- A central coordinating agency, the Science and Technology Agency, administers the budgets and oversees technological projects;
- Technological advisory bodies exist in all key agencies of the government;
- A national economic plan exists which accounts for R&D expenditure and manpower;
- A mechanisms exists for controlling the flow of information into and out of the country;
- Specialized institutions exist to promote the interaction of basic research with applied and developmental activity; and
- There are programs to promote public support for new technologies of major international significance.

The author cited some problems in Japan that tend to inhibit innovation.

- Academic scientists are cool to government-sponsored research; and
- Intense concentration on importation has left Japan incapable of promoting creativity.

88. Love, Sidney F.; Richard H. Irving; "Delphi Decision Processes"; RESEARCH AND DEVELOPMENT; September 1975; pp. 30-36.

89. Lyons, Richard D.; "Experts Upset by Drop in Innovative Research"; THE NEW YORK TIMES; May 31, 1978.

90. McClelland, W.A.; "The Process of Effecting Change"; ARMY RESEARCH AND DEVELOPMENT NEWS MAGAZINE; April 1969; pp. 18-23.

91. Machonachie, Bill; "Satellites - The Path Ahead for Better Marine Communications .... Eventually"; TANKER AND BULKER INTERNATIONAL; August 1976; pp. 13, 15 & 36.

92. "Managing Technological Affairs"; EUROPEAN SCIENTIFIC NOTES; January 31, 1978; pp. 16-18.

93. Manalytics, Inc.; GOVERNMENT-INDUSTRY COST-SHARED CONTRACTS; A report to the Office of Experimental R&D Incentives; Research Applications Directorate (RANN); National Science Foundation; July 1975; 82 pp.

94. Mansfield, Edwin; "Federal Support of R&D Activities in the Private Sector"; Joint Committee Print; PRIORITIES AND EFFICIENCY IN FEDERAL RESEARCH AND DEVELOPMENT: A COMPENDIUM OF PAPERS; Washington, DC; October 29, 1976; pp. 85-115.

Edwin Mansfield addresses the question of what type of R&D the federal government should support in attempting to promote the nation's economy.

One of the principal conclusions is that the government should shoulder the prime responsibility for supporting basic research. Private industry will normally be little interested in such investments because the benefits are too hard to predict and will be too widespread to be of any particular benefit to those who made the investment.

NASA's success in technology transfer is cited. Among other things, NASA pays a research institute at Indiana University to receive and disseminate potentially useful information derived from NASA research. The marine industry has nothing comparable. Mansfield makes a strong case for the role of education in encouraging innovation:

> The Federal Government's policies to support education (in science and technology, and other fields as well) also encourage R&D in the private sector. Clearly, the extent of private R&D is determined in part by the quantity and quality of scientific and engineering talent available in the society. Further, better educated managers and workers seem to be better able to utilize research results, and more inclined to invest in R&D. The links between education, science, and

> technology are important, and the Federal Government's attempts to strengthen education certainly have helped to support R&D in the private sector.

In structuring an R&D program, Mansfield recommends against single-minded, large-scale crash programs:

> Instead, it should be characterized by flexibility, small-scale probes, and parallel approaches.
>
> Second, any temptation to focus the program on economically beleaguered industries should be rejected. The fact that an industry is in trouble, or that it is declining, or that it has difficulty competing with foreign firms is, by itself, no justification for additional R&D. More R&D may not have much payoff there, or even if it does, the additional resources may have a bigger payoff somewhere else in the economy.

Another pertinent conclusion is that technological development, in general, is best left to private industry:

> Although there may be cases where development costs are so high that private industry cannot obtain the necessary resources, or where it is so important to our national security or well-being that a particular technology be developed that the government must step in, these cases do not arise very often. Instead, the available evidence seems to indicate that, when governments become involved in what is essentially commercial development, they are not very successful at it.

Other conclusions are that government-supported research is most successful when technology and market are properly coupled and that centralized R&D planning has pitfalls:

> If the experience of the last 25 years in defense R&D and elsewhere has taught us anything, it has taught us how difficult it is to plan technological development.

Technological change, particularly of a major or radical sort, is marked by great uncertainty. It is difficult to predict which of a number of alternative projects will turn out best. Very important concepts and ideas come from unexpected sources. It would be a mistake for a program of this sort to rely too heavily on centralized planning.

Mansfield also discusses the question of firm size and likelihood of innovating. He concludes that small- to middle-sized firms are most likely to innovate. He also concludes, however, that a widely splintered industry -- such as building construction -- is likely to be slow to adopt new technologies.

95. MARAD '77, THE ANNUAL REPORT OF THE MARITIME ADMINISTRATION FOR FISCAL YEAR 1977; U.S. Department of Commerce; Maritime Administration; Washington, DC; May 1977; 105 pp.

96. MARATECH - R&D TECHNOLOGY TRANSFER JOURNAL; U.S. Department of Commerce; Maritime Administration; Washington, DC.

97. Marcus, Henry S.; PLANNING SHIP REPLACEMENT IN THE CONTAINERIZATION ERA; Lexington Books; D.C. Heath and Company; Lexington, MA; 1974; 135 pp.

98. Marine Board; INFORMATION AND DATA EXCHANGE FOR OCEAN ENGINEERS, AN APPROACH TO IMPROVEMENT; National Academy of Sciences; Washington, DC; 1975.

This study was started in 1972 by a Panel of the Marine Board. The Panel received a broad assignment.

Ocean Engineering is characterized, and information and data are defined. Many excellent information and data sources were found to exist, but it was found that the largest deficiency, in the judgment of the Panel, is the lack of awareness by potential users of existing sources of information and data. Even with those few specific systems that are designed to meet the needs of ocean engineers, the Panel found that engineers are largely unaware of what the information and data systems have to offer. The Panel's survey revealed that the ocean-engineering

community is unfamiliar with the number of data centers that exist, what data and information they contain, or how to make efficient use of the material once it has been obtained. Even the largest, oldest, most versatile, or most automated systems are completely foreign to many prominent practicing ocean engineers.

It was recommended that a focal point for guidance of the ocean engineering community be established in the NOAA Environmental Data Service. No new information or data services were recommended.

99. Marine Turbine Sale"; AVIATION WEEK & SPACE TECHNOLOGY; July 4, 1977.

100. THE MARITIME AIDS OF THE SIX MAJOR MARITIME NATIONS; U.S. Department of Commerce; Maritime Administration; Washington, DC; November 1977; 429 pp.

The bulk of the study concerns subsidies, loans, credit assistance, cargo preference, and tax allowances used to promote shipping and shipbuilding in Japan, United Kingdom, Norway, Sweden, West Germany, and France.

Among the miscellaneous aids touched upon is that of R&D. The authors report the following annual level of government spending for maritime R&D:

Japan	\$4 - \$5 million
United Kingdom	\$2 million
Norway	0
Sweden	0
West Germany	\$1 million
France	0

The report, unfortunately, says nothing about government support in the form of education for either shipboard officers or naval architects and marine engineers.

The report contrasts shipyard productivity in the various nations. Japan, which reportedly spends the most for R&D seems to be improving the fastest. Sweden, on the other hand, has the highest productivity in the face of <u>no</u> government dollars spent on research.

101. Maritime Cargo Transportation Conference; A SURVEY OF RESEARCH IN U.S. SHIPPING LINES; National Academy of Sciences; Washington, DC; June 15, 1957; 14 pp.

102. Maritime Research Advisory Committee; PROPOSED PROGRAM FOR MARITIME ADMINISTRATION RESEARCH; National Academy of Sciences; Washington, DC; 1960.

103. MARITIME SUBSIDIES; U.S. Department of Commerce; Maritime Administration; Washington, DC; 1976; 144 pp.

104. MERCHANT FLEETS OF THE WORLD: 1977; U.S. Department of Commerce; Maritime Administration; Dec. 13, 1977.

105. Miller, Rory K.; "Land Bridge, Mini-Bridge, and Micro-Bridge: A Question of Getting It Together"; TRANSPORTATION JOURNAL; Fall 1977; pp. 64-66.

106. Morison, Elting E.; "A Case Study of Innovation"; Reprint of article from ENGINEERING AND SCIENCE MONTHLY; April 1950.

107. Morison, Robert F.; "Industry Backs Ship Subsidies"; JOURNAL OF COMMERCE; Washington, DC; February 10, 1978.

The article summarizes recommendations made by several U.S. maritime lobbying groups before the House Merchant Marine Subcommittee. All of them favored bigger and better subsidies.

108. Morison, Robert F.; "U.S. Shipping Subsidies Questioned"; JOURNAL OF COMMERCE; Washington, DC; February 8, 1978.

109. Myers, Edith, "Technology is Not the Problem"; DATAMATION; April 1978; pp. 179-181.

110. Nason, Howard K.; Joseph A. Steger; George E. Manners; SUPPORT OF BASIC RESEARCH BY INDUSTRY; National Science Foundation; Washington, DC; 1978; 55 pp.

111. "Navigation Gear: New Technology has made it Virtually Foolproof"; MARINE ENGINEERING/LOG; February 1977; pp. 43-57.

112. NAVY TECHNOLOGY TRANSFER FACT SHEET; Vol. 2, No. 5; May 1977; 4 pp.

113. "New Report Shows R&D Growth at Standstill"; SCIENCE & GOVERNMENT REPORT; June 1, 1978; pp. 4-6.

114. "New Traffic Managers' Tool: Ship-to-Satellite-to-Shore"; CONTAINER NEWS; July 1977; pp. 38-39.

115. Nixon, Richard M.; Presidential memo regarding patents - for Heads of Executive Department and Agencies; Washington, DC; August 23, 1971; 2 pp.

116. OCEAN CARRIER SERVICE IMAGE AND MARKETING PRACTICES, U.S. Department of Commerce; National Maritime Research Center; Kings Point, NY; 1976; pp. 4-17.

While not focused directly on innovation, this report discussed the need for a proper marketing strategy in selling marine services. Both the federal government and the individual carrier can take action to aid the development of a marketing strategy. The federal government can allow easing of subsidy restrictions that impede competitiveness, provide a focal point for coordination among U.S. carriers, perform market research, and persuade other goverments to eliminate discriminatory practices.

An individual carrier can take action to formulate and implement revised pricing policies, develop an effective promotion program, improve service quality, and review use of sales agent versus direct sales office.

The carrier can influence the following type of market barriers or deterrents: established carrier/customer relations; carriers reputation among transport users; inertia caused by traditional practices; constraining scope of service; quality of service; and human factors (such as morals of personnel).

Federal policies can influence the following market barriers: restrictive practices imposed by subsidy rules; illegal carrier practices in the U.S. trade (including rebating and cost absorption); cross-trade inflexibility; uncertainty about subsidy trade to replace aging vessels; and discriminatory practices of foreign governments.

The following are relatively non-controllable market barriers: degree of worldwide shipping competition; and shipper/consigner favoritism for national flag carriers.

The article concludes that a well-developed marketing strategy is important for a liner service (or an innovation in liner service). Both the individual carrier and the federal government can take action to aid the development of an improved marketing stragegy.

117. Opheim, J. Eldon; former Director, Port of Seattle; presentation to National Academy of Sciences, Committee on Innovation and Technology Transfer in the Maritime Industry; Washington, DC; February 9, 1978.

118. PATENT POLICY FOR CONTRACTS AND GRANTS; U.S. Department of Commerce; Department Administrative Order Series; Washington, DC; June 13, 1977; 11 pp.

119. Pelz, Donald C.; Fred C. Munson; Linda L. Jenstrom; "Innovation: A Conceptual Framework"; revised working paper prepared for the National Academy of Sciences, Committee on Innovation and Technology Transfer in the Maritime Industry; Washington, DC; June 5, 1978.

120. Penn, Richard; Chief, Special Projects; Experimental Technology Incentives Program; National Bureau of Standards; presentation to National Academy of Sciences, Committee on Innovation and Technology Transfer in the Maritime Industry; Washington, DC; February 9, 1978.

The Experimental Technology Incentives Program is in the National Bureau of Standards. It differs from the Experimental Research and Development Incentives Program in the National Science Foundation in that the NSF program must always involve a university link in addition to industry. The NBS program is designed to work directly with industry.

ETIP is dedicated to experimentation, to trying things before doing them on a large scale.

ETPI has looked at government procurement. Government has traditionally bought the cheapest item that would meet a set of very precise specifications. There is a shift in military

procurement to try to buy an existing commercial product rather than writing special specs that may eliminate a commercial product.

Among the concerns of ETIP is an attempt to establish factually the cost/benefit trade-off for compliance to new regulations, and evaluation of the effects of pending and enacted regulations on innovation. Regulation and the slow pace with which federal regulations are issued and implemented (FTC issues only 4 or 5 per year) leaves companies in a limbo, afraid to invest too much money complying with a potential regulation that may or may not materialize.

Management of companies sometimes hides behind the flag of antitrust if the venture is thought to be high risk or there is management fear.

Standards development is a very slow process. ETIP is trying to find ways to speed voluntary standards development.

Research has shown that the most likely result of the government's infusing of large amounts of capital into an area is to drive out private capital. If the government comes in, it will not take the high-risk ventures, but rather it funds good risks, and venture capital is driven out.

Five elements for a successful demonstration and diffusion project include:

- Low-risk technology;
- Cost-sharing by users;
- Initiative from outside of federal government;
- Strong system for commercialization already exists; and
- Absence of tight time constraints.

To properly transfer technology, you must work on a pull rather than push program. Most government technology programs are push-type programs.

121. Penrose, William H.; "Barriers and Incentives to the Transfer of Technology: Maritime Satellite Communications"; CASE STUDIES IN MARITIME INNOVATION; National Academy of Sciences; Washington, DC; 1978; pp. 65-69.

(see Appendix of this report for reprint)

122. Pfeiffer, Robert J.; "Containerization: 19 Years After Inception"; paper delivered at Seatrade Conference on Pacific Shipping; San Francisco, CA; June 14-15, 1977; 14 pp.

123. Piore, Michael J.; "Labor's Role in Technological Change"; TECHNOLOGICAL INNOVATIONS AND ECONOMIC DEVELOPMENT: HAS THE U.S. LOST THE INITIATIVE?", Proceedings of a Symposium on Technological Innovation; Washington, DC; April 19-20, 1976; pp. 57-69.

This paper does not focus on factors affecting the innovation process, but deals principally with the problems of unemployment resulting from advances in technology.

A society of low unemployment will create an atmosphere where students and faculty in the universities feel free to take risks that are necessary for innovation. Small entrepreneurial firms that are creative and deal with a diversity of jobs are more innovative than large firms that are undergoing small cumulative changes.

124. Pitkin, Marvin; Assistant Administrator for Commercial Development; U.S. Department of Commerce; Maritime Administration; "Ocean R&D -- Rules of Thumb for Organizations"; Presentation at OCEAN '78; Washington, DC; 1978; 8 pp.

125. PROFITS '76; Office of the Assistant Secretary of Defense (Installations and Logistics); U.S. Department of Defense; Washington, DC; Dec. 7, 1976.

126. Public Law 95-224 - "To Distinguish Federal Grant and Cooperative Agreement Relationships from Federal Procurement Relationships, and for Other Purposes"; February 3, 1978; 4 pp.

127. Raven, J.A.; "Paperwork Blockage in World Port Congestion"; CONTAINER NEWS; August 1977; pp. 42-43.

128. THE REGULATED OCEAN SHIPPING INDUSTRY; U.S. Department of Justice; U.S. Government Printing Office; Washington, DC; January 1977.

129. Renehan, L. Arthur; "The Innovation and Implementation of LASH"; CASE STUDIES IN MARITIME INNOVATION; National Academy of Sciences; Washington, DC; 1978; pp. 71-88.

(see Appendix of this report for reprint)

130. Renouf, Anthony; "Japan, Inc."; SEATRADE; December 1977; pp. 113-139.

131. REPORT OF THE TASK GROUP ON ANTITRUST IMMUNITIES; U.S. Department of Justice; U.S. Government Printing Office; Washington, DC; January 1977; 69 pp.

132. Roberts, Edward B.; Alan L. Frohman; "Innovaha?tion"; TECHNOLOGY REVIEW; March/April, 1978; pp. 32-46.

133. Roberts, Markley; "Adjusting to Technological Change"; ALF-CIO AMERICAN FEDERATIONIST; February 1973; 6 pp.

This article points to collective bargaining as a way of labor-management arrangements to protect workers' jobs and/or income against adverse effects from technological change. The article cites various approaches taken in collective bargaining, including advance notice, training and retraining, "no lay-off" job protection, attrition, "red circle" wage rates, seniority protections, rehiring rights, early retirement, "bridge" benefits for early retirees, work-spreading, transfer and relocation rights, severance pay, and other devices to cushion the impact of innovation and technological change.

This article is relevant to problems of unions and workers accepting innovation and technological change which may adversely affect jobs and income.

134. Schenker, Eric; Harry C. Brockel; Editors; "Labor Utilization and Its Effect on U.S. Port Planning and Development"; PORT PLANNING AND DEVELOPMENT AS RELATED TO PROBLEMS OF U.S. PORTS AND THE U.S. COASTAL ENVIRONMENT; Cornell Maritime Press, Inc.; Cambridge, MD; 1974; pp. 61-81.

Thomas W. Gleason says that technological advances are healthy for the maritime industry and that the benefits from the increases in productivity that accrue from new technology should be shared both by labor and management. For management, it means increased profits and efficiencies in operations. For longshore labor, it means a decent wage, job security, and meaningful fringe benefits. Gleason notes "a changing climate in labor-management relations" and cooperation in the maritime industry.

Joseph P. Goldberg of the U.S. Department of Labor looks at new technology in longshore and maritime industry and concludes "The U.S. experience well supports the role of well-organized employers and unions in confronting the challenge of change, while adjusting existing arrangement and maintaining others." He discusses productivity, job security, manning, flexibility, jurisdiction, and labor-management structure. He concludes that innovation has created problems, but finds that labor-management relations have achieved solutions to these difficult problems. "The role of government has been primarily that of mediator and catalyst in particularly difficult periods, and of assurance of the public interest, with the basic arrangements reached by the parties themselves. Firm solutions have not been reached nor have they been expected. Throughout this dynamic period the parties have been aware of the need for continuing joint discussion and adaptation."

135. Schmeltzer, J.E.; "Engineering Features of the Maritime Commission's Program"; SOCIETY OF NAVAL ARCHITECTS AND NAVAL ENGINEERS TRANSACTIONS, 1940.

136. Schon, Donald A.; "Innovation by Invasion"; INTERNATIONAL SCIENCE AND TECHNOLOGY; March 1964; pp. 52-60.

This article asserts that the principal source of major technical change in mature industry is innovation by invasion. In traditional industry, change is incremental. However, for innovation of major technological and economic significance, such innovations tend to come from outside the traditional industry, from foreign technology, from independent inventors or from the startups of new small firms.

Factors that deter the implementation/diffusion of innovation include:

- Traditional industries are old, linked to their past and to a craft-based rather than science-based, technology;
- These industries tend to lack entrepreneurship, generate low profits, invest little in new technology and possess a heavy commitment to old methods and equipment; and
- Innovation causes dislocations in organizations and workers that results in protective actions.

The article recommends a change in the traditional approach.

> We pay a price for technical change. Traditionally, we have paid the price by supporting the victims of change: by subsidies, tariffs, import quotas. But this technique has not worked. It has merely deferred the eventual decline of obsolete industry. Henceforth, we must promote industrial mobility: the ability of industry and workers to move to new skills and new regions.

137. THE SEALIFT READINESS PROGRAM; Maritime Transportation Research Board; National Academy of Sciences; Washington, DC; June 1975; 102 pp.

138. SEA POWER FACTS AND STATISTICS; U.S. Department of the Navy; OP-09D; Washington, DC; November 1978; 30 pp.

139. SHIPBUILDERS COUNCIL OF AMERICA ANNUAL REPORT: 1976; Shipbuilders Council of America; Washington, DC; March 2, 1977.

140. "Shiphandling Simulator Trains Deck Officers of Large Ships on Land"; MARINE ENGINEERING/LOG; July 1977; pp. 38-39.

141. "Shipper Choice of Carriers May Be Influenced in Future by Incentive Programs or Cargo Preference Laws"; AMERICAN SHIPPER; September 1976; pp. 6 & 8.

142. STATEMENT OF GOVERNMENT PATENT POLICY - BASIC CONSIDERATIONS AND POLICY; Washington, DC; 6 pp.

143. STATISTICAL QUARTERLY; Shipbuilders Council of America; Washington, DC; First Quarter 1977; 4 pp.

144. "Statutory/Regulatory Demands Increase U.S. Shipyard Costs"; SHIPYARD WEEKLY; Shipbuilders Council of America; Washington, DC; February 2, 1978.

145. Sweezy, Eldon E.; Institute of Public Administration; presentation made to National Academy of Sciences, Committee on Innovation and Technology Transfer in the Maritime Industry; Washington, DC; February 9, 1978.

The Institute of Public Administration has cooperated with the National Science Foundation's Experimental Research and Development Incentives Program to study why innovations falter and fail. (See reference 32)

Industries covered in the study included non-agricultural tractors, engines, chemicals, iron and steel, computers, instruments, and plastics.

The British have a concept called "shelf research" in their government laboratories. When something hits a technical barrier, they simply take the thing, park it, and make note of the "but-if" question. The researcher moves on to new problems, but keeps an eye on the "but-if". When new information develops, the researcher reevaluates.

Some important conclusions in the IPA study include:

- Capital accounted for 15 percent of the innovations that died;
- Laws and regulations, including housing, building codes, zoning, regulations, patent, and antitrust accounted for 17.5 percent;
- Market accounted for 27.5 percent of the failures;
- However, management was a big reason for the failure of innovations with 25 percent. Management either made the wrong decision, didn't get all the facts ahead of time, or they organized the structure of the company in such a way as to make it impossible for innovation to succeed.

Middle-sized companies have much more of a problem than either large or small companies because they have not institutionalized the decision-making, fact-finding capacities that the

single head of a small firm or boards of large firms have.

You cannot get an advisory opinion on the antitrust issue from the Justice Department. They wait till you violate the law before they'll talk to you.

If there is a high-risk situation in the development of an innovation, many people in the private sector feel government should help with capital investment, either by making the capital costs of the risk more tolerable or by making technological assistance available.

The interface between public and private sectors has been ignored. The government ought to align itself with the generation and utilization of technology to improve the total national welfare.

In new venture companies, capital was the most prominent reason and management and organization were the second reason for failures.

146. TECHNOLOGY: BITING THE HAND THAT LEADS US; Dialogue on Technology #9; Gould, Inc.; Rolling Meadows, IL; 1977.

147. TECHNOLOGY, TRADE, AND THE U.S. ECONOMY; Report of a Workshop Conducted by the Office of the Foreign Secretary; National Academy of Engineering; National Academy of Sciences; Washington, DC; 1978; 169 pp.

148. "Technology Transfer"; TECHNOLOGYMART; January-February 1973; pp. 21-24.

The article describes a team approach used at Stanford Research Institute for NASA to encourage use by the private sector of a new space-type technology. The emphasis is on getting the potential user to participate in the planning at an early stage. A second point is that NASA offers adaptive engineering, which they feel is essential if a new technology is to find its way into the public sector.

149. Tempest, E.H.; "A Case Study of the Power Line Disturbance Monitor"; TECHNOLOGY TRANSFER IN RESEARCH AND DEVELOPMENT; Naval Postgraduate School; Monterey, CA; 1975; pp. 21-31.

There are several ways to force the transfer of technology. One that has been identified and discussed in the literature is by contract. In its simplest form, the contractor must learn the (new) technology in order to meet the contract requirements. Once this new technology is learned by the contractor, there is a high likelihood that it will be used in other business opportunities. This paper is a case study of one such contract arrangement. The contractor, after building several units (electronic devices) for the Navy, went on to market a commercial product. The sales of the product and the resulting growth of the company were substantial.

150. "Texaco VLCC Officers First in U.S. to Use Shiphandling Simulator"; MARITIME REPORTER; April 1, 1977; p. 27.

151. TRANSTEC '77; Committee of Directors of Research Association; Conference on the Transfer of Technology; The Hyde Park Hotel; London, England; May 9-10, 1977.

152. "UK Simulator Comes on Stream"; SEATRADE; June 1977; pp. 77 & 79.

153. "U.S. Government to Review Industrial Innovation"; NATURE; Vol. 273; June 1, 1978; pg. 330.

154. U.S. TECHNOLOGY POLICY - DRAFT STUDY; Office of the Assistant Secretary for Science and Technology; U.S. Department of Commerce; Washington, DC; March 1977; 178 pp.

This paper discusses U.S. technology policy in its relationship to the nation's economic welfare and makes specific recommendations for an improved policy.

The goal of U.S. technology policy should be to maximize our capacity to develop and utilize technology for national purposes. Market economic criteria alone are not adequate for making social choices and for determining the national goals that technology policy should help achieve.

Since technology is a pervasive force throughout society, it is affected by a large variety of government actions. In the context of this paper, U.S. technology policy is the sum of actions taken by the federal government affecting the production, diffusion, and utilization of technology.

155. Velez, Raymond; "Ocean Conferences in World Competition"; TRANSPORT 2000; January/February 1977; pp. 24-25.

156. Vogel, Ezra F.; "Guided Free Enterprise in Japan"; HARVARD BUSINESS REVIEW; May-June 1978; pp. 161-170.

157. von Hippel, Eric A.; "Users as Innovators"; TECHNOLOGY REVIEW; Vol. 80; No. 3; January 1978; 11 pp.

158. "We Can Put a Man on the Moon, But ..."; EXXON USA; Quarter Four 1976.

The paper describes the formation of Public Technology, Inc. (PTI), a non-profit organization funded by the National Science Foundation. PTI manages the operation of the Urban Technology System that has placed "technology agents" in twenty-seven cities of various sizes across the United States. The objective of the program is essentially an urban counterpart of the well-known ally of U.S. farmers, the county agricultural agent. Many examples of successful technology transfer projects are described.

In terms of incentives, the program supplies a person who is free from the day-to-day management demands of the city and so can be effective in evaluating, recommending, and selling new technology. The incentive justification is economic.

159. Weldon, Foster; "Cargo Containerization in the West Coast - Hawaiian Trade"; OPERATIONS RESEARCH; September/October 1958; pp. 649-670.

160. Weldon, Foster; Former Vice President of Research, Matson Navigation Co.; Presentation to National Academy of Sciences, Committee on Innovation and Technology Transfer in the Maritime Industry; Atlanta, GA; December 15, 1977.

161. Wiesner, Jerome B.; "Has the U.S. Lost its Initiative in Technological Innovation?"; TECHNOLOGICAL INNOVATIONS AND ECONOMIC DEVELOPMENT: HAS THE U.S.

LOST THE INITIATIVE?; Proceedings of a Symposium on Technological Innovation; Washington, DC; April 19-20, 1976; pp. 1-11.

This report discusses the problems facing industry in the United States in general terms. Much of the discussion, particularly on the government's role in generating initiative for innovation, applies to the marine industry.

Society is presently faced with numerous problems that should act to spur innovation. Indeed, simply maintaining the standard of living already achieved is a major problem. The impact on society of the new technologies required to solve these problems will be less severe in the future than it has been in the past.

The author recommends the following changes to spur innovation:

- Promote the development of consortiums assisted by federal funds to acquire the large amounts of capital needed to finance major projects;
- Government should share the cost of proving the safety of new processes or products with industry; and
- More support should be given to universities.

Factors that act as deterrents to innovation include:

- Restriction of the flow of information between universities, industry, and the government;
- Government regulations and policies -- i.e., patent protection is inadequate;
- Emphasis placed on last year's problems rather than taking a long-term future look;
- Only the largest corporations can generate the capital required to deal with the complexity of modern processes and devices;
- Government domination of business matters that stifles investment;
- Passage of the Mansfield Amendment has restricted the contribution of the

Department of Defense to basic research; and
- Individual grants covering a short-time span are not effective for long-term projects.

Greater cooperation between the government, industry, and the universities and longer-range planning, particularly by the government, would promote innovation.

162. White, William; "Effective Transfer of Technology from Research to Development"; RESEARCH MANAGEMENT; May 1977; pp. 30-34.

163. Williams, Winston; "Shipping Sinks Deeper Into Slump"; NEW YORK TIMES; July 9, 1978; pp. 1 & 11.

164. Wirt, John G.; "NS SAVANNAH: A Federal Demonstration Project," CASE STUDIES IN MARITIME INNOVATION; National Academy of Sciences; Washington, DC; 1978; pp. 29-35.

(see Appendix of this report for reprint)

165. Young, Robert T.; President, Society of Naval Architects and Marine Engineers; "Era of Vitality and Innovation Ahead for Marine Industry"; presentation at California Maritime Academy's 4th Annual Maritime Industry Symposium; May 25, 1978; 3 pp.

166. Zimmie, William E.; Chairman, Zimmite Corp.; Chairman, Hyde Products; Presentation to National Academy of Sciences, Committee on Innovation and Technology Transfer in the Maritime Industry; Atlanta, GA; December 15, 1977.

Mr. Zimmie has had numerous successes and failures in innovating in the marine industry. Particular successes cited were the use of PVC piping in Great Lakes ships and the development of chemical treatment of muddy ballast.

The incentives to innovation that he identified included

- Profit;
- Pride;
- Challenge; and
- Power.

He listed several deterrents within the industry, including

- U.S. shipbuilding industry failure to attract good people because it is a no growth industry;
- Middle and upper management avoid taking risks because they fear they might lose their jobs;
- Competent people tend to be driven out of the industry by incompetent management;
- Professional stratification within the industry narrows opinions and reduces competition;
- ABS and other classification societies are steeped in tradition. Their rules are based too much on experience and not enough on sound engineering;
- Low profits inhibit R&D and limit the investment capital the industry can attract;
- Antitrust laws inhibit technological progress; and
- Current subsidy systems suppress creativity.

He suggested the following as incentives to help promote innovation within the industry.

- More rapid tax write-off or a variable write-off like the Canadians use;
- Loosen antitrust laws; and
- Innovation risk insurance.

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER

2. GOVT ACCESSION NO.

3. RECIPIENT'S CATALOG NUMBER

4. TITLE (and Subtitle)
Innovation in the Maritime Industry, Appendix,

5. TYPE OF REPORT & PERIOD COVERED

6. PERFORMING ORG. REPORT NUMBER

7. AUTHOR(s)
Committee on Innovation and Technology Transfer in the Maritime Industry

8. CONTRACT OR GRANT NUMBER(s)
N00014-75-C-0711

9. PERFORMING ORGANIZATION NAME AND ADDRESS
Maritime Transportation Research Board, National Academy of Sciences/National Research Council
2101 Constitution Ave., NW, Washington, DC 20418

10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
NA

11. CONTROLLING OFFICE NAME AND ADDRESS
Office of Naval Research, Code 434
Department of the Navy
Arlington, VA 22217

12. REPORT DATE
May [redacted]79

13. NUMBER OF PAGES
242

14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)

15. SECURITY CLASS. (of this report)
Unclassified

15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Distribution of this report is unlimited

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES
Financial support provided by the Department of Commerce, Department of Defense, and Department of Transportation.

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

National Shipbuilding Research Program
Containerization
Landbridge
Shipboard Automation
Port of Seattle
LASH
Hydrofoils
Air Cushion Vehicles
Highly Skewed Propellers
Gas Turbines
(continued)

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)
This volume, the second in the set addressing innovation in the maritime industry, contains case studies developed for the National Research Council Committee addressing that issue. Case studies include: The National Shipbuilding Research Program; Evolution of the Concept and Adoption of the Marine and Intermodal Container; Landbridge Services; History and Current State of Shipboard Automation; Port of Seattle Growth Through Modern Customer Services; The Innovation and Implementation of LASH (Lighter Aboard Ships); Hydrofoils in the U.S. Maritime Industry; Air Cushion Vehicles, Highly Skewed (continued)

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

19. Contra-rotating Propellers
Nuclear Ships

20. Propellers; Development of Gas Turbine Propulsion: the G.T.S. JOHN SERGEANT; Contra-rotating Propulsion Systems for U.S.-Flag Merchant Ships; A Federal Demonstration Project: N.S. SAVANNAH.