THE CONCEPT OF A
VARIABLE MISSION SHIP
AN EXAMPLE

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ABSTRACT

The concept of a variable mission ship, specifically designed for rapid conversion from one specialized mission to another is developed. First, the need for an expanded U.S. flag merchant marine is established. The variable mission concept is then presented as an incentive to attract additional private and government funds to the liner industry. This concept is noted to have commercial/commercial and commercial/military significance. The commercial/military mode is selected for emphasis in the thesis and the applicability of this mode to military missions is then developed. As an example, a variable mission catamaran is developed which, through conversion, can operate in either a roll-on/roll-off mode or a container ship mode.

THESIS SUPERVISOR: P. Mandel

TITLE: Professor of Naval Architecture

ACKNOWLEDGEMENT

I received considerable assistance from two men in the preparation of this Thesis. Professor S.C. Reed provided the ideas and concepts on a sufficiently grand scale to prevent my becoming enmeshed in trivial details.

Professor Philip Mandel consented to act as my Thesis Supervisor. In this capacity he brought the ideas into focus, defined the boundaries and coined the phrases that appear throughout the paper.

The method of presenting the material is due to a third man, Mr. B. Franklin, who, two hundred years ago, provided wisdom in the art of persuasion that remains incompletely understood today.

The typing is that of my wife, Carole. It consumed much effort and time.

I extend my thanks.

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INTRODUCTION

The situation in which the confirming physical observation follows the complete development of the concept is extremely rare. Generally the concept results from the attempts of the hangers-on to explain the observations of the genius. This thesis is no exception.

The initial observation was that multipurpose ships do several things adequately, none optimally; and that the modern shipbuilding industry can accomplish large changes in a ship's configuration in relatively short periods of time. This initial observation was made by Professor S.C. Reed, Associate Professor of Naval Engineering at Massachusetts Institute of Technology. A second observation was the recognition of the similar roles in minesweeping and in fishing that might be played by a single vessel. The result was the minesweeper/fishing vessel design of H.A. Chatterton.*

The present thesis begins the development of a concept which suggests that Chatterton's MS/FV is not an isolated incident, but rather is a first example whose lessons are widely applicable. This concept envisions a ship that is truly variable in mission, as opposed to the more commonly seen multi-purpose ship. A variable mission ship is perceived to be one which undergoes a complete metamorphosis in its change of mission. Before change it is a specialized ship performing a specialized mission. After change it is a

specialized ship performing a different specialized mission.

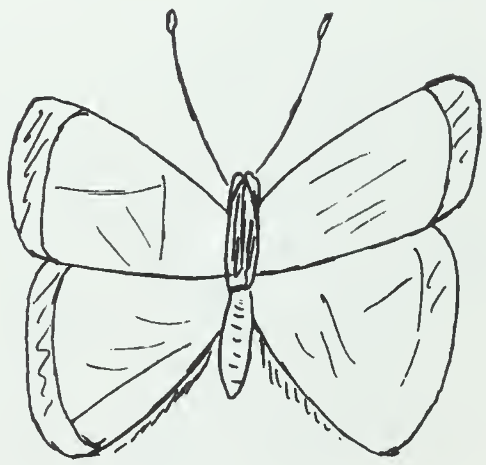
Part I develops the variable mission concept from both the maritime commercial and military points of view. In Part II a pair of example missions are chosen and a specific ship design and its performance of these missions is analyzed.

It should be noted that the concept of the variable mission or metamorphic ship as it is developed in this thesis tends to emphasize the commercial/military mission package as opposed to the commercial/commercial case. This emphasis results from (1) the fact that the author's experience has been largely in the military field and, (2) the author's inability to obtain, in the time available, sufficient data to develop two profitable missions within the commercial sphere. There is nothing about the concept, however, that limits it to a commercial/military design. It is fully as applicable to a changing commercial market as it is to a war or other international crisis.

*Chatterton, Howard A. An Analysis and Optimization of a Combination Minesweeper/Fishing Vessel. Massachusetts Institute of Technology Department of Naval Architecture and Marine Engineering Report N. 68-16. August, 1968.

PART I

THE VARIABLE MISSION CONCEPT



Previously, however, to the solicitation, I endeavored to prepare the minds of the people by writing on the subject in the newspapers, which was my usual custom in such cases,....

B Franklin

PART I

THE VARIABLE MISSION CONCEPT

I-1 MERCHANT MARINE

I-1-1 Need for Modernization

The basic missions of the U.S. flag merchant marine were stated in 1936 under Title I, Section 101 of the Merchant Marine Act.

> It is necessary for the national defense and development of its foreign and domestic commerce that the United States shall have a merchant marine (a) sufficient to carry its domestic water-borne commerce and a substantial portion of the water-borne export and import foreign commerce of the United States and to provide shipping service on all routes essential for maintaining the flow of such domestic and foreign water-borne commerce at all times, (b) capable of serving as a naval and military auxiliary in time of war or national emergency, (c) owned and operated under the United States flag by citizens of the United States insofar as may be practicable, and (d) composed of the best equipped, safest, and most suitable types of vessels, constructed in the United States and manned with a trained and efficient citizen personnel. It is hereby declared to be the policy of the United States to foster the development and encourage the maintenance of such a merchant marine.[1*]

In addition to the legislated missions mentioned, two other functions of the U.S. flag fleet are prominent. First, the federal government has regarded the reserve fleet as a mechanism by which freight rates in the shipping markets may be stabilized in times of heavy demand for services. Both World War I and World War II saw the development of incredibly high freight rates prior to U.S. entry into the war. These rate increases were due principally to the fact that this country had

*References appear at the end of each Part.

depended upon foreign vessels for its international trade during peacetime and, with the advent of war, found it difficult to charter foreign vessels in sufficient quantities.[2]

Since World War II the United States government has had at its disposal a large reserve fleet with which it can alter the balance of supply and demand in the shipping markets virtually at will. Thus, during the Korean (1950-1953) and Suez (1956) crises relatively stable rates were maintained in the shipping markets by reactivation of reserve fleet vessels.[3]

A second and more recently developed function of the U.S. flag fleet is to act as a positive factor in a rapidly deteriorating U.S. balance of trade. During the three years 1964-1966 for example, the U.S. balance of payments (as measured on the liquidity basis) ran a total deficit of $5.5 billion.[4] During these same years the U.S. flag fleet provided a positive contribution of $2.2 billion.[5] That is, had the services provided by the U.S. flag fleet been performed instead by foreign owned and operated vessels, the balance of payments deficit for these years would have been $7.7 billion. This is a sizeable impact and it takes on added significance in these days of slim foreign trade balances and domestic inflation.

It is apparent that there are four major functions or missions of the U.S. merchant marine.

1. - Carry, under U.S. flag and in modern ships, a substantial portion of U.S. foreign trade.
2. - Maintain freight rate stability.

3. - Make a positive and significant contribution to the U.S. balance of payments.

4. - Serve as a military auxiliary in time of national emergency.

Is the U.S. merchant marine of today performing these missions? Table I shows the percentages of total U.S. ocean-borne export and import tonnage carried by U.S. flag vessels as a group and by U.S. liners in particular (as a percentage of total liner tonnage*), with the remainders being carried under foreign flag.

It is apparent that, as a group, U.S. flag vessels are not carrying anything like a substantial portion of the country's foreign trade tonnage. The 8.0-9.0% of years 1962-63 compares unfavorably with the same figures for other trading nations in 1962-63.[6]

Country	Percentage of tonnage carried by national flag
Denmark	23.0
France	58.7
West Germany	37.0
Japan	46.2
United Kingdom	52.0
Netherlands	16.0

U.S. liners, though, have been able to compete more effectively with foreign liner services and have maintained 20-

*For a definition of the distinction between liner and other tonnages see section I-1-2.

TABLE I

Year	Percent of Total U.S. Export and Import Tonnage Carried by U.S. Flag Vessels	Percent of Total U.S. Export and Import Liner Tonnage Carried by U.S. Flag Liners
1937	26.5	43.2
1938	26.0	37.4
-		
1954	27.9	37.7
1955	23.5	39.2
1956	20.5	39.6
1957	17.8	39.4
1958	11.6	33.1
1959	9.7	29.9
1960	10.5	30.2
1961	8.8	27.3
1962	8.9	28.1
1963	8.5	29.2
1964		30.4*
1965	9.0**	23.0*
1966		23.0*
1967	7.0**	

Except as noted below, all figures are taken or adapted from <u>Changing Patterns in U.S. Trade and Shipping Capacity</u>, U.S. Department of Commerce, December 1964.

* <u>1967 Annual Report of the Maritime Administration</u>, U.S. Department of Commerce, November 1967.

** "Inadequacy of Maritime Trade Cited." <u>The Journal of Commerce</u>, January 11, 1968, p. 25.

Note: The large drop in the U.S. flag liner percentages in 1965 and 1966 is attributed by the Maritime Administration to the heavy Vietnam sealift requirements that developed in these years (and continue to the present).

30% of the liner market in recent years. This success is due in large part to the receipt of operating differential subsidies by many of the firms providing liner services. The relative success of the liners takes on added significance in view of the fact that, even though total liner tonnage has recently been 15-20% of total U.S. oceanborne tonnage, the dollar value of liner cargo represents about 80% of the dollar value of all cargo.[7] Thus the liner industry attracts most of the higher value cargoes.

The figures above describe past performance of the merchant marine. Future world trade projections paint an even gloomier picture. While U.S. trade has been growing steadily in total tonnage and value, total world trade has increased much more rapidly. U.S. flag shipping has not only been losing its fractional share of U.S. trade, but it has not taken part in the growth in world trade. U.S. trade is expected to triple within thirty years.[8] Total world trade will more than quadruple in that time. U.S. flag shipping has had a difficult time trying to hold a constant share of a slowly growing market. It will be immeasurably more difficult in the future to capture a larger share of a rapidly growing market.

In spite of the relative success of the U.S. flag liner industry, and without considering either numbers of ships or the effects of cargo preference laws and subsidy programs, it can be concluded that today's U.S. flag merchant marine is not carrying a substantial portion of U.S. oceanborne foreign trade.

Further, it will not do so in the future. Thus the merchant marine is not performing adequately as regards its first major function.

During the Korean (1950) and Suez (1956) crises the U.S. government had a reserve fleet whose average age was between seven and fifteen years. The ships were in relatively good shape, reasonably modern, numbered about two thousand[9], and comprised 14-18% of total world deadweight tonnage.[10] They were effective transport vehicles. Today these ships are more than twenty-five years old, obsolete, number about one thousand[11], and comprise 3.6% of world deadweight tonnage.[12] It is doubtful that they could be reactivated and modernized so as to have an appreciable effect on market conditions during an international crisis. It should be noted that some of these ships have been put to use during the relatively limited Vietnam conflict. During the period July 1965 to April 1967 a total of 161 ships were reactivated at a shipyard activation cost of about $450,000 each (cost does not include outfitting, towing, husbanding, etc.).[13] Nevertheless, in event of major disruption of the shipping markets, it does not seem likely that the U.S. reserve fleet could achieve the dominance necessary to stabilize freight rates.

In regard to the balance of payments function the effect of the U.S. merchant marine is twofold. First, the U.S. flag fleet serves to prevent the loss of revenues to foreign shipping. As noted above, it saved $2.2 billion during 1964-1966.

Second, the U.S. merchant marine as a whole earns a considerable amount of foreign revenue. In 1965 foreign revenue earned amounted to $680 million, making shipping services the seventh largest export item (after machinery, transportation equipment, metals and manufactures, wheat, chemicals and corn).[14] The merchant marine is effective in its role of supporting the balance of payments. However, a larger, more competitive fleet would provide a welcome boost to today's declining trade balance.

The fourth, and last, function of today's merchant marine is not so easily evaluated. The Department of Defense has been both hesitant and ambivalent in its judgment as to the effectiveness of the merchant marine in its role as a military auxiliary.

For national defense considerations the U.S. merchant marine consists principally of U.S. flag vessels, those flag of convenience vessels considered by the Navy to be under effective U.S. control, and the government reserve fleet. In 1963 the numbers of ships in these categories were approximately as follows:

U.S. flag[15]	920
Flag of convenience[16]	443
Reserve fleet[17]	1819
Total number of vessels	3182

The question of the adequacy of this group of aging ships to meet national defense needs has been argued for years. Its

answer depends to a great extent upon current thinking and strategy within the Department of Defense. Throughout the decade of the 1960's the concept of forward positioning has tended to mask the need for updating the merchant marine. In his 1962 Annual Report the Secretary of Defense had this to say:

> Our combined military and civil sealift capability continued to be generally adequate during fiscal year 1962, and current plans provide for no major changes in the composition of our transport fleet.[18]

And, in the 1963 Annual Report:

> .....The possibility of further reductions in lift requirements is being tested by the prepositioning of equipment in "floating depots" stationed in forward areas.[19]

In general the thinking has been that MSTS would provide a nucleus fleet, directly controlled by the military, that would provide those missions and capabilities not found in the commercial merchant marine.[20,21] Thus, the forward depots, when combined with an increased airlift capability and a specialized MSTS fleet, would tend to negate the requirement for a massive modernization of the merchant fleet.

Except for specific weaknesses brought out by the Vietnam War build-up[22](lack of an adequate roll-on/roll-off capability, lack of shallow draft tankers, lack of refrigerator ships, lack of cargo ships with a heavy lift capability) the thought that the merchant marine was generally adequate has remained dominant right up to the present time.

The weaknesses highlighted by the Vietnam operations,

when coupled with the refusal of Congress to fund any substantial numbers of the fast deployment logistic ships, suggest that today's merchant marine is not adequate to satisfy strictly military needs, to say nothing of being able to simultaneously maintain the commercial trade of the country.

In concluding this section, then, it is clear that the U.S. merchant marine performs inadequately in three of its four major roles. In the fourth role, balance of payments, improved performance would be welcome. There is a definite need for modernizing and increasing the capacity of the fleet.

I-1-2 Characteristics of the Liner Market

United States oceanborne trade falls into three general areas: liner, irregular and tanker services. The liner services are characterized by their scheduled, common carrier operations. Liner ships operate on fixed routes and on a stable schedule, seeking their business from the general public. Although the dollar value of annual liner cargo represents about 80% of the value of total annual U.S. oceanborne trade, the tonnage of liner cargoes has grown very slowly over the past decade, increasing from about thirty-nine million tons in 1954 to about 47.2 million tons in 1963.[23] U.S. flag liners have generally carried 20-30% of this tonnage. About two-thirds of the U.S. flag tonnage is carried by ships receiving an operating-differential subsidy from the federal government.[24]

Some of the more important characteristics of the liner

markets are outlined below.

(1) Liner cargoes are predominantly high valued goods. In 1963 the 47.2 million tons of liner cargo consisted of 36.2 million tons of general cargo (higher value) and 11.0 million tons of bulk commodities (lower value). By comparison, the irregular shipping services (tankers not included) carried 12.0 million tons of general cargo and 127.5 million tons of bulk commodities.[25] This division of cargo resulted (in 1966) in an average cargo value of 655 dollars per ton for the U.S. flag liners and of forty-four dollars per ton for the irregular services.[26] The ability of the liners to attract high valued cargo is significant in view of the fact (mentioned below) that the rate-setting conferences tend to set rates that are proportional to the value of the cargo.

(2) Liner cargoes are generally carried by conference vessels under conference rates. The rate-setting conferences are regional organizations of shipping firms and operate to promote the members' interests. They are of prime benefit to the shipping firms and perform functions that are denied by the anti-trust statutes to most other U.S. firms and industries.

> Directly or indirectly, conferences perform at least four major functions: (1) price-setting; (2) allocating output among the members; (3) dividing revenues; and (4) controlling entry.[27]

As a result of the performance of the conferences, freight rates tend to be higher than marginal costs would indicate

and are certainly higher than they would be without conference protection.[28] A further conference benefit to the liner firms is the practice of the conference in setting higher rates per measurement ton (one MT equals 2240 lbs or 40 cu. ft., whichever dominates) on higher valued cargoes. For example, the following rates were applicable on the Hampton Roads, Virginia to Hamburg, Germany route in 1962:[29]

Agricultural implements, unpacked	$22.25 per MT
Kitchen utensils	36.25
Cameras	70.25
Typewriters	71.50
Paintings and antiques	176.50

Clearly the ship that is able to attract and handle large volumes of higher valued cargoes will have a much higher revenue potential than will a ship carrying lower valued cargoes.

(3) Liner ships operate for the most part on steady, advertised schedules. While these schedules are required by the Maritime Subsidy Board in the case of U.S. subsidized shipping, they are also necessary in order to attract cargo from the general public and in order to maintain steady industrial customers.

(4) The liner industry today is marked by increasing specialization and a "transport systems" orientation concerned with the total transportation system from shipper to consignee. This orientation is a direct result of the three preceding items. Any field marked by high revenue potential, monopoly pricing and a steady schedule of operations is ideally situated to attract large amounts of capital. Since future mar-

kets are more easily predicted than in, say, a highly competitive industry, less risk exists for the investor. Much effort can be put into analysis, engineering design, and management planning functions as well as into equipment. The result of the ability to finance and undertake these long range planning activities is that the liner industry is becoming more capital intensive and more concerned with the productivity and revenue producing potential of the ship-port combination.

Clearly a long term goal of carrying a substantial portion of U.S. trade under U.S. flag requires improvement in <u>all</u> areas of shipping, not just the liner services discussed here. However this paper concentrates on the liner service. That service, with its emphasis on productivity of the ship, demands that a high degree of design, engineering and management technology be combined with large amounts of capital. U.S. industry as a whole is very good at bringing both high levels of technology and large amounts of capital to bear on specific problems.[30]

There are, potentially, at least two modes of operation in which a variable mission ship can serve to attract capital to the U.S. flag liner industry and to aid in increasing the capacity of the fleet. The first mode is commercial/commercial in nature; the second commercial/military in nature. The two modes are discussed in the following sections.

I-1-3 Commercial/Commercial Variable Mission Ship

A variable mission ship offers to its owner two or more

highly specialized missions, together with a capability for converting between them. To emphasize the significance of this capability it is necessary to understand the implications of specialization for liner shipping.

The profitability of a highly specialized ship is a strong function of its ability to generate revenues. The ship represents a large capital investment and any idle time spent in port is extremely expensive. Also expensive is any underutilization of the ship's annual ton-mile capacity.

A specialized ship operating in a specialized market would be expected to generate higher revenues and profits than a more general purpose ship operating in that same market. When demand in the market falls, though, the specialized ship is at a disadvantage. While the general purpose ship shifts easily to more diverse cargoes, the specialized ship makes this transition slowly and expensively, if at all. This is, potentially, a very costly disadvantage of specialization. Consider, for example, the cases of the container ship and the barge carrying ship. As long as container and barge cargoes are plentiful the ships perform efficiently and can generate higher revenues than a general purpose cargo ship. But suppose that there was an excess of container or barge shipping capacity and the utilization rates of the specialized ships fell. These ships would then be forced into direct competition for more general cargo. An estimate of how they would fare in this competition is available from a study made using a simulated

voyage technique.[31] This study took actual shiploads of cargo as carried on six voyages in 1965-66 by a general purpose, WW II cargo ship. It then placed a container ship and a barge carrier on the same routes with the same cargoes and analyzed the results. Some of these results are summarized here.

(1) A port combination is defined as occurring when cargo is available at a port visited and is destined for another port on the ship's schedule. Due to an inability to make up unit loads, the barge carrier had to reject the available cargo at 42.5% of the port combinations. The figure for the container ship was 28.9%.

(2) Lost tonnage is defined as cargo tonnage available which is rejected because it cannot be unitized or because it is available in such a small amount that it would not be economical to carry it. Lost tonnage, as a percentage of tonnage actually carried, was four percent for the barge carrier and fifteen percent for the container ship.

(3) Cubic utilization of the two ships, the number of cargo units (containers or barges) carried as a percentage of the maximum number of units that could be carried, was about thirty-five percent for the barge carrier and twenty percent for the container ship.

These results point out the dilemma of the owner of the specialized ship. His ship's efficiency offers a high revenue potential but leaves him at the whim of the specialized market for realization of this revenue. This paper proposes the var-

iable mission ship as one answer to the dilemma. The conversion capability of a ship of this type provides the operator with an added option in his efforts to keep his ship profitably employed. He can not only move his ship from port to port or from trade route to trade route, but he can also shift from one specialized service to another. In this sense his profits are now less vulnerable to fluctuations in any one particular market. The idea of shifting the ship from one commercial market to another is discussed further in section II-4.

I-1-4 Commercial/Military Variable Mission Ship

The commercial/military version of the variable mission concept can serve to attract additional federal funds to the existing construction subsidy program. Under this program there would be, today, ample private funds for ship construction provided matching federal subsidy funds were also available. The rate of construction is constrained by the limited availability of federal funds. That this is so can be seen from the fact that at the end of fiscal year 1967 the Maritime Administration had requests pending for construction subsidy on seventy-two new and converted ships. In contrast, only twenty-four or twenty-five ships were expected to be authorized during a combined 1967-68 program.[32]

In section I-1-1 it was pointed out that today's U.S. flag fleet does not adequately fulfill its national defense responsibilities. Accordingly, a variable mission ship, one

of whose specialized missions satisfied a demonstrated military need, would provide added incentive for federal funding of liner construction. It is this commercial/military aspect of the variable mission ship that is emphasized in the remainder of this paper.

Section I-2 below shows that the national defense can be well served by a ship able, in times of national emergency, to perform a specific military mission.

I-2 MILITARY

I-2-1 Functions and Performance of the United States Navy

The basic purposes of the U.S. Navy are described in the Annual Report of the Secretary of the Navy.

> 1. To support and defend the Constitution of the United States against all enemies, foreign and domestic.
> 2. To insure the security of the United States, its possessions, and areas vital to its interests by timely and effective military action.
> 3. To uphold and advance the national policies and interests of the United States.
> 4. To provide assistance in civil defense as an additional task and, as feasible at the time, with forces not required for essential military operations.[33]

From these broad purposes derive specific missions and functions of the naval forces.

> 1. To organize, equip, and provide naval forces for the conduct of amphibious operations.....
>
> 2. To organize, train, and equip naval forces for.....antisubmarine warfare;.....
>
> .
> .
> .
> etc.[34]

In the ideal, unconstrained situation the approach used in performing these functions would follow the philosophy stated by Secretary of Defense Robert McNamara in 1964.

> When I assumed office, President Kennedy gave me two primary instructions which President Johnson has reaffirmed: First, to develop the military structure required for a firm foundation for our foreign policy without regard to arbitrary budget ceilings.
> Second, to procure and operate this force at the lowest possible cost.[35]

Time and experience have shown that this unconstrained prob-

lem does not exist; that, in reality, the U.S. Navy must operate under budget constraints. There are two major reasons for the existence of these constraints. First, national security and well-being are affected by internal as well as external threats and problems. Thus non-military programs compete with military programs for available funds. Second, even if there were no non-military competition, it is surely true that anticipated military problems and their projected solutions would grow so as to use all available funds, resulting in the budget constrained situation.

Given the existence of budget constraints, then, it is true a priori that every Navy function, no matter how general or how detailed, must fall into one of the following categories:

Category I - Those functions that can be considered as being accomplished. That is, sufficient trained men and modern equipment are available to perform the function to the maximum extent possible within the current state of the art.

Category II - Those functions that can be considered as being either partially accomplished or, for all practical purposes, totally unaccomplished.

Further, due to the existence of the budget constraint, there must be some functions in Category II.

The antisubmarine warfare field provides examples. Within

this field there are at least three basic functions:[36]

1. Protect the U.S. Navy fleet
2. Protect the U.S. merchant shipping fleet
3. Protect the continental U.S. from attack by submarine-launched ballistic missiles.

The first function fits into Category I, as being essentially accomplished within the state of the art. The next two fall into Category II. The Navy simply does not have sufficient numbers of vessels to guarantee full performance in these areas.

Within budget constraints Navy and Department of Defense managers must rank their requested functions on a priority basis and spend their money accordingly. New and exotic weapons systems will thus tend to draw more attention and funds than will the more traditional and mundane systems (compare the Polaris missile forces with the mine-sweeping forces, for example). Within its budget constraints the Navy attempts to maintain as many modern ships as is possible, relying upon the Selected Reserve, MSTS and the merchant marine as back-up forces in time of emergency.

When the constraints are severe as they have been in recent years, some of the first areas to give up their claim on funds are routine modernization, repair, and replacement of general purpose, active duty ships. "The Department of Defense has for some years been pushing the fleet modernization problem into the future."[37] Thus discussion centers today on an

active naval fleet, about sixty percent of which is more than twenty years old and cannot be modified to handle new weapons systems and equipment.[38]

In performing its required functions the Navy has relied principally upon the active fleet and the Selected Reserve[39] for military missions. The warships in the inactive reserve fleet are largely an ineffective force today due to their age, to the time delay inherent in activating and manning them, and to their small number.[40] Supply and transport missions are to be covered principally by MSTS and the merchant marine.

> The Government's policy is to depend on the [national defense] reserve fleet and the merchant marine for emergency expansion and to maintain in the MSTS fleet the types of ship particularly suited to meet specific military needs ---such as shallow-water tankers, wide-hatch and extra heavy-boom cargo ships, and forward mobile depot ships.[41]

In meeting emergencies, then, the Navy must rely essentially upon active duty ships for the effective performance of its functions. This paper seeks to focus attention on the Category II naval functions. Since it is clear that the Navy cannot afford to maintain modern, active duty ships in sufficient numbers to perform all its missions, this paper suggests that a search be made through the Category II functions to seek out those that can be performed <u>without</u> the use of an active duty ship. Active duty ships are expensive to man and operate; and, if their function is technically specialized, they are expensive to modernize and maintain. In today's complex world a great many ships become technologically obsolete long before they wear out from a physical standpoint. If it

were possible to accomplish some functions without having to maintain an active duty ship then it would be possible to transfer these functions from Category II to Category I at little cost. Overall effectiveness of the naval forces would then be increased. The following paragraphs will show that functions of this nature do exist.

I-2-2 Some Recent International Emergencies

Past deployments of naval forces suggest that not only do wartime-only missions exist, but that there also exist substantial time periods during which required ships may be mobilized. These time periods could be used to convert a variable mission ship from its commercial mode to its military mode. Two fairly recent deployments are discussed below

Korea - 1950[42]

Jan-Mar 1950 U.S. Far East Command received intelligence reports that a North Korean attack was expected in spring or early summer.

April-May 1950 North Korean military build-up widely noticed. Rhee government in South Korea became alarmed.

May-June 1950 United Nations Commission established a system of border observers.

25 June 1950 North Korean army attacked across the 38th parallel.

27 June 1950 President Truman ordered General MacArthur to use his air and naval forces against the invading army

and to use the 7th Fleet to neutralize Formosa.

30 June 1950 President committed U.S. ground troops to action.

8 July 1950 Chief of Naval Operations ordered reactivation of selected mothball fleet units.

15 September 1950 Amphibious landings at Inchon.

The rapid build-up from late June onward placed a heavy load upon Navy logistics efforts and brought into sharp focus the failure of the military forces as a whole to plan for a limited war. To lift ammunition to the Far East, Commander Service Forces Pacific had a single ammunition ship. In order to accomodate the build-up it was necessary to put special linings in the holds of several attack cargo ships and make them do the job.

The enemy was essentially unable to wage a war at sea. Thus mine warfare was the only major naval threat that actually materialized. With many of the Navy's minesweepers deactivated (at outbreak of war only seven active duty minesweepers were in Far East areas) a crash reactivation program was required. In spite of all efforts during the war, stringent economies before the war had so depleted the mine forces that they remained a major naval deficiency throughout the emergency.

Other naval shortages involved hospital ships and fleet stores issue ships (the only ones in the Pacific Fleet had been deactivated); communications congestion due to limited facilities and rapidly growing quantities of high precedence

traffic; gasoline tankers to support aircraft and vehicles; and reefer ships.

In general, the Navy's mobilization was a good example of making do with what was available until the desired ships could be reactivated. Fortunately relatively modern mothball and reserve fleets existed from which the necessary ships could be drawn.

Suez - 1956[43]

April 1956 Egypt, Syria, Saudi Arabia and Yemen formed a joint command directed against Israel.

April-June 1956 President Nassar fired Arab nationalism and concluded extensive armaments agreements witht the Soviet Union.

19 July 1956 U.S. decided not to help finance the Aswan Dam. World Bank and Britain withdrew their offers of financial aid on the dam.

26 July 1956 President Nassar nationalized the Suez canal.

30 October-6 November Anglo-French offensive and landings against Port Said and Port Fuad.

On 26 July Britain and France did not have the forces necessary for an effective and successful intervention in the canal zone. They formed a joint command in early August and mobilized some twenty thousand British reservists. Landing craft, liners for troop transports, and tankers for water carriers were requisitioned from private firms. It wasn't until the end of October that the joint forces were strong enough

to carry out the landings in the canal zone.

In addition to mobilization problems, the joint forces had serious communications difficulties throughout the operation. British communications were centered in an 11,000 ton depot ship and those of the French on a 3,000 ton depot ship. Both proved insufficient for the purposed of keeping close control over the landing forces.

There are two significant lessons to be learned from these conflicts. The first, and most obvious, is that military actions require many ships and missions that are simply not needed in times of peace. Such ships as minesweepers, gasoline tankers, communications and command ships, and hospital ships are not needed in large numbers except during wars or other conflicts. These are wartime-only missions, as opposed to more basic and continuing missions such as ASW protection of the active naval fleet. The personnel required for their accomplishment can be obtained from reserve training programs. At the present time the ships required must come from other active duty assignments or from the reserve fleet.

The second and far more important lesson of Korea and Suez is that crises in the modern world tend to be preceded by periods of civil violence, military build-up, and political unrest.

Thus definite warnings of trouble appear prior to the conflict. Korea and Suez were not unique in this respect. Virt-

ually every military crisis over the last two decades has developed in the same manner.

Lebanon - 1957-58[44]

May 1958 Armed riots by opposition to President Chamoun. Strikes, barricades in the opposition dominated cities of Beirut, Sidon and Tripoli.

mid-May 1958 U.S. announces step-up in arms shipments to Lebanese government. Extra battalion landing team sent to Mediterranean.

14 July 1958 President Chamoun requested U.S. intervention.

15 July 1958 U.S. troops landed near Beirut.

Cuba - 1962[45]

29 August 1962 U-2 flight showed clear evidence of construction of surface-to-air missile sites.

Aug-Sept 1962 President Kennedy increased the frequency of U-2 observation flights.

Sept-Act 1962 Military build-up in Cuba continued rapidly but it was defense oriented.

14 October 1962 U-2 flight shows launch pads and buildings for ballistic missiles.

22-24 October 1962 Quarantine established at sea by U.S. Navy ships.

Dominican Republic - 1965[46]

24 April 1965 Armed coup, army revolt and street fighting occur.

27 April 1965 President Johnson ordered U.S. troops landed to protect U.S. citizens.

28 April 1965 First Marines landed.

30 April 1965 Army and Air Force tactical units landed

It is clear that the decision as to when conditions are serious enough to require military intervention is a subjective thing. The Dominican Republic, for example, underwent several years of unrest prior to the revolt on 24 April 1965 which led to U.S. military action. Nevertheless the development of these crises suggests that a warning period during which military conflict becomes probable does exist in most cases.

The observations of the existence of warning periods and wartime-only military missions suggest that it would be advantageous to have available reserve ships which could be activated in short periods of time. In the past the mothball and national defense reserve fleets have provided these ships. In the future they will not. It seems reasonable to suggest that the planning of future naval force levels include an analysis to identify wartime-only missions and that, where possible, these missions be accomplished by commercial/military variable mission ships. A variable mission ship would offer several advantages.

(1) The military payload package for complex missions could be kept technologically up-to-date at much less cost

than could an inactive reserve ship.

(2) The ship would be kept in operating condition and in good repair by the owner as he used it in the commercial market.

(3) In some cases (command and communications, for example) the payload package could be used for shore training purposes for reserve unit operators.

(4) The Department of Defense could buy one ship in ten, for example, and operate it in its military mode to train reserve crews.

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The Wall Street Journal, April 25, 1969, p. 1.
The Boston Globe, April 20, 1969, p. 2.
The Wall Street Journal, April 20, 1969, p.3.

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38 destroyers and destroyer escorts
12 minecraft
23 ASW aircraft squadrons
15 other aircraft squadrons

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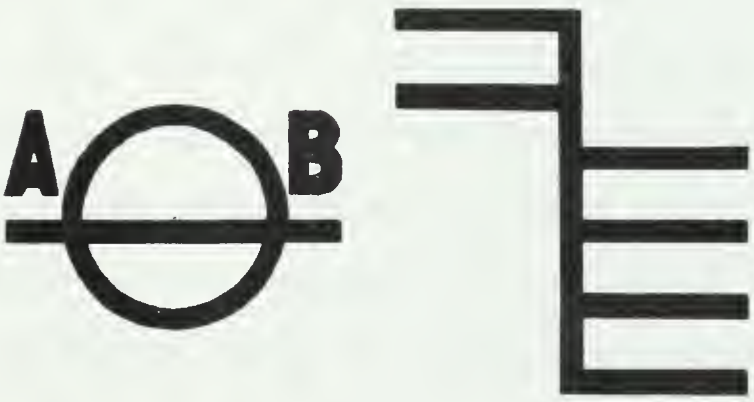
PART II

AN EXAMPLE



It has been remarked as an imperfection in the art of ship-building that it can never be known, till she is tried, whether a new ship will or will not be a good sailer; for that the model of a good-sailing ship has been exactly followed in a new one which has proved, on the contrary, remarkably dull....

...Besides, it scarce ever happens that a ship is formed, fitted for the sea, and sailed by the same person. One man builds the hull, another rigs her, a third lades and sails her. No one of these has the advantage of knowing all the ideas and experience of the others, and, therefore, cannot draw just conclusions from a combination of the whole.

B Franklin

PART II

THE EXAMPLE

II-1 CHOICE OF MISSIONS AND SHIP

II-1-1 Commercial Mission

The choice of a liner service mission for a specialized ship is relatively easy to make today. The appearance and subsequent success of containers in domestic shipping in 1956 ensured that it would be only a matter of time until they were introduced on the international routes. The established conference lines hoped to make a gradual transition to containers and, for a while, even placed penalty charges on container shipments. All hopes were dashed in April, 1966 when non-conference, non-subsidized Sea-Land Service, Inc., opened a weekly all-container schedule on the North Atlantic routes.[1] The rush by shipping firms to develop container capacity continues today.

A look at projected trade figures suggests that the frantic development of container shipping capacity will prove to be a good investment. In section I-1-1 it was estimated that annual U.S. foreign trade tonnage will triple in quantity by the year 2000. World tonnage is expected to more than quadruple in that time and about 15% of these tonnages are expected to consist of cargo that can be carried in containers.[2] In U.S. trade alone an increase in containerizable cargo from about 30 million tons annually in 1963 to about 90 million tons annually in 1990-2000 is a good possibility.

The existence of this growing container market was considered together with the fact that containers lend themselves to standardization of ships, port facilities, and inland transport modes. The result was a decision to use the container ship mission as one role of the variable mission ship analyzed in this paper.

II-1-2 Military Mission

A roll-on/roll-off (Ro-Ro) capability was chosen as a second mission for the example ship. There were two principal reasons for this choice. First, a military need for Ro-Ro capability is well documented. Although section I-2 suggested the need for such other missions as command and communications, mine sweeping, and antisubmarine warfare, the need for these missions is highly subjective and is not well documented. Further, the technical characteristics of these missions are frequently treated as classified information. In contrast, the military need for Ro-Ro capability was pointed out vividly by J.A. Field[3] and has been repeatedly emphasized in Department of Defense Annual Reports over the past ten years. The technical characteristics of the Ro-Ro mission are not classified.

A second reason for the choice was that a "military" Ro-Ro mission is, in fact, an added employment option of the commercial operator. If container ship utilization is low he might shift to commercial Ro-Ro operation or even charter

his ship to MSTS. These possibilities are discussed briefly in section II-4-4.

II-1-3 Ship Choice

A specialized ship operating in a specialized market succeeds or fails according to its ability to generate revenues. Revenues are proportional to the ton-mile per day capacity of the ship. This capacity is dependent upon speed and port turnaround time, both of which are crucial considerations. An appreciation of the interplay of these two features may be gained by considering an example. On a 7200 mile round trip a 20,000 ton deadweight ship with a 25 knot speed and $7\frac{1}{2}$ day turnaround time has a capacity of 5.33 million ton-miles per day. A $12\frac{1}{2}$ knot ship of the same deadweight on the same route, but designed for a $1\frac{1}{2}$ day turnaround time, has an equal capacity and would generate the same revenues. Because of its lower initial and operating costs the $12\frac{1}{2}$ knot ship would be much more profitable. With a turnaround time reduced to $1\frac{1}{2}$ days, the 25 knot ship has a capacity of 9.61 million ton-miles per day, 80% greater than that of the $12\frac{1}{2}$ knot ship, and can thus justify its higher cost.

The importance of turnaround time led to the decision to analyze a catamaran container ship. A single hull container ship tied up at a wharf can be serviced by two or three gantry cranes simultaneously. The catamaran, on the other hand, if moored between finger piers, offers the possibility of simul-

taneous service by four to seven cranes and promises great reductions in turnaround time.

The Ro-Ro mission is also well served by the catamaran. Single hull Ro-Ro ships tend to be volume limited due to low utilization of bale cubic and are estimated to require about double the cubic volume of a container ship to carry the same weight of cargo.[4] A catamaran, on the other hand, offers up to 50% more usable volume and deck area than does a single hull ship of equal total displacement and promises to carry more Ro-Ro tonnage. Further, its improved stability renders it less sensitive to load distribution, allowing heavy military vehicles to be stowed with relative ease.

As regards turnaround time, the catamaran offers the Ro-Ro mission the same advantages it offers the container ship mission. Where a single hull vessel has two, three or four loading ramps, a catamaran may have four to ten, thus decreasing port time drastically.

II-2 DESIGN SUMMARY

II-2-1 Characteristics

The initial intent in design was to build an analytical-empirical model of the ship design process. This model was to be sufficiently accurate to allow the development of an economically optimal container ship. Unfortunately, information available on large catamarans is not sufficient today to allow this type of model building. Perhaps the best study to date (at least in terms of analyzing large numbers of ships) was done by General Dynamics Corp. for the Maritime Administration.[5] This study was only recently completed and was not available in time to be used in this thesis.

Two principal areas of weakness stood out in the search for design information. The first area is resistance and powering. The effects of hull form and of the separation distance between the hulls on total resistance are only incompletely understood and the few theories that do exist have never been subjected to full-scale test. The best summary to date appears in a paper by Turner and Taplin;[6] but even this represents an ad hoc and not a systematic approach to the question.

The second area of weakness is in the estimate of steel structure weights, particularly in the cross-structure between the two hulls. The cross-structure design has been done for some smaller ships[7] under 300 feet in length, but no work on larger ships seems to have been undertaken.

In view of these two weaknesses it was necessary to dis-

card the idea of trying to develop an optimal ship. Rather, the approach of designing a sufficient ship was undertaken. This approach proceeded as follows:

1. The 700 ft symmetrical design of Turner and Taplin was chosen as the ship to be analyzed.
2. The cross-structure for this ship was analyzed for weight estimates by following a procedure parallel to that of Lankford.[8]
3. The ship was then analyzed in terms of its costs and revenue generating capabilities.

Table II and Figures 1 and 2 summarize the characteristics of the ship. Section II-2-2 discusses some aspects of the design and section II-3 presents a detailed description of the conversion of the ship from the container mission to the Ro-Ro mission.

II-2-2 Design Assumptions

The example ship was assumed to operate as a container ship on the North Atlantic trade routes at a service speed of 25 kts. A required endurance of 8850 miles at 25 kts is sufficient for a round trip from Boston to Hamburg and back, a 500 mile coastal journey at each end of the trip, and two day's reserve. The service speed of 25 kts is assumed to require 80% of installed shaft horsepower. The design is a basic, functional, uncomplicated ship whose only novel features are the catamaran form and the variable-mission capabil-

TABLE II

Length between perpendiculars	700 ft
Length overall	724 ft
Beam	214 ft
Beam (each hull)	65 ft
Hull separation	84 ft
Displacement, full load	46800 long tons
Draft, full load	30 ft
Depth	58 ft
Service speed (at .80 SHP installed)	25 kts
Endurance at service speed	8850 naut. miles
Installed shaft horsepower	112,000 SHP
Crew size	52
Transverse metacentric height, full load	184 ft
For each hull	
Block coefficient	.600
Prismatic coefficient	.615
Midship section coefficient	.975
Hatch width	54 ft
Hatch width as percent of beam	83%
Acquisition cost, one ship, with containers	$40.7 million
Acquisition cost, each of three, with containers	$37.3 million

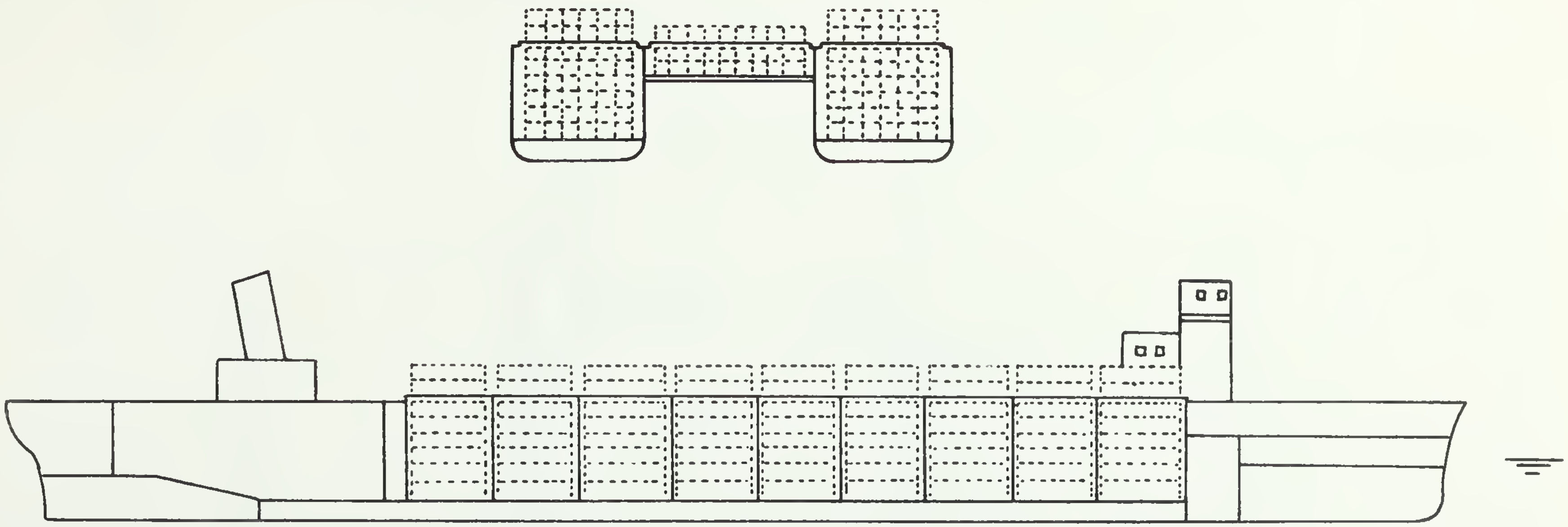


FIGURE 1

Inboard Profile

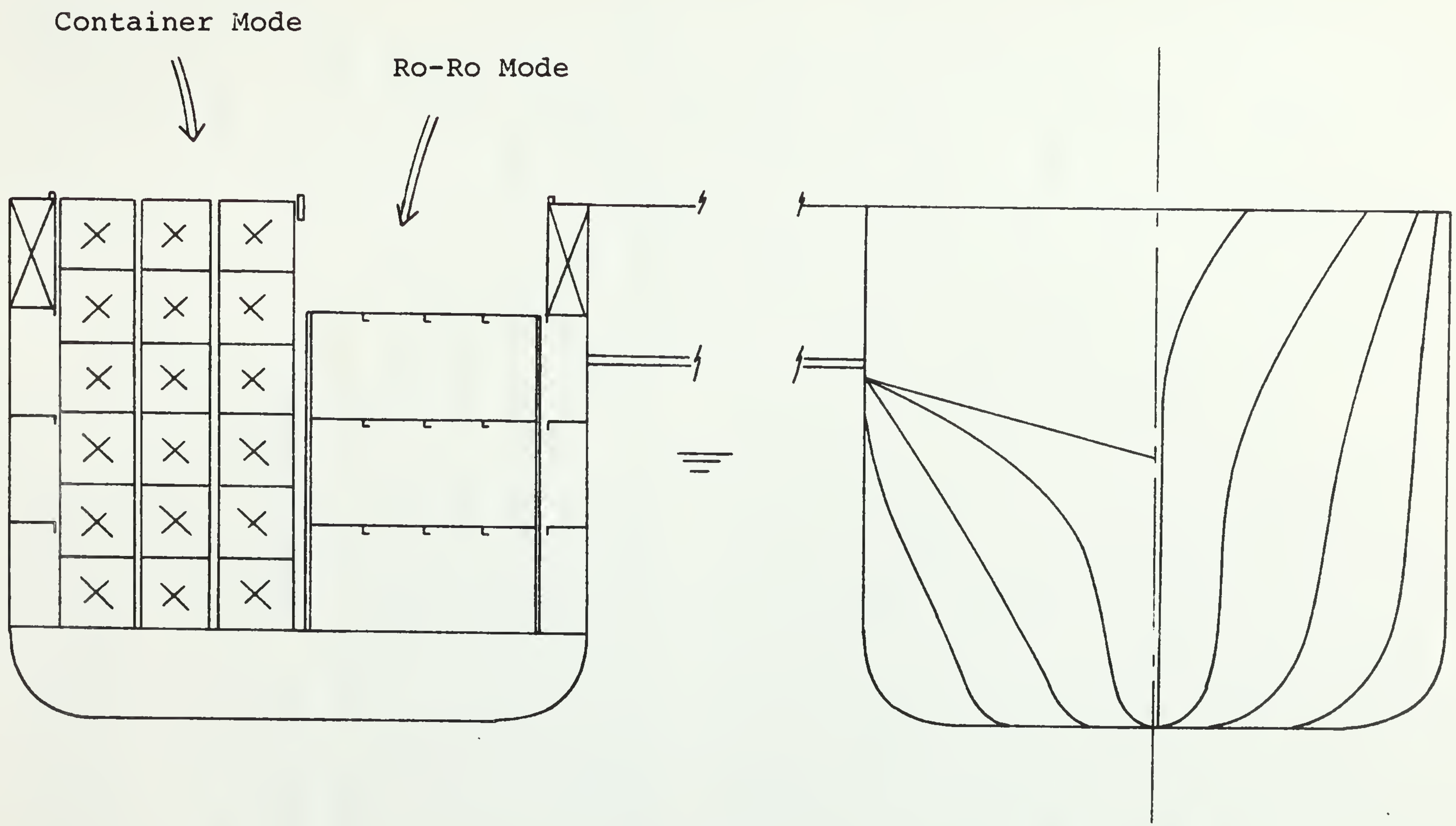


FIGURE 2
Midship Hold Section and Body Plan

ity. Conventional weight summaries are given in Table III.

In order to qualify for federal construction subsidies a design proposal must meet certain requirements in regard to national defense features. The Navy prefers that cargo ships have sustained speeds in excess of 20 kts; that container ships carry their own cranes, except where doing so would place them at a competitive disadvantage; and that the feasibility of installing 'tween decks in container ships be considered.[9] The service speed of 25 kts in this design clearly meets the speed requirement. Since the catamaran container ship considered here is intended to operate between modern container terminals it has not been provided its own cranes. The alternate Ro-Ro mission is felt to be sufficient to ensure Navy certification of the value of the ship in time of national emergency.

Powering requirements were estimated from the data of Turner and Taplin. The installed 112,000 SHP reflects a 3% appendage allowance, a 75% propulsive coefficient and a 25% service margin. The propulsion plant consists of a pair of modern, oil-fired steam, reheat power plants, one in each hull. Remote control is effected from a central control station in the bridge superstructure forward. Each engineroom is equipped with a local operator's console for instrumentation, alarm and local control purposes.

Propulsion machinery weights were estimated from Johnson and Rumble[10] and Benford.[11] The figure of 3900 tons is con-

TABLE III

	Weight in long tons
Hull structure	15100
Hull engineering	1800
Outfitting	1840
Propulsion machinery	3900
Light ship displacement	22640
Full load displacement	46800
Dead weight	24160
Crew and effects, misc.*	74
Fuel (for 8850 miles)	7100
Maximum available payload (container mode)	16986
Conversion modules	2760
Maximum available payload (Ro-Ro mode)	14226

*Includes crew and effects, fresh water, lube oil, provisions and stores.

servatively heavy. Endurance fuel weight of 7100 tons was estimated using the procedure of Hauschildt[12] and allowing a service factor of 22% on the design fuel rate of 0.4 lb/SHP-hr.

Steel weight estimates proved to be a difficult problem for this ship. Much work has been done to correlate data for single hull ships, but little exists on catamarans. The approach used was as follows:

1. Estimate steel weights of the two hulls independently of the cross-structure.
2. Estimate loads, required section modulus and weight of the cross-structure.

The hull steel weights were estimated from Benford[13,14], Mandel[15,16] and Johnson and Rumble. The three figures were within 20% of each other and the heaviest (13,030 tons, Benford) was chosen as a conservative estimate of the weight of the two hulls.

A gross weight estimate for the cross-structure was obtained by following the design procedure of Lankford. Since sea response data was not available for a large catamaran, the response operator for Lankford's 251 ft catamaran was nondimensionalized as suggested by E.V. Lewis.[17] From this point Lankford's procedure for estimating sea loads was followed step-by-step, assuming the ship would experience one year continuous duty in the North Atlantic. The resulting

weight estimate was about 3.7 tons per foot of cross-structure, giving a total cross-structure weight of about 2070 tons.

Acquisition costs were estimated using procedures of Benford and Johnson and Rumble. The figure due to Johnson and Rumble was the higher ($40.7 million) but was by far the more realistic. Further, it is a conservative influence in the economic comparisons made in section II-4.

II-2-3 Capabilities

The proposed catamaran is an expensive ship. It offers the possibility of high revenues to its commercial operator and a much needed Ro-Ro capability to the military. Table IV summarizes the ship capabilities in each of the two missions.

When in the container mode the ship may be weight or volume limited. The weight limited case is illustrated by assuming the gross weight of each container to be thirty long tons, the maximum recommended by the International Standards Organization. Even though the ship has the cubic capacity to carry 1065 containers, 742 in holds and 343 on deck, with a container weight of thirty tons the ship can carry only 566 containers due to its maximum available payload weight (see Table III). At a weight of 15.94 tons per container the ship could carry its full load of 1065 containers. For lesser container weights the ship becomes volume limited. To make an estimate of the condition of the ship under an "average full load" condition a stowage factor of 112 cubic feet per ton in-

TABLE IV

Container Mission	
Container size	40'x8'x8'
Number of containers:	
In holds in two hulls	544
In holds in cross-structure	198
Topside on hull decks (2 tiers)	224
Topside on cross-structure (1 tier)	99
Total	1065
Available payload weight (fuel for 8850 miles)	16,986 tons
Maximum containers at 30 tons each	566
Roll-on/Roll-off Mission	
Total available parking area with 11'6" minimum clearance	306,100 ft^2
Available payload weight(fuel for 8850 miles)	14,226 tons
Maximum number of medium tanks at 43.5 tons each(10'8" high)	327
Unused parking area with tanks loaded	100,000 ft^2
Maximum number of Ford Falcons at 1.39 tons each(5' high)	2410
Unused payload weight with Ford Falcons loaded	10,876 tons

side of the container is assumed.[19] With a usable volume equal to 88% of that enclosed by the outside dimensions of the containers[20], cargo weight per container is thus 20.1 tons for a 40'x8'x8' container. An average, empty, 40 ft container weighs about 3.1 tons[21] to give a gross weight of 23.2 tons per container. In this "average full load" condition the ship can carry 735 containers.

The container ship catamaran can be serviced by as many as five pier-mounted gantry cranes. At an upper limit of twenty containers per hour per crane[22] the ship can be loaded and unloaded of 1065 containers in about twenty-two hours.

In the Ro-Ro mode the ship may also be either weight or volume limited. The Ford Falcon and medium tank figures shown in Table IV illustrate the two cases. The ship can be serviced by at least five loading ramps and can load and offload these vehicles in less than twenty hours.

II-3 CONVERSION PHASE

II-3-1 Module Description

The conversion packages or modules chosen for this ship are simple steel frameworks that fit into the container cells. They were chosen after consideration of three principal points:

1. High handling rates for containers mitigate against sliding them around on the 'tween decks of a Ro-Ro ship.
2. The mission change package must represent a minimum capital investment, be durable and maintenance free, and be easily handled as a package or a module.
3. The mission change process must cause a minimum of interference with routine ship services, systems and spaces.

Consideration of the first point resulted in a decision to design the catamaran as a true container ship with as many container cells as could be accommodated. The mission change package would then convert the ship from container to Ro-Ro operation at some loss in cargo deadweight tonnage. The last two points weighed heavily against such devices as cranes or elevators and resulted in the simple, box-like structure described below.

The complete conversion package consists of 34 modules, 8 ramp type and 26 deck type. The ramp type is depicted schematically in Figure 3. Each ramp type module measures

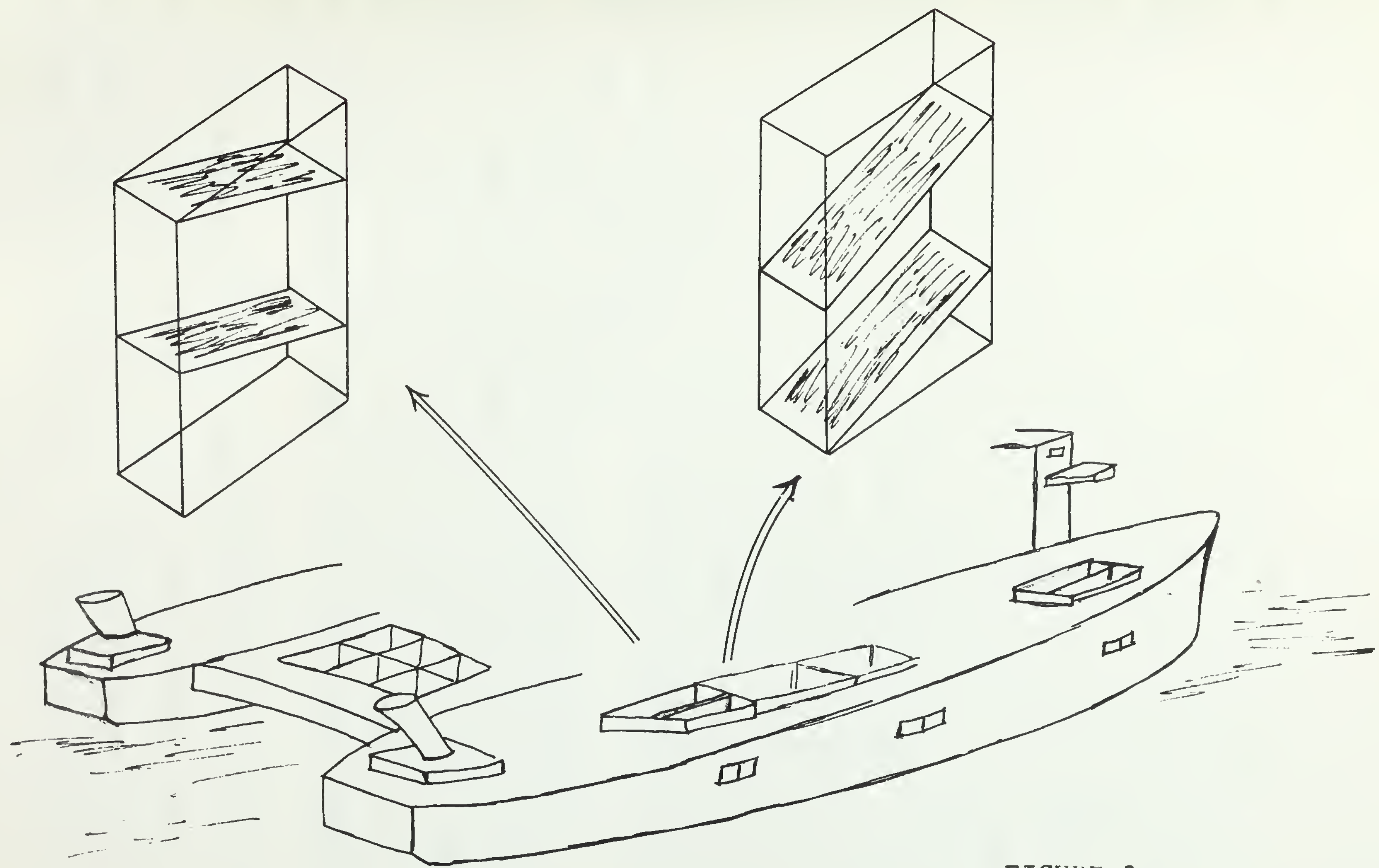


FIGURE 3

Ramp Modules

about 40 ft x 16.8 ft x 48.2 ft and replaces 12 containers in a 6 high by 2 across cell section. Two such sections are at the forward end of each hull and two more are at the after end. Vehicle entry ports are permanently installed in the hull at the second deck level. From the second deck the ramps provide access to all four internal parking decks (including the tank deck) and the topside main deck. The 8 ramp type modules are estimated to weigh 480 tons and cost $160,000.

Each of the 26 deck type modules is 36 ft in height and contains three horizontal decks which match deck ledges inside the ship so as to provide increased parking space. These ledges can be seen in Figure 1. The deck type modules are in three widths to conform to the different container cell groupings. The largest of these is estimated to weigh 90 tons. The 26 deck type modules as a group are estimated to weigh 2280 tons and cost $520,000.

No modules are installed in the cross-structure. Deck clearance inside this structure will accept two stacked containers or vehicles up to about 16 feet in height. This clearance allows the stowage of large vehicles. Decks in the two hulls have clearance of about 12 feet and accept smaller vehicles.

The modules have been described here as one-piece frameworks. In shipyards where either crane lifting capacity or available height clearances are inadequate to accommodate the one-piece units the modules may be constructed in sub-units.

Each sub-unit would then be fitted with standard A.S.A. corner fittings and stacked in the cell like an ordinary container.

II-3-2 Mission Change

Total capital investment in the catamaran mission change package (including modules, spreader frames and loading ramps) is estimated to be less than $1 million. Continuing costs of the package are maintenance, storage rental, and opportunity loss on the capital if the package is not used.

Conversion time from mission to mission is conservatively estimated at 10 hours. With several cranes available it could be as little as two hours. From a military reaction time point of view the worst case situation would be a mobilization when the ship was in Europe. Delay would be six days travel time, ten hours conversion time, and travel time to the required military loading site. Of those emergencies described in Part I only the Dominican Republic incident had a warning time sufficiently short to preclude mobilization and deployment of the catamaran as a Ro-Ro ship. In that incident there was only a four day delay between the initial armed coup and the landing of the Marines.

Low cost and short conversion time are the major attractions of the catamaran mission change package. Still, two other advantages bear mentioning.

(1) The catamaran does not have to go into a shipyard for conversion. Virtually any port with a crane to lift containers could install the modules. From a military viewpoint

this means the modules could be stored where their probability of use was highest. For a commercial operator it means that he could store them at his own facilities.

(2) If designed in container-sized sub-units the modules would be portable. They could be transported by air or sea to any desired location or to a rendevous with the catamaran in order to reduce mobilization time.

II-4 ECONOMIC ANALYSIS

II-4-1 Introduction

The catamaran described in sections II-2 and II-3 was designed as a high speed, high capacity container ship. Its acceptance is dependent upon its performance on the trade routes. The following sections look at the ship from three aspects. Section II-4-2 determines the minimum required freight rate at which the ship can operate over the long term. Section II-4-3 compares the profitability of the catamaran, the Lykes Sea Barge Clipper (C8-5-82a) and the container ship proposed by Meyers.[23] Section II-4-4 discusses the hypothetical case where the commercial operator would find it profitable to use the Ro-Ro mission of the ship.

Throughout this part of the paper the following conditions are assumed.

1. 25 year, 7% mortgages
2. Straight line depreciation
3. 48% corporate tax rates
4. Ship is in its first year of operation
5. Salable cubic capacity is equal to 88% of the volume enclosed by the outer dimensions of the containers.

Unless otherwise noted, all operating cost estimates are made from Benford[24] in order to ensure uniformity and are corrected to present (1968) at 6% per year.

II-4-2 Minimum Required Freight Rate

The minimum required freight rate (RFR) is defined as that rate in dollars per cubic foot that must be earned on the total salable cubic capacity of the ship to just break even. That is, at minimum RFR the ship will earn sufficient revenue to pay income taxes and principal on the mortgage. Then the cash flow of the owner is exactly zero.

$$\text{Cash Flow} = \left(1 - \text{Tax Rate}\right)\left(\text{Total Revenue} - \text{Total Expense}\right) + \text{Depreciation} - \text{Principal Payment}$$

$$\text{Total Revenue} = \left(\text{RFR}\right)\left(\text{Salable Cubic}\right)$$

Information pertinent to the minimum RFR calculation is summarized in Table V. All figures in Table V are based upon a single round trip during the first year of operation of the ship and upon the total salable cubic capacity of the ship.

$$\text{Salable Cubic} = \left(1065 \times 40 \times 8 \times 8 \times 0.88\right)\left(2 \text{ trips}\right)$$

$$= 4.8 \text{ million cubic feet}$$

The principal payment on the mortgage is not included in the total expense figure. Setting cash flow equal to zero and solving for total revenue gives a total revenue of $860 thousand. Then, from the second equation, minimum RFR is $0.179 per cubic foot. Thus, if the owner could sell 100% of his container volume on both legs of the round trip he could charge as little as $0.18 per cubic foot($7.20 per MT) and still meet his mortgage payment.

TABLE V

Data for Minimum Required Freight Rate Calculation

Variable Mission Catamaran - Container Mode

Acquisition cost	$40.7 million
Round trip, Boston-Hamburg	12 days at sea and 2 days in port
Salable cubic (1065 containers carried)	4.8 million ft^3 or 120,000 MT
25 round trips per year, 15 days for maintenance and repair	
Mortgage payment, interest	$114,000
principal	26,000
Depreciation	65,200
Wages (52 man crew)	36,200
*Subsistence	2,280
*Stores and supplies	3,300
Maintenance and repair	17,600
Insurance	21,910
*Overhead and miscellaneous vessel expenses	9,680
*Fuel oil	108,000
*Port expenses	4,826
Administrative expense	26,851
*Container handling and other cargo expenses	525,600
Total fixed and marginal expenses	935,447
Fixed expenses	281,761
*Marginal expenses	653,686

TABLE V (cont'd)

Notes: (1) Container handling and other cargo expenses are estimated as explained in Appendix A. The figure includes container handling, maintenance, and replacement costs.

(2) All figures in this table are based upon a single round trip during the first year of operation of the ship.

A similar calculation, based upon the assumption that the owner could sell or carry only 566 containers (the weight limited case), shows that he would have to charge $0.249 per cubic foot in order to maintain a zero cash flow.

These figures compare favorably with the prevailing rates of $0.60 to $0.80 per cubic foot on the North Atlantic routes.

II-4-3 Comparison

This section compares revenues, expenses and profitability of the catamaran container ship, the Lykes Sea Barge Clipper and the container ship of Meyers.

The following assumptions have been made:

1. A freight rate of $0.60 per cubic foot is charged for container capacity of the Boston-Hamburg route. A rate of $6.85 per long ton is charged on liquid cargo carried by the Lykes ship.
2. The catamaran and Meyers' ship have a 50% utilization rate of their salable cubic capacity. The Lykes ship has a 50% utilization of its container capacity and a 50% utilization of its liquid stowage capacity.
3. All ships are in their first year of operation.

Table VI summarizes the results for the three ships. All figures are annual totals for the ship in question. Appendix A provides details of the calculations for the Lykes

TABLE VI

Comparison Figures for Three Specialized Ships

Catamaran Container Ship:	
50% utilization of salable cubic	
$40.7 million acquisition cost	
25 round trips per year	
Total revenue	$36 million
Total expense	17.4 million
After tax profit (including depreciation)	11.31 million
Capital recovery factor	0.277
Lykes Sea Barge Clipper[25]:	
50% utilization of salable cubic	
50% utilization of liquid stowage capacity	
$32.0 million acquisition cost	
24 round trips per year	
Total revenue	30.85 million
Total expense	13.75 million
After tax profit (including depreciation)	10.18 million
Capital recovery factor	0.319
Meyers' Container Ship[26]:	
50% utilization of salable cubic	
$19.5 million acquisition cost	

TABLE VI (cont'd)

17 round trips per year

Total revenue	$13.8 million
Total expense	7.7 million
After tax profit (including depreciation)	4.0 million
Capital Recovery Factor	0.205

Note: (1) All figures are annual totals for the ship during its first year of operation.

(2) A description of the method used to calculate expenses appears in Appendix A.

ship. Calculations for the catamaran were made in an analagous fashion. Figures for the Meyers ship were taken from his paper.

Both the Lykes and the Meyers ships were designed as high capacity, high revenue ships. The variable mission catamaran in its container ship mode compares favorably with them.

II-4-4 Commercial/Commercial Use

Section I-2-3 suggested the possibility of utilizing the variable mission capability of the catamaran within the commercial market to reduce the owner's vulnerability to changes in market conditions or to allow the owner to take advantage of out of phase fluctuations in the two markets (Ro-Ro and container).

As a first case assume the collapse of container freight rates. This assumption is not altogether groundless. There is considerable fear that the currently rapid expansion will lead to excess container capacity and falling rates.[27] It was shown above that the catamaran owner needs an average rate of $0.18 per ft^3 on his total available capacity in order to cover his long run average costs. Further, he needs a rate of $0.12 per ft^3 ($4.80 per MT) just to cover the marginal costs of making a round trip. If rates fell below $4.80 per MT he could minimize losses by leaving the ship tied up at the pier; by converting the ship to a Ro-Ro cap-

ability(if he owned the modules); or, possibly, by chartering the ship to MSTS in its Ro-Ro configuration.

A second, and far more interesting case, is the one in which the ship operator schedules conversions of the catamaran according to his predicted future market. For example, suppose that demand for container services was either uncorrelated with or was negatively correlated with demand for Ro-Ro services.[28] The fleet ship owner would see this condition in his bookings and could, with good information, allocate his ship to whichever service would provide maximum expected profit (or minimum expected loss). As transport systems become increasingly standardized and planning horizons grow, the ship owner will come to use network scheduling programs to allocate his ships. Such an optimal scheduling would take into account mission change time, costs and expected revenues over the available planning horizon. The owner would know just when it was worthwhile to change and when it was not. Essentially he would manage his capital investment in the ship much as he would any other capital investment.

II-5 REFERENCES

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21. The figure of 3.1 tons was obtained by the author by averaging the weights of various forty foot long containers described in *Jane's Freight Containers 1968-1969*.

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24. Benford, H. "The Practical Application of Economics to Merchant Ship Design."

25. Ship capabilities were taken from Germane, G.E. "Impact of Containerization on Ocean Transportation: Dimensions of the Problem." *Transportation Research Forum*, 1967. Oxford, Indiana: The R.B. Cross Co., 1967.

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28. An attempt by the author to identify the existence of these out of phase conditions proved inconclusive. Shipping firms are reluctant to release data on costs, capacity utilization rates, etc. Another attempt was made through the U.S. Department of Commerce's report series FT 990, Highlights of U.S. Export and Import Trade. Two categories were chosen: electric office machinery and computers as high value container goods, and automobiles as a Ro-Ro good. Total monthly exports and imports of each category were determined and the month-to-month changes compared. It was found that the directions of change were almost perfectly uncorrelated. While this one test is inconsequential when considering the ocean freight markets as a whole, it does suggest that not all markets move together.

PART III

CONCLUSIONS AND RECOMMENDATIONS

In the introduction to these proposals I stated their publication, not as an act of mine, but of some 'publicspirited gentleman,' avoiding as much as I could, according to my usual rule, the presenting of myself to the public as the author of any scheme for their benefit.

B Franklin

PART III

CONCLUSIONS AND RECOMMENDATIONS

The first half of this paper demonstrated the validity of the concept of a commercial/military variable mission ship. Through the catamaran example the second half demonstrated the economic and engineering feasibility of such a ship.

The earning power of the container ship catamaran was shown to compare favorably with other specialized ships. This point is important to the commercial operator. Even more important is the low cost and short conversion time for the mission change package. This point is important from the aspect of national defense and provides a stronger incentive for government aid to the liner construction program than do conventional liners.

The conclusions of this paper are:

(1) that the variable mission concept should be considered during the design formulation stages of new ships for both military and commercial purposes;

(2) that new ships may, in some cases, be thought of as basic, functional transport vehicles carrying different complex mission packages;

(3) that, when used, the variable mission ship offers the possibility of a large increase in effectiveness at relatively low cost.

The economic feasibility of a specific example of a commercial/commercial variable mission ship has only been

suggested in this paper. Study of the economic feasibility of commercial/commercial variable mission ships in general is recommended as a future topic. A detailed study of ocean freight patterns might serve to identify individual markets that could be exploited by a commercial/commercial variable mission ship. Another possibility is the case where changes in mission would be environmentally controlled due to seasonal changes in ice conditions or water levels. Many similar possibilities exist.

APPENDIX A

For purposes of profitability comparison the catamaran, the Lykes Sea Barge Clipper, and the container ship of Meyers[1] were chosen. The expense figures for Meyers' ship are given in his paper for a single round trip and the same format was used in the estimates for the catamaran and the Lykes ship. The procedure used was to first estimate revenues and expenses for a single round trip and then to multiply by the expected number of trips per year to get the annual totals for purposes of comparison.

All references to equation numbers in this Appendix correspond to the numbers in Benford.[2] The 1962 dollars of Benford are corrected to present (1968) at 6% per year (factor of 1.42).

The following steps outline the estimates made on the Lykes ship.

<u>Ship Characteristics</u>[3]

Acquisition cost[4]	$32 million
Maximum number of 20'x8'x8' containers	1550
Maximum liquid load capacity	35,000 tons
Fuel rate at 20.8 kts	150 tons per day
Length between perpendiculars	723
Beam	107
Operating draft	31

Depth	72.5
Shaft horsepower	33,000
Cubic number	56,200

Round trip (RT) on Boston-Hamburg route:

	Sea time at 20.8 kts	14 days
	Turnaround time (2 ports)	1 day
	Total round trip	15 days
Round trips per year		24

Revenue per Round Trip

Container freight rate assumed $0.60 per cubic foot

Liquid load freight rate assumed $6.85 per long ton

50% utilization of containers and liquid load capacity is assumed.

Container Revenue = (2)(1550)(20x8x8)(.88)(.5)(0.60) = $1.045 million per RT

Liquid Load Revenue = (2)(35,000)(.5)(6.85) = $239,000 per RT

Wages

A crew of 42 was assumed.

Eqn (26): with 24 round trips per year, crew cost per RT is $32,000.

Subsistence

Benford estimated annual cost at $770 per man in 1962.

Cost per RT - $1910

Stores, Supplies

Eqn (29): Cost per RT - $1465

Maintenance and Repair

Eqn (27): Hull - $8700 per RT

Eqn (28): Machinery - $2740 per RT

Insurance

Eqn (31): Protection and Indemnity - $2400

Eqn (32): Hull and Machinery - $13,850

War Risk - Benford estimated 0.1 percent of invested cost in 1962.

Cost per RT - $1895

Total Insurance Cost - $18,145 per RT

Other Vessel Expense, Misc. Operating Expense

Benford estimated $65,000 + $2 x Cubic Number in 1962.

Cost per RT - $10,500

Fuel Oil

Benford estimated cost at $2.15 per barrel in eastern U.S. in 1962.

Cost per RT - $41,300

Port Expenses

Eqn (33): Cost per call - $1890

Two ports of call - $3780

Eqn (34): Cost per day - $682

One half day turnaround time in each port gives total cost of $682 also.

Total Port Expense - $4462 per RT

Other Cargo Expenses, Container Operation

These two categories total $43,950 per RT for the Meyers ship but are otherwise unexplained. This figure is equivalent to $0.019 per cubic foot of the salable cubic capacity of Meyers' ship. It is assumed that the same cost of $0.019 per cubic foot applies to the Lykes ship as well.

Cost per RT - $33,200

Liquid load expenses are unknown, but are felt to be low compared to the figure for containers.

Administration and General, Advertising, Organization

The total figure is taken to be the same as that of Meyers

Cost per RT - $26,851

Vessel Depreciation

A 25 year, 7% mortgage is assumed. The 7% includes mortgage insurance premiums. During the first year the figures are:

Interest per RT - $93,300

Principal per RT - $21,400

Cargo Handling and Freight Acquisition

For containers, Meyers' figure of $0.10 per foot of salable cubic capacity is assumed.

For liquid load $2.00 per long ton is assumed.

Container handling - $174,500 per RT

Liquid handling - $70,000 per RT

Summing the expenses (not including principal on the mortgage) gives a total round trip expense of $572,373 or $13.75 million per year.

Round trip revenue was $1.284 million or $30.85 million per year.

At a 48% tax rate, after tax profits with depreciation added in are $10.18 million which is the figure shown in Table VI.

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