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THESIS

SEASHEDS, A SEALIFT ENHANCEMENT FEATURE:
AN ANALYSIS OF METHODS EMPLOYED FOR
LIFTING DOD'S OUTSIZE CARGO

by

Tommy J. Johnson

September, 1993

Thesis Co-Advisors: Dan C. Boger
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This thesis examines seasheds as a method for carrying non-containerizable military cargo on commercial containerships in the U.S. merchant marine fleet. Seasheds are enhancement features for containerships that convert them for the purpose of carrying military unit equipment. Seasheds were developed by the Department of Defense during the 1980s to provide carriage of outsize military cargo for strategic deployments, and they have not been utilized for commercial applications. They have been used in only two military employments, Display Determination '89 and Operation Desert Sortie in 1991. Performance reports indicate they successfully handled outsized military cargo which otherwise could not be transported on unmodified containerships. However, the lack of commercial applications hinder their usefulness outside of DOD sealift requirements. Costs and times required to load and unload a containership under the normal sequence of seashed activities are compared with activities required if seasheds were preboarded on a specified containership to enhance readiness of merchant marine fleet containerships by making them more compatible with DOD's sealift requirements. A cost-benefit analysis is performed to assess the time and expenses that could be saved for DOD if seasheds were preboarded on containerships. Examination of Seasheds is recommended for contingencies that require logistics-over-the-shore (LOTS) operations.

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by

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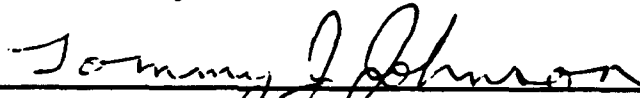Lieutenant, United States Navy
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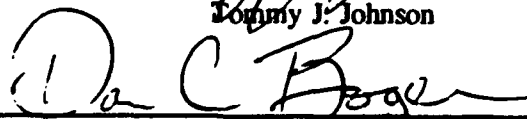of the requirements for the degree of
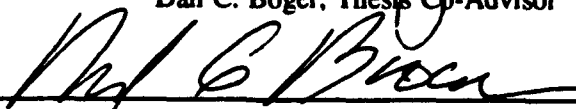
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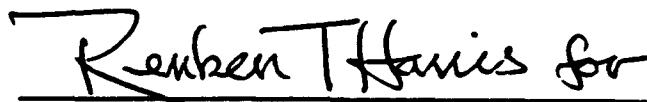
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ABSTRACT

This thesis examines seasheds as a method for carrying non-containerizable military cargo on commercial containerships in the U.S. merchant marine fleet. Seasheds are enhancement features for containerships that convert them for the purpose of carrying military unit equipment. Seasheds were developed by the Department of Defense during the 1980s to provide carriage of outsize military cargo for strategic deployments, and they have not been utilized for commercial applications. They have been used in only two military employments, Display Determination '89 and Operation Desert Sortie in 1991. Performance reports indicate they successfully handled outsized military cargo which otherwise could not be transported on unmodified containerships. However, the lack of commercial applications hinder their usefulness outside of DOD sealift requirements. Costs and times required to load and unload a containership under the normal sequence of seashed activities are compared with activities required if seasheds were preboarded on a specified containership to enhance readiness of merchant marine fleet containerships by making them more compatible with DOD's sealift requirements. A cost-benefit analysis is performed to assess the time and expenses that could be saved for DOD if seasheds were preboarded on containerships. Examination of Seasheds is recommended for contingencies that require logistics-over-the-shore (LOTS) operations.

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I. INTRODUCTION

When the United States goes to war, it goes overseas - and 95% of all its military cargo goes by sea. It follows that U.S.- controlled cargo ships in adequate number and mix are vital to our national security interests. Additionally, it makes good sense to haul and control a fair share of U.S. commerce in U.S.-flag, civilian-owned and -operated merchant ships. Today's U.S.-flag fleet does not meet the criteria for hauling our normal imports and exports, and both government- and civilian -owned ships fall short of meeting our emergency military needs. (Ackley, 1992)

A. BACKGROUND

The war in the Persian Gulf demonstrated many of the strengths and weaknesses of the nation's strategic sealift capabilities. The United States Transportation Command (USTRANSCOM), in concert with its transportation component commands -- Military Airlift Command (MAC), Military Sealift Command (MSC), and Military Traffic Management Command (MTMC) -- moved nearly 504,000 passengers, 3.7 million tons of dry cargo, and 6.1 million tons of petroleum products into the area of responsibility (AOR). (Matthews and Holt, 1992)

One of the most telling weaknesses in Operation Desert Shield/Desert Storm, however, was the reduced size of the U.S.-flag merchant fleet, which shrank from 3,000 vessels after World War II to 367 in 1990. (Ackley, 1992) Many of those 367 ships are commercially efficient containerships

which require high-tech cargo piers or offboard cargo handling equipment for loading and unloading. (Ackley, 1992) Additionally, containerships are not designed to haul outsized military cargo such as tanks, trucks, artillery, and aircraft which cannot fit into a container.

> The situation would only get worse. The Maritime Administration (MARAD) predicted that the U.S. Merchant fleet would continue to decline, from 168 militarily useful dry cargo ships in 1990 to 35 by the year 2005. (Matthews and Holt, 1992)

The 367 active U.S.-flag merchant ships will not be around forever. Some maritime experts estimate that, unless policies are changed, the U.S.-flag dry cargo fleet will decrease about 85% through the year 2005, and militarily useful tankers will decrease about 70%. The combined loss may represent more than 200 ships. (Ackley, 1992)

During Operation Desert Shield, USTRANSCOM turned to foreign flag ships to meet the logistics needs of the deployment. Fortunately, the political climate was favorable because Operation Desert Shield/Desert Storm was a U.N.-sponsored action, and the U.S. did not have to declare a national emergency, whereby control of U.S.-flag ships would be taken by the government under the legal provisions of the Sealift Readiness Program. Instead, foreign flag vessel were used to lift the outsized equipment requirements which were not met by U.S.-flag ships.

B. PROBLEM

Reliance on foreign flag ships to meet a military emergency is a precarious situation which could jeopardize the effectiveness of the nation's sealift capability and hence national security. It is difficult to predict the continued successful use of foreign flag vessels in the future. For example:

> Some of our allies made ships available but prohibited them from entering the combat zone. The crew of the Japanese freighter Sea Venus, which was loaded with military vehicles, refused to carry its cargo to Saudi Arabia. Similar manageable incidents occurred during the U.S. logistic support of Israel in the 1973 war and during the Viet Nam War. In the former case, U.S.-chartered Liberian tankers would not deliver petroleum products to Israel; and in the latter case, some Asian crews in foreign-flag ships would not sail with war supplies from Oakland to South Viet Nam. (Ackley, 1992)

Considering the reduced size and declining trend of the U.S.-flag fleet described thus far, the strategic issue which arises is how the U.S. can regain a strategic sealift capability to ship outsized military cargo wherever and whenever it is needed without dependence on allied support.

In an effort to ameliorate the sealift shortfall during the 1980s, along with other sealift enhancement features, the government acquired 890 seasheds, an enhancement feature that permits containerships to carry outsized military equipment. However, utilization of seasheds during Desert Shield and Desert Storm was very low. They are positioned in Bayonne, New Jersey; Charleston, South Carolina; and Port Hueneme, California. Yet, of the 890 available, only 13

were utilized. The specific issues that are examined in this thesis are:

- What are the times and resources required to set-up and install seasheds?

- What are the hindrances to the employment of seasheds?

- Would there be an increase in readiness of the RRF with seasheds preboarded on containerships in the event of a crisis situation?

C. SCOPE, LIMITATIONS, AND ASSUMPTIONS

This research is concerned with the policy issues involving the utilization of seasheds and the consequences of their non-utilization in exercises and war-time contingencies. A technical analysis of various containership capabilities is beyond the scope of this study. However, a group of technical drawings which illustrate the spaces which can be occupied by seasheds and containership cargo stowage adapters (CCSAs) by modern containerships and combination container-breakbulk ships is provided in Appendix A.

The Army is considered the primary consumer of the sealift of outsized equipment. Navy amphibious ships, including the Marine Corps combat cargo, LASH, and other ships capable of carrying outsize equipment are purposely excluded from this thesis in anticipation of their military mission employment during deliberate action planning or

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crisis action planning. Employment of commercial containerships capable of accommodating a mix of seasheds, CCSAs, and heavy duty flatracks in anticipation of exhausting the supply of RO/ROs, will be the primary focus of this thesis since unit equipment carriage is essential during mobilization.

D. RESEARCH METHODOLOGY

This thesis examines containerships in which seasheds must be carried if the ships are to be employed. It explains deployment planning and how the employment of seasheds could be included in the process. A significant amount of information was obtained from personal interviews with individuals assigned to transportation commands, government transportation agencies, and private industry. The primary methodologies employed included the following:

- Interviews with officials from Military Sealift Command (MSC), U.S. Transportation Command (USTRANSCOM), Military Traffic Management Command (MTMC), and Maritime Administration (MARAD)

- Interviews with consultants, McCaffery and Whitner Inc., a recent provider of cost estimates for containership conversions for seashed installation.

- Review of published and unpublished articles on seasheds and containerships.

- A model of activities required to employ seasheds is designed and simulated for analysis of the costs and times required for seashed employment.

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In addition, a time-versus-cost tradeoff analysis is conducted using the critical path method and project crashing techniques which are decision support technologies designed to aid in accurate cost and time estimates for unique projects. Project crashing is used to project cost alternatives.

Actual cost data from after action reports from Display Determination '89, performance data from Operation Desert Sortie, as well as financial data provided by Military Sealift Command, was used to the greatest extent possible; however, some assumptions and estimations were necessary to formulate the model. This research should be considered useful for providing a method of analyzing seashed employment cost and time tradeoffs for future studies.

E. THESIS CONTENTS

Chapter II next provides an overview of sealift requirements and the sealift mix alternatives available. Chapter III covers the background of containerization and the military usefulness of containerships with and without seasheds. It also addresses the advantages and disadvantages of seashed to government and industry.

Chapter IV presents seashed employment information such as deployment planning factors, transportation feasibility, seashed availability, and the types of military units that could employ seasheds for their deployment.

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This information and other data is analyzed in Chapter
V. A model is formulated which simulates some of the data
to generate cost and time estimates. These estimates are
used to compare normal operations with the use of preboarded
seasheds on a containership. The summary and conclusions
are presented in Chapter VI. It also includes
recommendations for further research.

II. SEALIFT REQUIREMENTS

The purpose of this chapter is to examine military
sealift requirements as viewed by government agencies, such
as the United States Transportation Command (USTRANSCOM)
and, the Maritime Administration (MARAD) of the United
States Department of Transportation, which employ the
sealift assets provided from the U.S.-flag fleet and
government owned sealift assets. It discusses the sealift
mix alternatives and considers policies which could minimize
the risks of a shortfall in sealift capability.

> Although certain military mission requirements will
> still dictate the development and acquisition of
> specialized transportation assets not found in the
> commercial market, the majority of transportation assets
> can be expected to be available from the commercial
> sector. It is recognized however, that a successful
> military cargo system that employs intermodal systems is
> dependent upon an actively functioning U.S. Flag
> merchant fleet that can be readily available to perform
> sealift missions. The greater the compatibility of
> equipment of the U.S. Flag fleet with DOD's sealift
> requirements, the greater can be the reduction in costs
> associated with the development, acquisition and
> stockpiling of specialized Government-owned assets.
> (MARAD Report No. MA-RD-840-90015, 1990)

A. THE SEALIFT MIX

A clear-cut lift requirement level has not been
established since the radical changes in Eastern Europe,
including the reunification of Germany and the

disintegration of the Soviet Union. America is the sole superpower in the world and has an unprecedented leadership role in world affairs. Unilateral military action on a large scale is not a likely contingency because the U.S. continues to be influential within the United Nations. However, a leadership role in military or humanitarian actions such as Operation Restore Hope in Somalia may help shape future sealift requirements.

Historically, sealift has provided 90-95% of the overall lift requirements for major combat expeditionary operations. Although the Persian Gulf War was consistent with this proportion, the inability of the U.S. flagged fleet to meet the surge requirement in the initial phase without the assistance of foreign flagged vessels has identified a shortfall in sealift capability.

> The war in the Persian Gulf heightened USTRANSCOM's concerns for the health of the nation's maritime industry. At the end of World War II, there were thousands of US-flagged Merchant Marine ships carrying over 50% of US foreign ocean-going trade. By 1970, the number of ships in the US Merchant Marine had dropped to 894 with a corresponding decrease in the amount of US trade they carried. The United States, the largest trading nation in the world, carried in 1990 less than four percent of its trade on US-flagged ships. (Matthews and Holt, 1992)

A recent study conducted by MARAD, initiated to address alternatives to stockpiling government-owned National Defense Features (NDFs) and Sealift Enhancement Features (SEFs) cited that the military sealift capacity of our U.S.-flag fleet is declining yearly. It further stated that the

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versatile, militarily useful breakbulk ship is fast fading from the fleet and is being replaced by the large specialized non-self-sustaining containership which reduces the flexibility needed to meet traditional military sealift requirements. (MARAD Report No. MA-RD-840-90015, 1990) The exact cause and effect relationship of containerized shipping and the decline in militarily useful breakbulk shipping is beyond the scope of this thesis. However, the issue that is presented by its decline is whether DOD should consider employing enhancements of U.S.-flag containerships which remain available by using seasheds or if DOD should continue to utilize foreign shipping to carry its unit equipment as a money saving measure.

The ships considered militarily useful include, among others, those dry cargo vessels considered most useful for military mobilization. They are not confined to U.S. flagged fleet assets, but are drawn from ships fitting any of the following criteria:

- An ocean-going dry cargo vessel over 6,000 Dead Weight Tons (DWT).

- A coated tanker between 6,000 and 80,000 DWT.

- An integrated tug-barge unit.

- A dry cargo ship with special military capability.

- A National Defense Reserve Fleet (NDRF) or Ready Reserve Fleet (RRF) vessel retained for national defense purposes.

- A NATO dry cargo vessel.

- U.S. and effective U.S.- controlled passenger ships (EUSC).

- A vessel meeting the above criteria in the EUSC.

Ships that are _not_ militarily useful include dry bulk or ore ships, LNG/LPG, special product tankers, refrigerator ships, ferries, harbor tugs, tankers over 80,000 DWT, any size uncoated tanker, and Great Lakes operators. (Sweeney, 1984)

B. ROLL-ON/ROLL-OFF (RO/RO) VESSELS

Military Sealift Command relies heavily on commercial transportation to meet sealift requirements. RO/RO vessels have been the most militarily useful. In the late 1960s, commercial fleets began using containerships. As a result, ships capable of handling military unit equipment, such as breakbulk and RO/RO, became commercially unprofitable (MSC Annual Report, 1990). The trend toward containerships was accompanied by a significant shrinkage of the U.S. maritime industry. In fact, with the sole exception of containerized liner shipping, in which U.S. operators have been able to maintain a respectable share of U.S. trade, U.S. shipping in general carries a negligible proportion of U.S. foreign trade. (Frankel, 1986)

MARAD has purchased 12 RO/ROs for the RRF in June, 1993, bringing the total RRF to 109 ships. The average age of the purchased vessels is 13 years, and their procurement cost

was $266.2 Million. Three of them were already U.S. flagged, and the others were foreign flagged vessels before their purchase. (Corkrey interview, 1993) With DOD's budget dwindling each year and an identifiable shortfall of sealift capability, the Navy is looking more closely at the containership as an alternative shipping method in the sealift mix.

According to Stopford, container movements worldwide increased from 17.4 million twenty-foot equivalent units (TEU) in 1975 to 55 million TEU in 1985, a threefold expansion in ten years. These figures cover total container movements through ports, including empties. They also cover feeder and local services. (Stopford, 1990) Because they are competitive internationally, the number of U.S. flagged containerships is not eroding as rapidly as breakbulks and RO/ROs.

If U.S. defense planning includes military intervention without allied support, then more compatibility with the commercial shipping industry will increase DOD's ability to lift large scale requirements in the timeframes required.

The upward trend of containers and downward trend of militarily useful vessels places the U.S. commercial shipping industry and DOD shipping requirements on divergent paths. This is largely due to the incompatibility of containerships with outsized bulky unit equipment such as tanks, trucks, bulldozers, and helicopters. Military

strategists voiced concern about the lack of surge sealift capability and convinced Congress to approve a major sealift enhancement program in the 1980s. The cost for the program was over $7 billion. The Navy acquired eight fast sealift ships; 13 Maritime Preposition Ships configured to support three Marine Expeditionary Brigades; 11 other afloat prepositioning ships to carry chiefly U.S. Army and Air Force equipment; two hospital ships; two aviation logistics support ships; and 96 ships for the Ready Reserve Force. (MSC Annual Report, 1991) As Figure 1 indicates, 77 militarily useful ships are controlled by MSC as of March of 1993.

C. THE RISK OF SHORTFALLS IN SEALIFT CAPABILITY

During the 1980s the major focus of military strategy was aimed at potential conflicts between superpowers, and contingencies were planned for larger threats than Iraq. Given the seapower that the former Soviet Union wielded, its capability to strategically disrupt sea lanes of communications (SLOCs), and its larger force structure compared with Iraq's, it follows that those military plans would almost certainly leave more than sufficient capacity for sealift on a smaller scale, sufficient to handle a threat of Iraq equivalent size in the Persian Gulf. However, we can reasonably expect spot and/or regional

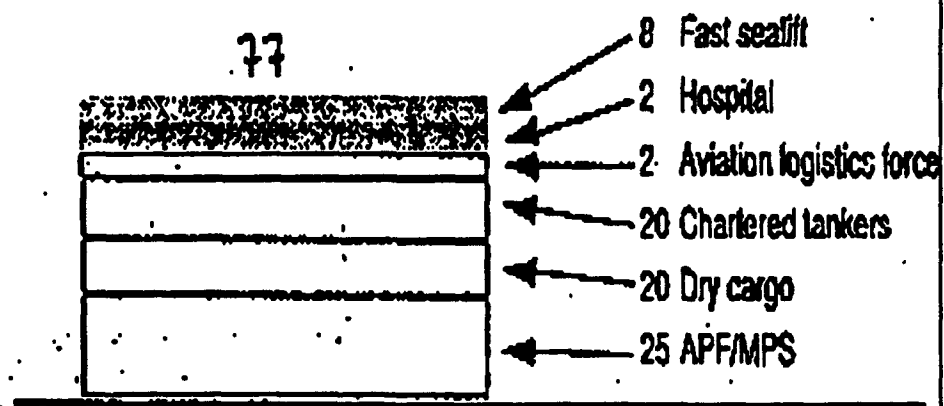# ACTIVE STRATEGIC SEALIFT

March 1993

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8 Fast sealift
2 Hospital
2 Aviation logistics force
20 Chartered tankers
20 Dry cargo
25 APF/MPS

Figure 1 Source: MSC Headquarters Code (N52)

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shortages of specific types of transportation assets throughout any major response to mobilization, deployment, or crisis; every contingency cannot be planned for. Some contingencies will be dismissed by planners as being realistic but not probable and, upon their occurrence, will wind up evolving into a crisis situation. For example, after Operation Desert Storm the scarcity of RO/RO and combination RO/RO-container vessels was readily identified as a problem that must be addressed by DOD. In that crisis situation, the contingency of deploying to the Persian Gulf resulted in a RO/RO shortfall partially as a result of dismissing the contingency as realistic but improbable.

After identifying the sealift shortfalls from Desert Shield, General Hansford Johnson, the Commander-in-Chief of U.S. Transportation Command, testified before the House Armed Services Subcommittee on the needed sealift reforms. He stated that the military needs the following improvements in strategic sealift to guarantee necessary power projection capabilities:

- Build eight to 10 new Strategic Sealift Ships (SSS). These ships would serve the same role as the FSSs, but would incorporate the diesel propulsion system and would travel at only 25 knots.

- Purchase 20 more modern RO/RO ships on the open market. These ships would be added to the Ready Reserve Force (RRF), and replace a comparable number of breakbulk ships.

- Purchase an unnamed number of Afloat Prepositioning Ships.

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- Improve the readiness and maintenance level of the RRF (Sowers, 1991)

An alterative view of this testimony stated that not only is this request tremendously expensive, but empirical evidence also strongly suggests that strategic mobility policy makers may have incorrectly interpreted the lessons to be gained from the government's dependence on foreign-flagged ships during the war with Iraq. A different perspective might indicate that the U.S. had not exhausted all its available sealift assets. Rather than buying more military-owned ships, perhaps the U.S. could meet its sealift requirement without foreign assistance if it used the largely untapped sealift source of the U.S. merchant containership fleet.

Foreign ships transported approximately 15% of the cargo tonnage during Desert Shield. (Sowers, 1991) One question that this fact raises is: Since the U.S. transported 85% of the cargo, can containerships make up the shortfall that foreign-flag ships were asked to carry? The answer is yes when the seashed and flatrack enhancements are considered. However, the cost could be higher than foreign charters. Fiscal constraints, requiring judicious cost effective decisions in the current operating budgets, cause military officials to view seashed sealift enhancement features (SEFs) as a last ditch measure because of expected high costs and large differences in estimated costs associated

with their use. This thesis provides a cost estimation procedure that should dramatically reduce the cost estimate differences, and a decision support model that makes the estimated cost and loading time more accurate.

The next chapter discusses the background of containerships in which seasheds and flatracks can be employed. It examines their military usefulness and compares their employment in military operations with commercial operations.

III. CONTAINERSHIPS, SEASHEDS, AND FLATRACKS

The purpose of this chapter is to provide background

information on the commercial industry's development of

containerized shipping and the Department of Defense's

utilization of containers in shipping. It contains

information on significant issues impacting DOD's use of

containerization, and is focused on the evolving issues

which have impacted the structure of the maritime industry

and its capability to provide strategic sealift for DOD. A

specific assessment of the industry's free market mechanisms

compared with DOD's alternatives for attaining sustainable

sealift capabilities is presented in this chapter. Special

emphasis is given to the impact that outsized equipment has

on sealift capabilities, because it is the equipment that

seasheds and flatracks were designed to carry.

A. BACKGROUND

At sea, container tankers were introduced in the New
York to Houston trade in 1956, and in 1958 the
California to Hawaii trade was containerized. The first
deep sea container service was started on the North
Atlantic in early 1966 by Sea-Land, a company set up by
Malcolm MacLean, who was a trucker rather than a
shipowner. His experience with the trucking industry
had convinced him of the merit of a cargo handling
system that could use all three transport modes - road,
rail and sea. The major European liner shipping
companies had by this time also made the decision to set
up their own container services. This involved a major

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investment in completely new ships, shore-based handling
facilities and of course containers themselves.
(Stopford, 1990)

The coastal shipping business had been in a steady
decline after World War II because breakbulk service could
not compete against trucks and railroads. (Muller, 1989)
But, by using the trucking concepts of containerized
transport, MacLean was able to develop a comparative
advantage for waterborne trade.

> He experimented without interference from foreign
> shipping lines because he was dealing with intra-U.S.
> (and territorial) traffic. After perfecting his system
> and methods on domestic service, MacLean invaded the
> international field. (Muller,1989)

As the economic resources to supply different sizes of
containers and intermodal systems became scarce, a
requirement of the deep sea trade arose that all countries
should use the same standard containers. To meet this
requirement, the International Standard Organization (ISO)
devised a standard set of external container dimensions,
initially offering a box 8 feet high and 8 feet wide, with
four optional lengths, 10 foot, 20 foot, 30 foot, and 40
foot.

In practice, the 20-foot container became established as
the primary mode of international container business. Out of
the total container stock of 4.8 million TEU (twenty-foot
equivalent units) in 1986, about two thirds were 20-foot
units and the remaining third were mainly 40-foot units.
(Stopford, 1990)

The impact of the container revolution on the maritime
industry is not straightforward and simple to trace through
direct competition among independent competitors. It has
been affected by governments and shipowner conferences as
well as shipper associations.

> The overwhelming efficiency of containership operation
> forced many shiplines to convert to this more efficient
> system, move on to other trade routes, or perish,
> despite the helping hand of government regulation and
> subsidy or conference protection. (Muller, 1989)

The number of ships in the U.S. flagged fleet has
dramatically decreased since containerization has developed
into its role as the predominant method for shipping cargo
in the world shipping market. The causes and effects of the
decline in the U. S. Merchant Fleet are beyond the scope of
this thesis, but it is worth noting that the military
usefulness of this fleet is a topic which is relevant to
this thesis and is discussed further in this chapter.

1. Commercial Advantages of Containerization

The history behind containerization makes the
advantages easy to identify and makes the decisions for the
shipper who is familiar with containerization relatively
simple. They are traceable to several economic advantages
that containerization supplies the shipper, the carrier or
both parties. The following list contains only a few of the
major advantages of containerization.

1) Containerization permits door-to-door service without intermediate handling of the contents at transshipment points, because they can be transferred between ships trucks, aircraft, and trains.

2) Less congestion at ports.

3) Reduced risk of loss or damage to cargo.

4) Mechanization of cargo handling reduces labor cost.

5) Containerization has permitted fleet reduction. On the average one containership has displaced six smaller and slower breakbulk ships. (Not necessarily an advantage to the military shipper; each ship sunk by the enemy would mean a larger cargo loss.)

6) Intermodalism improves the customer service benefits to the customer by offering:

- A single bill of lading;

- A through rate that covers both maritime and surface transportation costs;

- Greater reliability of delivery over loose shipments; and

- In-transit visibility (electronic tracking is easier to employ). (Sowers, 1991)

2. Disadvantages of Commercial Containerization

The list of disadvantages is also long but it is greatly overshadowed by the commercial advantages; the major disadvantages relevant to this thesis are listed below.

- Containerization is capital intensive. The required investments range from large inventories of containers, containerships, container handling equipment, chassis, and large developed terminals, to automated inventory systems.

- Outsize equipment is not containerizable. While various specialized containers are designed to handle outsized material, bulk, and liquid, these types of containers are not always available.

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- Some trade routes are imbalanced with more imports than exports. This means empty containers must be transported back to the origin without profitable trade goods. (Sowers, 1991)

3. Initial Military Uses for Containers

The first documented use of containers by the military was with the Army Transportation Corps during the Korean War:

> The principal reason was to afford protection to valuable material, which was subject not only to environmental damage but also to pilferage. This initial use of the container for military purposes led to the subsequent development of the CONEX (container express) in 1953. The introduction of CONEX was the first large-scale effort by the DOD to incorporate the container concept into the military transportation system.... As the benefits of containerization were embraced by commercial liner firms, use of containers in ocean transportation multiplied. The Vietnam conflict stimulated DOD's interest in the use and the importance of containerization. When the limited benefits of the CONEX container proved inadequate to handle the volume of material required, a concerted effort was made by DOD, to introduce commercial container service. During this period most of the containerizable dry cargo, aside from ammunition, was converted to container service. (Sweeney, 1984)

By the end of the Vietnam conflict, containerization had developed into an industry standard for commercial shipping and the vessels that replaced the older breakbulk vessels were containerships capable of carrying containers stacked in cells within the ship and on deck.

4. DOD Containerization Policy

The Department of Defense has defined objectives, as stated in DOD Directive 4500.37 of 2 April 1987 "Management

of the DOD Intermodal Container System," to establish a container oriented distribution system capable of meeting potential mobilization and deployment goals. The objective was aimed at establishing containerized shipments as the preferred method of movement of military vehicles, equipment, and supplies unless cost effectiveness or peculiar shipping requirements are overriding factors.

The objectives are not limited to container control issues such as their development, purchase, or lease. The purpose of the DOD containerization objective is to enable the attainment of mobilization and deployment objectives by employing transportation industry assets supplemented by DOD assets.

The directive does not make policy in which systems are recommended for procurement for the mobilization and deployment requirements but rather recommends cooperative effort of the military services and the commercial transportation industry. DOD's preference is to use the commercial industry's common intermodal equipment such as freight containers, flatracks/platform containers, terminal equipment and line-haul equipment. In order to utilize the commercial transportation infrastructure, DOD-furnished equipment should be intermodal equipment that fulfills each service's unique requirements.

While speaking on the topic of containerization during a seminar on MSC's operational roles in strategic

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sealift, Marine Lt. Colonel Dan Dykstra of MSC Headquarters
Plans Division (N52) pointed out:

> We should rely on the commercial sector as much as we
> can before we attempt to set up a system for ourselves
> when they already have a system that works. (Dykstra
> interview, June 1993)

Such a policy would support the objectives of DOD
containerization in promoting government and private sector
cooperation whenever possible. However, when the commercial
sector cannot commit its assets to provide for unspecified
contingency requirements, the Government is exposed to a
risk of a shortfall in strategic sealift assets.

The inventory of militarily useful U.S. flag ships,
as of March 1993 and as tabulated by MSC, is presented in
Figure 2. Of the 260 ships considered militarily useful by
MSC, eighty-six are containerships and eight are
container/breakbulk ships.

U.S. FLAG
MILITARILY USEFUL

March 1993

260

- 2 passenger
- 126 tanker
- 1 FLO/FLO
- 8 container/breakbulk
- 7 LASH
- 10 RO/RO
- 86 container
- 5 container/RO/Ro
- 10 breakbulk
- 6 car carriers
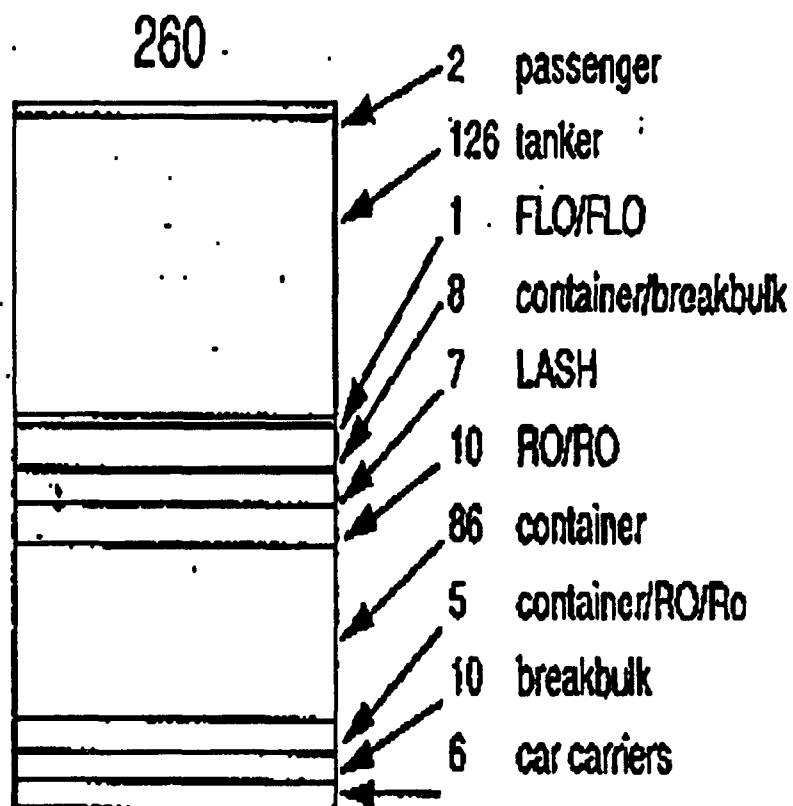
Figure 2   Source: Military   Sealift   Command
Headquarters Code (N52) Plans Division

B. CONTAINERSHIPS AND INTERMODALISM

From the early development of containerships, multiple types of ships were built with different capabilities which may be classified into two general categories: self-sustaining containerships (SSCs) and non-self-sustaining containerships (NSSCs). The SSC can load and unload its cargo with its gantry crane or integral lifting equipment. The NSSC is not equipped with lifting equipment and must depend on external cranes to load and unload its cargo. Supporting both of these ship designs requires flexibility, because although they both carry containerized cargo, their cargo handling requirements for loading and unloading at a port are different. Hence, the major port services that each ship type receives are different.

> As trade routes were developed to take advantage of the newer containerships, major ports were redesigned into elaborate containerports with giant container cranes; thus there was no need to incur additional expense by constructing self-sustaining containerships... This progressed to the point that all of the containerships now under construction in the United States are non-self-sustaining. The trend has also been toward larger and faster vessels in order to further increase the advantage of service and volume. (Sweeney, 1984)

The development of major ports with mechanized cargo handling capabilities led the commercial container handling companies to construct intermodal freight routes which expanded to cover land, sea, and air routes.

Intermodalism and containerization are advantageous to
shippers and carriers in several ways:

- Reduced congestion in the port by mechanized cargo
  handling.

- Reduced cargo handling costs because cargo is handled
  fewer times between origin and destination.

- Less cost for idle time for shipowners and delayed
  service to shippers.

- Less labor cost shoreside to load and discharge a
  containership compared with a breakbulk ship.

- Door-to-door transportation service provided by
  utilizing more than one mode of transportation. A
  container may be transported by any combination of
  truck, rail, sea, and sometimes air.

C. MILITARY USEFULNESS OF CONTAINERSHIPS

The Maritime Administration (MARAD) of the U.S.
Department of Transportation has identified features that
can enhance a commercial ship's military capability.
National Defense Features (NDFs) or Sealift Enhancement
Features (SEFs) basically fall into three categories:
productivity enhancements, survivability enhancements, and
operational enhancements. Table 1 is an initial list of the
potential ship enhancement features described by MARAD.
Each enhancement, as evaluated by MARAD, is matched with
commercial ship types based on its military mission
enhancing capability.

Table 1: INITIAL LIST OF POTENTIAL SHIP ENHANCEMENTS

Source: MARAD Report No. MA-RD-840-90015, 1990

PRODUCTIVITY ENHANCEMENTS

A. Heavy-Duty Flatrack
B. Container Hardpoints
C. Seashed System
D. Lighter Stowage Ancillaries
   (Weather Deck Fittings)
E. Crane Enhanced Containership
F. Containership Strike-up System
G. Vertical Replenishment (VERTREP) Deck
H. Vehicle Tiedown System
I. Troopship Configuration
J. UNREP Consolidation System
   (Dry Cargo/Ammunition)
K. Modular Cargo Delivery Station
L. Side Loadable Ancillary
   (Rails for Side Loadable Causeway Sections)
M. Alongside Lighter Mooring
N. UNREP Consolidation (POL)
O. Astern Refueling Rig
P. Modular Fuel Delivery Station
Q. RO/RO 'Tween Deck
R. LASH Lift Beam
S. Tank Top Support Structure

SURVIVABILITY ENHANCEMENTS

A. Damage Control Equipment Upgrade
B. Compartment Subdivision
C. Exclusion of Gray Cast Iron
D. Positive Ventilation
E. Chaff Launcher
F. Closed Loop Fire Main
G. Fire Suppression System
H. NBC Washdown

OPERATIONAL ENHANCEMENTS

A. Communications Upgrade (Nonsecure)
B. Communications Upgrade (Secure)
C. Lighting Package
D. Navigational Enhancement
E. Refueling Riser
F. Coated Tanks and Pipes (JP-5 Capability)
G. Additional Berthing
H. Water Distiller Upgrade
I. Bow Thruster
J. Pumping Rate Upgrade (Cargo Oil)

Four mission areas are used to evaluate whether a commercial ship is militarily useful with the enhancements included:

- Combat Logistics Force (CLF) Resupply;
- Replenishment of Combatants;
- Reinforcement and Sustainment; and
- Assault Follow-on Echelon (AFOE) Resupply.

The assessment of the enhancements are judged to be mission essential, preferable, insensitive, or not applicable. Each enhancement is also assessed from a commercial viewpoint. The commercial viability of the productivity features offer the greatest compatibility with military applications. A few of the survivability and operational enhancements offer potential for military usefulness. After it has been assessed, an enhancement can be deemed desirable, undesirable, or insensitive and prioritized from both the military and the commercial viewpoint. (MARAD Report No. MA-RD-840-90015, 1990)

1. Productivity Enhancements

Commercial containerships have the capability to carry large quantities of containerizable cargo at relatively high rates of speed with a capability of rapid onload and offload in port operations. Pure containerships do not, however, have the flexibility of accommodating

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outsize cargo as do breakbulk ships, or the versatility of combination container RO/ROs or straight RO/RO ships. The containership can, however, be enhanced to fit the dimensions of outsize cargo by installing Sealift Enhancement Features (SEF) such as seashed or flatracks.

Because of the shortage of RO/RO, barge and breakbulk ships, in a major contingency, containerships must have the capability to carry surge cargo, i.e, initial combat equipment. Depending on the military unit, only about a quarter of the Army unit equipment, because of its size, can be carried in standard commercial containers.

Through seashed and flatrack programs, the Navy can provide the capability to carry large military vehicles and outsize cargo that cannot be containerized. A flatrack provides a means of carrying outsized cargo and may be used with or without containers or seasheds. Figure 3 illustrates a flatrack. Its steel frame, wooden floor and steel or wooden bottom support, and open sides are designed to fit inside the vertical cell guides of a containership.

Seasheds provide temporary decks in containerships for transport of large military vehicles and outsize military cargo that will not fit into containers. Figure 4 illustrates a seashed as it would be used in a containership hold. Each seashed is a structure (40'L x 24'W x 12.5'H) which fits into the cells of a containership and occupies the space of four and one-half containers (3 across and 1.5
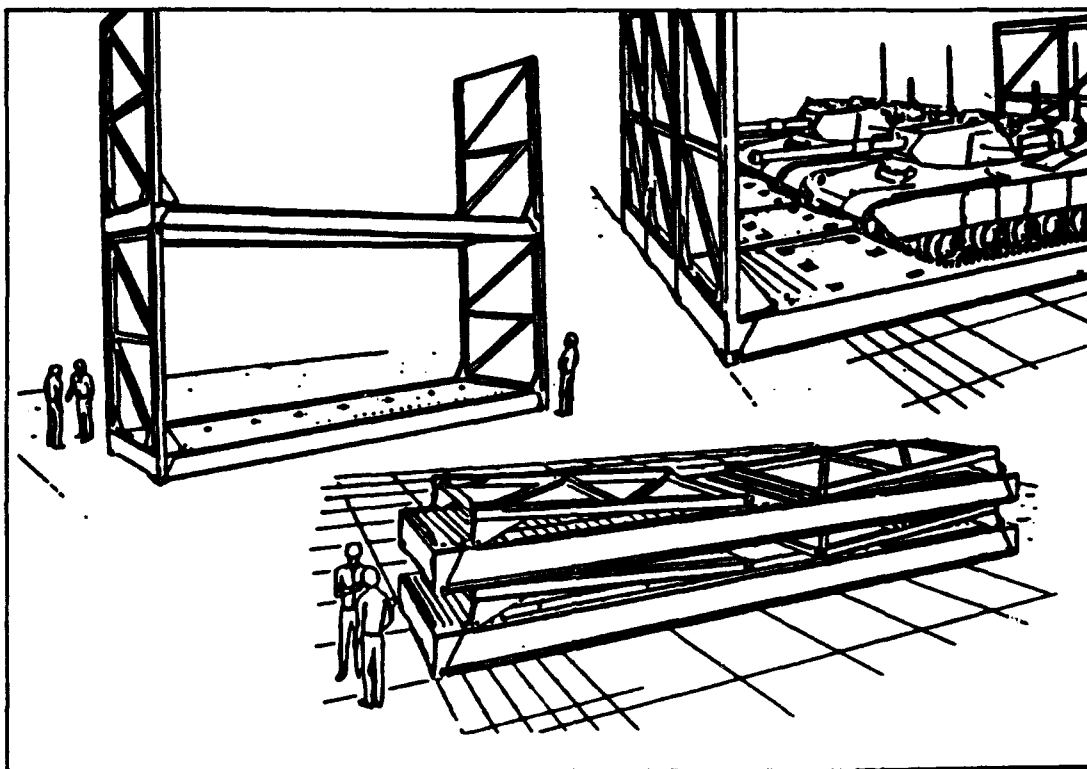
Figure 3 Flatracks

high). The ship's load-bearing container cell guides must be reinforced before seasheds can be installed.

Seasheds supplemented by flatracks enhance the military utility of commercial containerships by enabling them to transport a vast amount of Army and Marine Corps unit equipment which they otherwise could not have carried. Unlike flatracks, seasheds do not require handling during offloading operations and they are retained aboard as long as the containership is needed to carry vehicles and other outsize cargo. However, seasheds may be removed, permitting the ship to carry containerized supplies and ammunition on subsequent voyages.
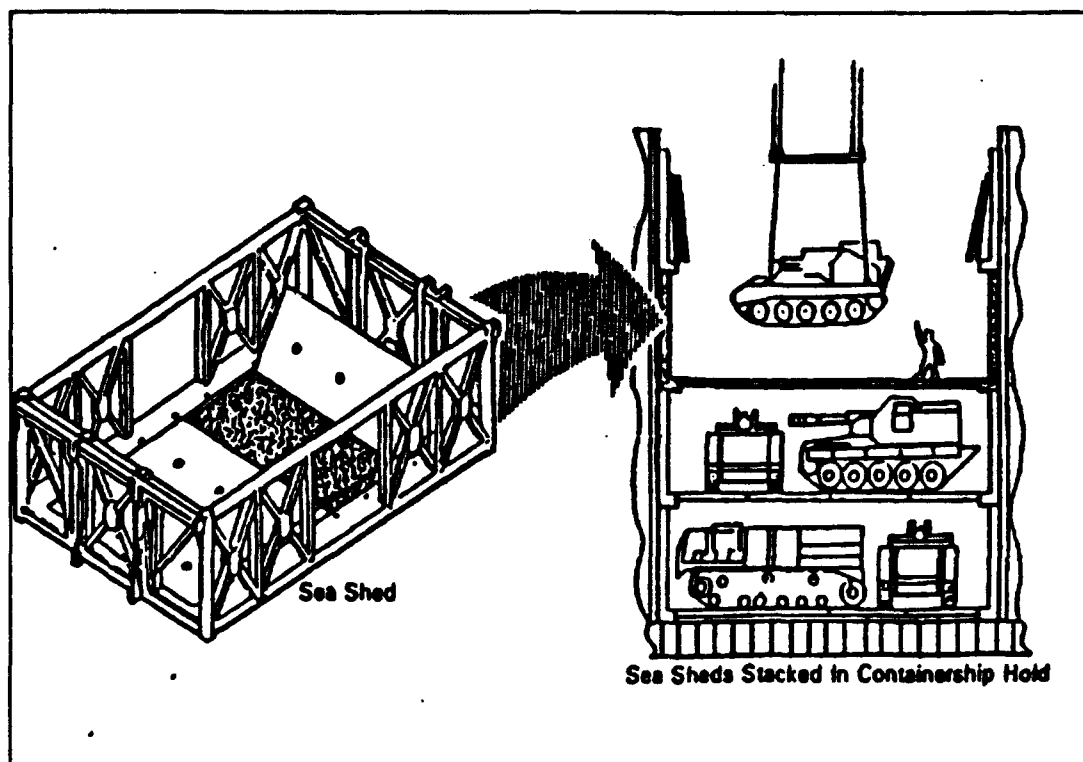
Figure 4 Seashed

Seasheds can be used for outsize cargo when there is
a shortfall of RO/RO vessels. The Navy flatrack is portable
and can be used individually or placed side by side with
seasheds or containers in the containership's holds.

Since seasheds and heavy duty flatracks do not
provide the capability of door-to-door service and are not
utilized by more than one mode of transportation, they are
not considered truly intermodal items of equipment.
However, DOD includes them as items of ancillary equipment
which can be used to enhance the productivity for
mobilization missions of intermodal containerships and
combination container-RO/RO ships.

Table 2 includes an index at the bottom which is helpful in explaining the meaning of the numbers and dashes assigned by MARAD in the matrix of the enhancements for the merchant ships in each category. The evaluation numbers most relevant to this thesis appear in the columns for containerships and combination container/breakbulk (COMBO). For example, flatracks are evaluated as mission essential for all of the mission categories considered by MARAD. Seasheds are evaluated as mission essential for point-to-point reinforcement and sustainment military operations and for Assault Follow-on Echelon support, but they are considered only preferable for use during combat logistics force (CLF) resupply and replenishment of combatant ships.

TABLE 2: ENHANCEMENT FOR MOBILIZATION MISSIONS - PRODUCTIVITY [1]/					
Enhancement	Merchant Ship Type				
	Container	Tanker	RO/RO	Combo	Break-Bulk
	Mission Category [2]/				
	ABCD	ABCD	ABCD	ABCD	ABCD
A. Flatrack	1111	----	----	1111	----
B. Seashed	2211	----	----	2211	----

[1]/ Selection Criteria: 1 = Mission Essential; 2 = Preferable; 3 = Insensitive; - = Enhancement does not apply.

[2]/ Mission Category: A = CLF Resupply; B = Replenishment of Combatants; C = Point-to-Point (Reinforce/ Sustain Military Operations); and D = AFOE support.

[3]/ This requirement probably applies to a small quantity of vessels in the total fleet.

Source: MARAD Report No. MA-RD-840-90015, 1990

2. Government's Advantages with Seasheds and Flatracks

There are major advantages to the government in having seasheds and flatracks in the custody of commercial carriers, as pointed out by the MARAD report on alternatives to stockpiling national defense features (NDFs) (MARAD Report No. MA-RD-840-90015, 1990). The most significant advantage is that during times of national contingencies, U.S. Flag vessels will be able to respond rapidly to sealift needs of the military. Furthermore, if these seasheds were

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already installed, no time would be lost by diverting a containership from the deploying unit's Port of Embarkation (POE) to a congested port where this NDF equipment is stored.

The containership with the seashed and flatrack NDF enhancements on board could arrive at its POE ready to load outsized cargo without delays for modifications and installations. These advantages provide significant reductions in loading time and will be discussed in greater detail in Chapter IV. However, numerous hindrances to using seasheds have prevented their usage to such an extent that reliable cost estimates cannot be established, and the benefits provided by reducing loading times are not clearly worth any added costs.

3. Maritime Industry Viewpoint on Seasheds and Flatracks

In Table 2, the enhancement features for productivity were displayed with respect to each ship type and evaluated for military usefulness in the missions of each ship. Flatracks were assessed as mission essential in containerships and combination container/breakbulk ships for in every mission category. Seasheds were assessed as preferable in resupply of CLF and in replenishment of combatants and mission essential when employed in point-to-point reinforcement/sustainment military operations or

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assault follow-on echelon support (AFOE). Table 3 compares

the productivity enhancements from the viewpoint of carriers

who may want to charter their ships with the DOD.

Table 3: ENHANCEMENT COMPARISON FROM MARITIME INDUSTRY VIEWPOINT [1]/

Enhancement Productivity	Merchant Ship Type				
	Container	Tanker	RO/RO	Combo	Break-Bulk
A. Flatrack	1			1	
B. Seashed	1			1	

[1]/ Selection Criteria: 1 = Desirable; 2 = Insensitive; 3 = Undesirable; and blank = not applicable to ship type.

Source: MARAD Report No. MA-RD-840-90015, 1990

The most prominent advantages for seasheds are:

- Seasheds enable the temporary conversion of a ship to be made without degrading the capability of the ship to perform its normal peacetime commercial functions.

- When DOD shippers need more unit equipment shipped to meet a required due date (RDD), conversions to seashed-installed ships increase the carriers' total space available for unit equipment.

- Work-through floors on seasheds allow them to remain in place during discharge.

- Seashed conversions do not require removal after a load has been delivered to the point of debarkation. This allows the seashed to return for subsequent cargo loading without further modification. Once a mission is completed, seasheds may remain installed or can be removed to restore the containership's original configuration.

When chartering for DOD the advantage that seasheds and flatracks would provide to commercial containership owners is the increased flexibility of cargoes the ship can carry for a small investment. (MARAD Report No. MA-RD-840-90015, 1990) The potential business the carrier can generate or maintain would generally dictate the number of seasheds it should carry on a ship-by-ship basis, which may range from zero up to the number cited in Appendix B.

4. Disadvantages of Using Seasheds and/or Flatracks

Containerships are not commercially viable unless they are making a profit. Methods of moving outsized equipment on containerships need to involve:

• Minimum cost for cargo handling;

• Minimum interference with expected revenues; and

• A profit for the carrier.

Combination container-breakbulk ships are generally impractical in the US liner trades market because the container customers are delayed by the slower breakbulk loading and discharge procedures, which also affects ship productivity. (Niven,1987) Operationally, a seashed equipped containership can be quite similar to a combination container-breakbulk ship. However, Niven's observations are not applicable in this context because in chartering with government, the owner has moved the containership from the liner trade to the charter market. As with most chartered

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ships, there is only one shipper and hence no problem with one shipper being delayed by another. Also, the owner is paid by the day and is therefore not adversely affected by longer loading times. In this case, the entire ship is available for DOD unit equipment cargo, both oversized and containerized.

Traditionally, the government has avoided competing with industry. MARAD predicts that if seasheds and flatracks were made available to the commercial sector it could impact commercial shipping in two ways that may be harmful:

- Commercial equipment lessors could lose business due to government-provided seasheds and flatracks replacing equipment normally used from their inventory.

- If containerships carried more breakbulk cargo with seasheds and flatracks, the breakbulk shipping market could shrink further. (MARAD Report No. MA-RD-840-90015, 1990)

With these issues in mind, MARAD and MSC have outlined a Memorandum of Agreement (MOA) setting forth conditions and requirements associated with commercial uses of stockpiled NDFs such as seasheds and flatracks. There has been no agreement signed at this time, but a possible aspect of the government's cooperative program could be implemented in the form of a government lease program.

To reduce paperwork the lease program could be structured as a long-term agreement with equipment returned

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only as needed. The lease price may be reduced below market price to equipment providers in order to avoid direct competition with them and provide incentives to get NDFs into the commercial carrier. According to Mr. Dave Nava, Military Sealift Command Code (N9), it is possible that the government would lease the seasheds for one dollar to the carriers and make arrangements for their installation on a not-to-interfere basis to coincide with the vessels' periodic maintenance and overhaul schedules. (Nava Interview, 1993) The government would also save on its maintenance and storage costs once the seasheds were installed on commercial vessels.

The next chapter discusses seashed and flatrack employment during Desert Shield and Desert Storm. In Chapter V, economic analysis is used to illuminate the impact of cost effective decisions regarding the employment of seasheds for handling unit equipment.

IV. SEASHED EMPLOYMENT DATA

This chapter describes the way that strategic assets
such as seasheds and flatracks are considered for
deployments. Deliberate planning and crisis planning
processes are discussed first in this chapter in order to
explain the important processes in which seasheds must be
included if they are going to be used by military planners.
The chapter concludes with a discussion of actual
mobilization of forces, theater deployment, and employment
of seasheds and flatracks in the South West Asian theater of
operation.

A. DEPLOYMENT PLANNING FACTORS

As a result of DOD's deliberate planning process,
numerous high level computerized programs and Operation
Plans (OPLANs) exist. However, actual decisions thus far
have been based on specific plans tailored by consensus of
military commanders involved in supplying the required
equipment to the theater commanders without regard for a
pre-planned computerized system.

> Typically, strategic deployments are based on Operation
> Plans and their accompanying Time Phased Force
> Deployment Data (TPFDD or "Tip-Fid"), which are
> developed and executed using the Joint Operation
> Planning and Execution System (JOPES). The TPFDD
> identifies the scheme of deployment, including the
> sequence in which specific units deploy, their ports of

embarkation, and estimates of transportation requirements. At the outset of Desert Shield, however, the Commander in Chief, United States Central Command (USCINCCENT) did not have a TPFDD. (In fact, since 1989 there had been only one TPFDD refinement conference and that was for the Commander in Chief, U.S. Pacific Command.) All that was available for USCINCCENT's area of responsibility (AOR) was a Concept Outline Plan and draft Operation Plan for the United States Central Command's (USCENTCOM's) AOR, prepared by USCENTCOM with the assistance of USTRANSCOM and other supporting commands in the spring and summer of 1990. Essentially, USCENTCOM, USTRANSCOM, the Services, and the Joint Staff planned the initial phases of the deployment manually through direct conversations while constructing an execution TPFDD. (Matthews and Holt, 1992)

1. The Importance of Deployment Planning

In order to avoid chaos and reduce confusion when units are deploying, military deployment planners must keep refined deployment data. Once the United States Transportation Command (USTRANSCOM) loaded JOPES with a refined TPFDD, it proved crucial to Desert Shield/Desert Storm deployment order and discipline. As a result, General Hansford Johnson, Commander in Chief, USTRANSCOM, recommended that DOD maintain funding for incremental JOPES software for use in peace as well as war. "Train, train, train, use, use, use" was the "real key to success with JOPES" according to General Johnson. (Matthews and Holt, 1992) It is unclear whether seasheds are included in the latest revision of JOPES, but the phrase could apply to seasheds' use as well. If seasheds were included for use

while training, there is a strong chance that they would be used effectively during a crisis situation.

Figure 5 shows that in order to produce a refined TPFDD for an OPLAN, military commanders must identify the movement requirements, describe them in logistic terms that are commonly accepted, and determine the movement criteria for the type of cargo. It is acceptable to refer to outsize cargo in cubic feet, measurement tons (MTONs), or square feet. The preferred measurement of outsize cargo in USTRANSCOM is square feet and this thesis will use its measurement in square feet as well.
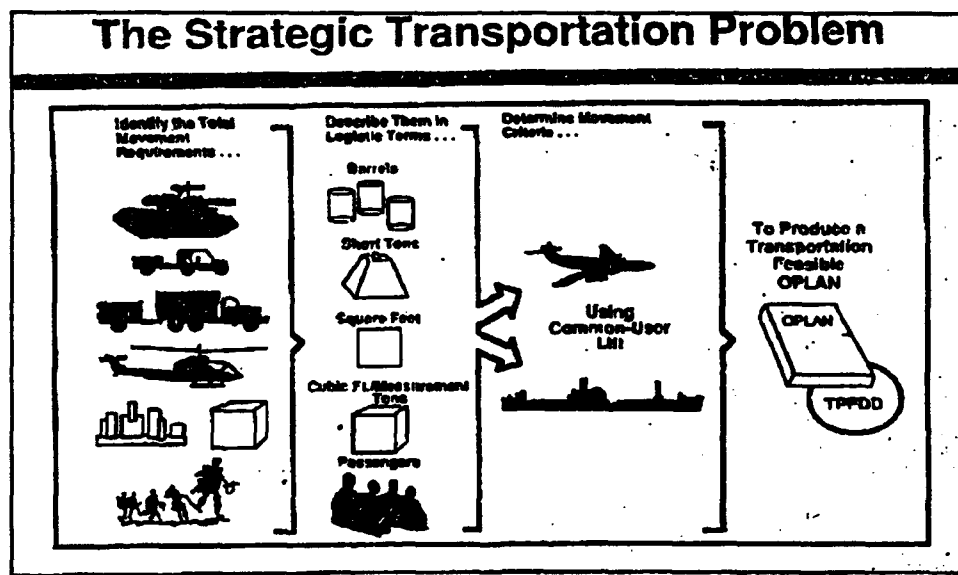
Figure 5 Source: Armed Forces Staff College Pub 1, 1991

a. Transportation Feasibility

The first time a non-self-sustaining-
containership (NSSC) was converted to carry seasheds was for
the Display Determination '89 exercise directed by the Joint
Chiefs of Staff. These converted ships were intended to
improve the sequence of arrivals for forces deploying to
their theaters of operation. The sequence of arrivals is
also called the closure profile.

The Department of Defense conducted the exercise
to test the use of commercial sealift assets to rapidly
deploy forces overseas to areas of conflict. The assets
were previously thought to be inappropriate for movement of
combat units.

> Exercise Display Determination '89 demonstrated the
> military usefulness of containerships. The exercise
> proved that containerships can enhance the rapid
> deployment of combat units to overseas theaters and
> improve force closure. (Translog, 1990)

Table 4 shows the nominal loading and unloading
times for various ship types. (MTMCTEA PAMPHLET 700-2,
1989) Using seasheds, flatracks, and containers, military
shippers can modify and load a containership in four to six
days. Deployment time is even quicker when only flatracks
and containers are used because the ship requires no
modification.

Discharge times vary depending on the policy
regarding the procedure to retrograde containers and

flatracks and the type of cranes available. Discharging a
containership in a port with modern containership handling
equipment can take as few as one to three days.

Table 4 : SHIP LOADING AND UNLOADING TIMES					
Type of Ship	Avg. MTONS	Avg. SQFT-[1]/	Avg Speed in Knots	Load Time In Days	Unload Time in Days
Breakbulk/ Container					
Slow SS -[2]/	15,867	51,485	17.3	4	4
Fast SS	15,341	36,951	20.7	5	5
Breakbulk					
Slow	15,053	59,149	17.7	4	4
Fast	18,891	18,891	20.4	4	4
Container					
Slow SS	18,684	0	17.0	1	1
Fast SS	24,702	0	20.0	2	2
Slow NSS-[3]/	24,259	0	17.1	1	1
Fast NSS	38,957	0	22.0	1	1
RORO/Container					
Fast SS	38,209	131,801	22.0	2	2
Fast NSS	19,300	201,600	25	1	1
Roll-on/Roll-off					
Slow SS	26,758	115,157	18.0	1	1
Fast SS	38,154	164,466	23.3	1	1
Fast NSS	19,300	161,960	28	1	1

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Table 4 (Continued): SHIP LOADING AND UNLOADING TIMES
Note: The ship data are for US-flag and Active Ready Reserve Force Vessels. -[1]/Includes container capacities except for containerships. -[2]/SS denotes self sustaining. (Ship can discharge in stream with its own gear.) -[3]/NSS denote non-self sustaining.(Ship is loaded/discharged by shore equipment.) Source: MTMCTEA Pam 700 - 2 Logistics Handbook for Strategic Mobility Planning. August 1989

b. Seasheds Currently Available for Deployment

During fiscal year 1993 the status of pre-installed seasheds include Military Sealift Command's (MSC's) Fast Sealift Ships (FSSs) and Auxiliary Craneships (TACs). All of the FSSs are equipped with thirty-five foot seasheds.

Forty-foot seasheds are installed in the MSC's craneships (TACs). Table 5 contains data about MSC's preboarded seasheds, container cargo stowage adapters, and flatracks associated with those ships. As indicated in Table 5, seasheds were not utilized for Team Spirit '93 exercises. Consequently, seashed cost and performance data is not available from that exercise. Therefore, for the purpose of this thesis research, employment data will be collected from the most recent employments of seasheds, Desert Sortie and Display Determination '89.

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Table 5: MILITARY SEALIFT COMMAND CRANESHIPS WITH FORTY FOOT SEASHEDS INSTALLED			
VESSEL NAME	SEASHEDS	Container Cargo Stowage Adaptors (CCSAs)	FLATRACKS
KEYSTONE STATE (T-ACS 1)	3	0	0
GEM STATE (T-ACS 2)	10	0	0
GRAND CANYON STATE (T-ACS 3)	10	0	0
GOPHER STATE (T-ACS 4)	12	6	0
FLICKER TAIL STATE (T-ACS 5)	13	6	11
CORNHUSKER STATE (T-ACS 6)	12	6	0
DIAMOND STATE (T-ACS 7)	13	4	4
EQUALITY STATE (T-ACS 8)	12	3	0
GREEN MOUNTAIN STATE (T-ACS 9)	2	1	0
EXERCISE TEAM SPIRIT '93	0	0	162
TOTAL	87	26	177
Source: Military Sealift Command Headquarters, Code N9			

c. U.S. Flagged Containerships Available For Conversion

There are several classes of commercial containerships which can be modified to carry outsized cargo using seasheds. Those vessels have a variety of configurations and a range of capabilities that makes each class unique. Appendix B contains the containership conversion cost per vessel and the number of seasheds and containership cargo stowage adapters (CCSAs) per vessel developed in a contracted study performed by McCaffery and Whitner, Inc. (McCaffery and Whitner, 1992). The study was performed for MARAD to estimate the cost of converting any of the containerships and container/breakbulk ships by installing seasheds.

The study provided estimates based on assumptions of 1990 dollars and used answers from questionnaires sent to U.S. shipyards that would be eligible to perform the conversions. The results of their study listed the ships that could be converted, the number of seasheds and CCSAs each ship was capable of carrying, and the estimated cost to convert each ship. The study provided drawings of how the seashed and CCSAs would be fitted in each ship as presented in Appendix A. It concluded with a list of recommended ships best suited for the conversions.

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This thesis has embellished those results by computing the total square footage provided per vessel as listed in Appendix B, graphing the results as shown in Figure 6, and computing the cost per square foot for each vessel. The computations in Appendix B were made by entering the number of seasheds and CCSAs per ship into a spreadsheet and summing the square feet provided (approximately 800 square feet per seashed or CCSA) in each set of seasheds and ccsas. The conversion cost per square foot is determine by dividing the estimated cost by the number of square feet available with the seasheds and CCSAs installed. This information will also be useful in Chapter V, where costs are analyzed in the decision support model.

The recommendations made by the McCaffery and Whitner study suggest a list of four combinations of vessel classes which could be modified and indicates their two most preferred options. Their recommendations included converting as follows:

- Option 1: Full conversion of all standard vessels except Economy Class. This option converts all seasheds convertible holds on the following classes: C5-S73B, C6-M146A, C6-M-F147A, C6-S69C(C), C6-S85A, C6-S85B, C7-M88A, C7-S-68C,D,E, C7-S88A, C9-M132B, C9-M-F148A(J), C9-M-F150A, C9-M-F151A, SL-D9, SL-D9(C), SL-D9(J).

- Option 2: Full conversion of all standard vessels and 33% conversion of the Economy Classes. This option converts all seashed convertible holds in the following classes: C5-S73B, C6-M146A, C6-M-F147A, C6-S69C(C), C6-S85A, C6-S85B, C7-M88A, C7-S-68C,D,E, C7-S88A, C9-M132B, C9-M-F148A(J), C9-M-F150A, C9-M-F151A, SL-D9, SL-D9(C), SL-D9(J). This option _fully_ converts 33% of the seashed

convertible holds of the C9-M-F141A class (Economy
Class). (McCaffery and Whitner, 1992)

Total Square Footage (Seasheds)
US Flagged Fleet Vessels Capacity
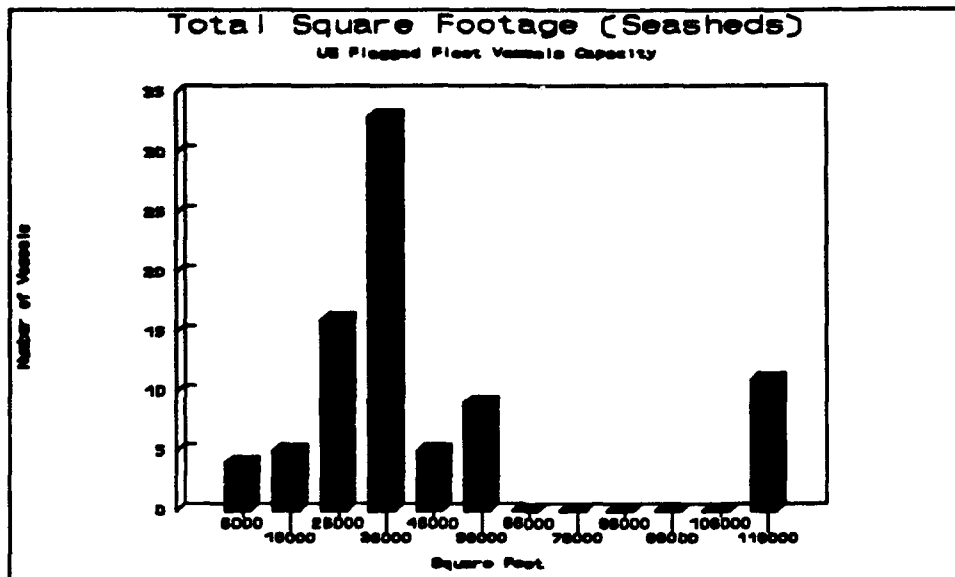
Figure 6 Square Footage Available from U.S.-flag
Containerships with Seasheds Installed

The total square feet offered by each vessel is
summarized in Figure 6. Figure 6 shows the number of square
feet that various groups of vessels in Appendix B can carry
and also shows the total number of vessels which can carry
the square footage in that range. Appendix B shows that the
economy class can carry substantially more cargo using
seasheds than the other classes; these ships carry in the
range of 112,000 square feet. A composite of the other
vessels after conversion shows a range of 30,000 to 40,000
square feet.

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d. *Types of Units that Could Employ Seasheds*

Which units should employ seasheds in their deployment? Any units selected by USTRANSCOM to have their unit equipment transported by seasheds would want their equipment to arrive in theater intact to the greatest extent possible. Unit commanders place high value on unit integrity. They believe that containerization would mean splitting up their equipment into hundreds of container boxes for transport on multiple ships. As a result, they favor roll-on/roll-off over container vessels so they can consolidate their cargo and unit equipment on as few ships as possible, thus maintaining unit integrity. (Matthews and Holt, 1992) Table 6 presents estimates for several types of Army units which could be selected for transport by containerships enhanced with seasheds or flatracks.

Table 6 shows that military flatracks and seasheds can carry more than 90% of each unit type including Air Assault, Airborne, Air Cavalry, Armored Divisions, Light Infantry, and Mechanized Infantry Divisions. By comparison, containers and privately owned commercial flatracks are significantly less able to carry much of the divisions' equipment. For example, Light Infantry divisions can ship 40 to 48 percent of its unit equipment by containership, but by using seasheds or heavy duty flatracks they could ship 97 percent of their unit equipment.

Table 6: PERCENT ARMY TYPE DIVISIONS DEPLOYABLE VIA CONTAINERSHIPS					
Type Division	Unmodified				Modified
	Containers		Flatracks		Seasheds
	20-Ft	40-Ft	Private owned	Heavy - Duty	
Air Assault Division	31	38	87	94	91
Airborne Division	39	49	93	97	96
Air Cavalry Regiment	18	19	64	95	91
Armored Division	8	8	50	98	94
Light Infantry Division	40	48	91	97	97
Infantry Division (Mechanized)	9	9	51	99	97

Source: MTMCTEA Study OA 88-5c-18 _Analysis of Containerization on Unit Strategic Deployment_, November 1988 as cited in MTMCTEA I⁼.n 700-2, August 1989.

B. TRANSPORTATION PROBLEMS

To survive, U.S.-flag commercial shipping must earn revenue. Earning revenue means moving cargo, and moving cargo means not waiting for a DOD call-up. Thus, short of a declaration of a national emergency, U.S.-flag ships do not get called into government service. (Ackley, 1992)

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1. The Transportation Problems Associated with Seasheds

Commercial U.S.-flag liner trade is too competitive for liner operators to take a ship off of its trade route to haul non-routine cargo on a one-time charter basis. Seasheds are not commercially employed and would require a charter hire to accomplish installations of seasheds for a one-time charter for DOD. Such an arrangement would disrupt the liner's scheduled trade route, and in most cases where the carrier has no other ship to replace the liner, it can result in the permanent loss of the trade route to competitors.

The most persistent problem that has hindered the use of seasheds is the high cost estimates for chartering ships as well as the modification costs. These cost estimates for charter ships have not been substantiated by previous research due to the lack of actual usage of seasheds.

a. Factors Which Hinder Seashed Employment

According to a USTRANSCOM research point paper which discusses plans to employ seasheds during Desert Storm redeployment, several factors hinder employing seasheds for deploying units. The following reasons are among those cited:

- Installation usually requires cell guide strengthening and modifications, a 3-day, 24 hour-a-day operation, or 5 to 6 days at a normal pace. Design and material lead

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time may also be additive considerations. Only a very few of the U.S. flag containerships have been modified to accept seasheds.

- Seasheds are located only at Bayonne, New Jersey; Charleston, South Carolina; and Port Hueneme, California and are normally moved by barge to the physical on-load site. This either limits the overall throughput capability to that of local shipyards or adds ship repositioning to the on-load time if an out-of-area industrial facility performs modifications.

- U.S. flag liner operators have been generally unwilling to remove containerships from very competitive trade routes for the time necessary to make cell guide modifications due to fear of permanent loss of container trade to the foreign flag competitors.

- Government has been unable to guarantee extended charter time and sufficient cargo to recompense operators for their lost container trade. (West, 1990)

Considering the cost of ship modifications and charter for containerships, use of seasheds is expected to be more expensive than chartering RO/ROs or breakbulk vessels to move unit equipment. (West, 1991) However, if the supply of RO/RO and breakbulk vessels was exhausted and only containerships could be used to carry military cargo, there would be no sealift alternative to using seasheds. The only choice would be simply when to ship the materials to the theater of operation.

The estimated cost for containership conversion and a single charter, reported to USTRANSCOM, for ships enhanced with seasheds is $187 per square foot, and the estimated cost for shipping when using flatracks is $44 per

square foot. (West, 1991) Further analysis of this cost breakdown is presented in this and the following chapters.

b. *Solutions That Were Proposed*

To overcome hindrances to seashed employment, on February 22, 1991, USTRANSCOM raised the possibility to DOD that the U.S. may need to rely on U.S. flag carriers and organic assets to a greater extent in future operations. Based on that assumption, USTRANSCOM proposed using seasheds and flatracks for redeployment during Desert Storm.

In a joint meeting on seashed usage between USTRANSCOM and Special Middle East Sealift Agreement (SMESA) carriers on February 21, 1991, the carriers' reaction was that large, bulky unit equipment should be transported on RO/ROs. They further recommended that containerization be used instead of seasheds in order to maximize efficiency. They also stated that flatracks are preferable to seasheds. They pointed to the large cubic capacity consumed by seasheds as the cause of its high expense and inefficiency. (COMSC Message 222259Z February 1991)

Since there had been no previous operational experience using seasheds (only one practice experience in Display Determination '89), USTRANSCOM decided to explore the pros and cons by employing them in an actual redeployment: Desert Sortie.

During May, 1991, a commercial breakbulk container vessel, SS Mallory Lykes, was outfitted with three CCSAs and six seasheds in Bayonne, New Jersey. The Mallory Lykes, a self-sustaining containership, was evaluated during Operation Desert Sortie by *Military Sealift Command* for future utilization of seasheds and flatrack systems in accomplishing unit movement. It was tested to demonstrate the use of seasheds and flatracks.

C. RESULTS OF DESERT SORTIE

1. Actual Performance

The test of seashed performance under actual working operations demonstrated the use of containerships using seasheds and flatracks for unit movement. Cargo that was not otherwise containerizable was carried with seashed enhancements. The results were summarized and reported by Commander, Military Sealift Command, South West Asia (COMSCSWA, 1991). The highlights of the report are discussed next.

a. *Cargo Handling Successes*

The total cargo loaded on Mallory Lykes in one load was 3,361 pieces occupying 40,440 square feet (8,309.93 M/T). Loading required 61 hours of cargo handling time. Seasheds and flatracks used were in an excellent state of preservation, and the cranes and topside equipment worked well with them. The Mallory Lykes carried more flatracks

than required, and the preparation and installation of those flatracks may have caused up to five hours of delay before cargo handling.

Figure 7 shows the performance of Mallory Lykes with the seasheds installed, loading 40,440 square feet as compared with similar breakbulk ships participating in Operation Desert Sortie. Among the ships participating, the Cape Bover's performance data is considered an outlier. The Cape Bover utilized tight stowage and enhanced its loading capacity through secondary loading, where cargo is stuffed inside of other cargo to exceed the square footage capacity of the vessel.
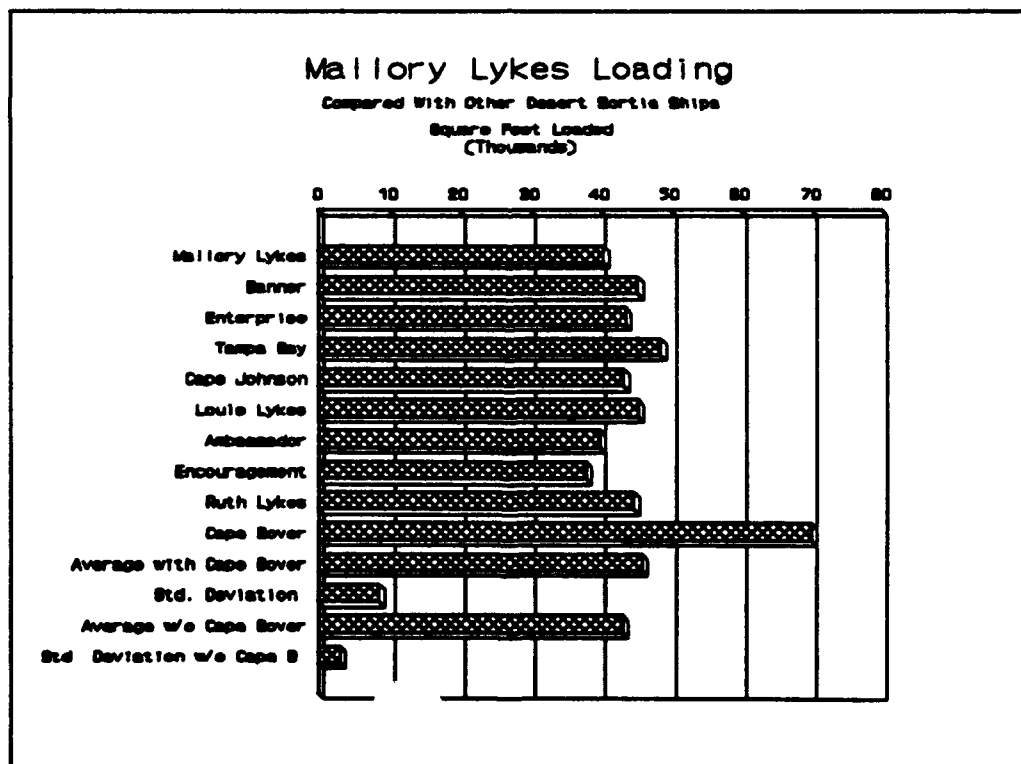
Figure 7
Source: Military Sealift Command Code (N9)

In comparison with ten other breakbulk ships
with similar capacities, Mallory Lykes was the fastest
loading ship per hour using the seasheds and CCSAs
installed. Figure 8 shows the hourly loading rates of the
ships as well as the average and standard deviation of
loading rates per hour. Mallory Lykes was more than a
standard deviation faster than the average vessel in the
group. It loaded 663 square feet per hour, while the
average loading rate was 468 feet per hour. However, this
can be explained in part by the different cargo type
characteristics.
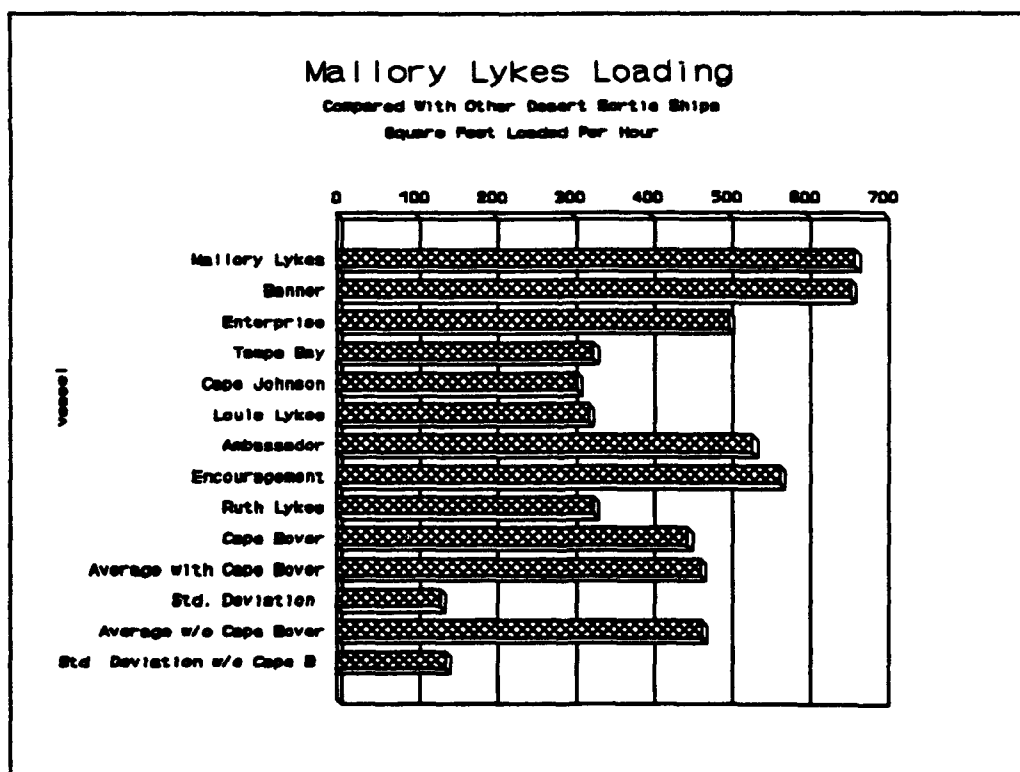
Figure 8
Source: Military Sealift Command Code (N9)

Figure 9 shows the percentages of each vessel's square footage utilized for stowage. The average space utilization was 94.64%. However, the type of cargo carried by seasheds on Mallory Lykes had an inherently poor stowage factor.

Cape Bover's percentage of square feet loaded creates an anomaly because it was counted as 140 percent. That causes the mean percentage of square feet loaded to be higher than it would be if all the ships counted only square footage of cargo loaded on their decks with the maximum percentage of square footage available equal to one-hundred percent. Excluding the Cape Bover, a more realistic extimate of the square foot utilization drops to 85 percent (from 94.64 percent). The Mallory Lykes square foot utilization was 80.89 percent.

The Mallory Lykes had 50,000 square feet available and loaded 40,444 square feet. Commander, Military Sealift Command, South West Asia (COMSCSWA) expected the broken stowage factor for the cargo to be 35 to 40%. Broken stowage is the amount of square footage which is unusable in the container or seashed due the bulkiness of the cargo. It is computed as 1- (stored amount)/(measured cargo storage space). Therefore, the broken stowage factor experienced by Mallory Lykes of 19.1 percent (1- 80.89%) was

better than expected for the track and wheeled vehicles it carried.
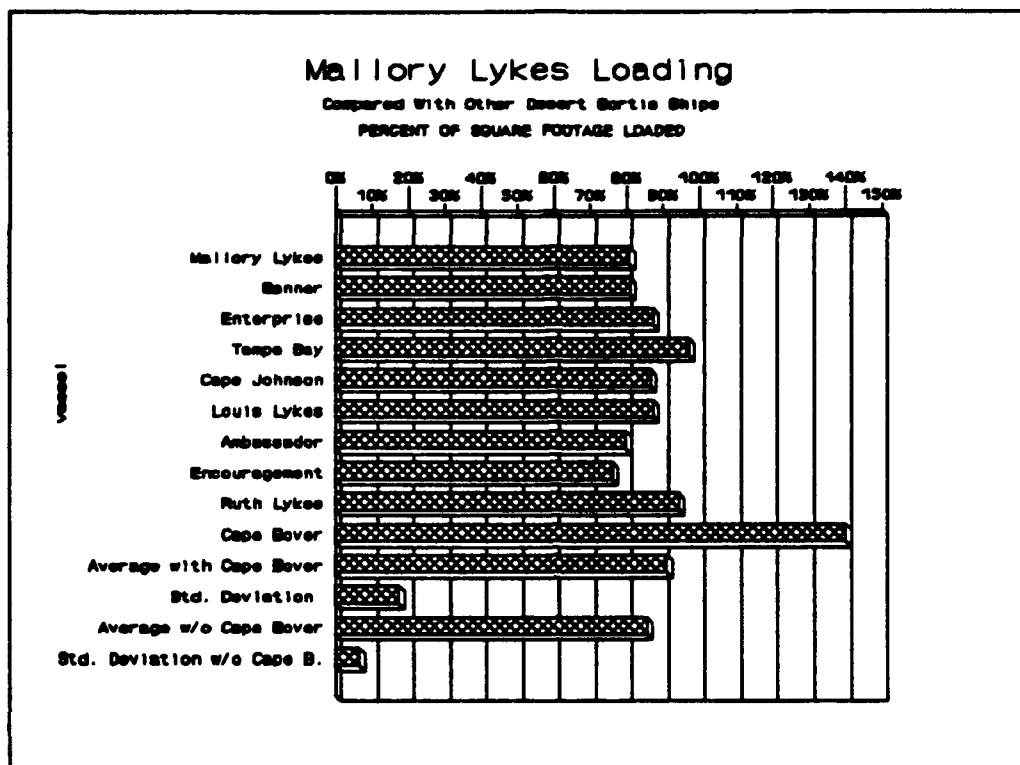
Figure 9 Source: Military Sealift Command Code (N9)

b. Cargo Handling Problems

Prior to Operation Desert Sortie, the significant perceived problems in handling cargoes using seasheds had not been identified in actual operations but had been noted in NAVSEA publications based on tests and evaluations of seasheds. Desert Sortie provided MSC with the unique opportunity to thoroughly document actual

performance including near-accidental situations and potential problems. A list of lessons learned from COMSCSWA shows the most significant general findings from the operation:

- The configuration of seasheds on Mallory Lykes presented a safety hazard to personnel steadying cargo from below. If a load should fall, personnel working in the hold would have little room to get out of its way.

- The 30" lip around the seashed deck prevented vehicles from being placed directly on their final location because the slings on larger vehicles would catch under the lip and no amount of steadying could place the load on its intended spot.

- Loading would occasionally be delayed while a driver was located to maneuver the vehicle into place under its own power.

- More than once the vehicle struck the side of the seashed.

- Only 80.89% of Mallory Lykes' available stowage was used.

- Manpower shortages for crane operators and truck drivers caused other delays. (COMSCSWA, 1991)

2. **Other Lessons Learned from Actual Employment of Seasheds**

Two of the recommendations regarding future seashed employment from Commander, Military Sealift Command, South West Asia, (COMSCSWA) were to:

- Identify, prior to deployment, units which are capable of being moved entirely on a container ship using containers, seasheds, and flatracks. Equip units thus

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identified with required containers before they are
moved to a staging area.

- Use a larger container ship with more seashed and
flatrack capability for future tests. That will allow
more flexibility in unit selection and in cargo
operations. (COMSCWA, 1991)

The latter recommendation is consistent with the
McCaffery and Whitener, Inc., consultant group's findings in
August of 1992. That study is further analyzed in the next
chapter.

3. Cost of Mallory Lykes Charter

The Mallory Lykes charter hire per diem was $24,000
per day for each time chartered trip. A time charter per
diem does not include the cost of fuel, port charges, or
canal tolls which are expenses directly reimbursed by the
Government. The estimated total cost for each trip was
approximately $1,600,000, inclusive of fuel, port charges
and canal tolls. (Fischer Interview, 1993) This estimate of
total cost makes the estimated cost per square foot
chartered approximately $39.60 per square foot
($1,600,000/40,440 sqft) instead of the previously estimated
$187 per square foot reported to USTRANSCOM prior to Desert
Sortie.

The next chapter uses the data presented in this
chapter to analyze the cost and time requirements that have
become the strategic issues involving whether or not to

employ seasheds for deployments. A decision support model

is presented to examine the time and cost factors involved.

V. SEASHED DATA ANALYSIS

A. PURPOSE

This chapter analyzes the time requirements and cost
estimates involved in determining the military usefulness of
seasheds for a particular exercise or deployment. It uses a
computerized decision support model to aid in simulating
seashed employment activities. The intent of the analysis
is to examine whether there would be a significant time
saving benefit to the government if the U. S. flagged fleet
enhances its military usefulness with pre-boarded seasheds.
A second issue is whether the costs (or savings) involved
in pre-boarded seasheds are worth the benefits.

To examine the seasheds' expected performance given the
time and budget constraints, this thesis presents a model of
sequential activities required to employ seasheds and then
utilizes the data discussed in previous chapters to project
the completion time and expected cost of using seasheds.
The method that is used for this analysis is a network
analysis tool known a the critical path method (CPM), which
is a technique used to plan, schedule, and control projects
through their completion. CPM is a formal approach to
project management that aids in decisions involving projects
that are complex, non-repetitive, unique and can be modeled

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as a network to illustrate interrelationships of activities required in the project. CPM is more fully explained later in this chapter's discussion of the critical path and cost crashing techniques.

B. DELIBERATE PLANNING OPPORTUNITIES TO EMPLOY SEASHEDS

Planning for minimizing the impact of a sealift shortfall requires military planners to adopt some assumptions about the size and location of a sealift requirement. When planning for the use of seasheds in a contingency that requires a large scale movement of outsize equipment, it would be helpful to simulate conditions in an operation such as a logistics-over-the-shore (LOTS) exercise.

A coordinated exercise such as Display Determination '89 (DD-89), which has performance evaluations, time requirements, and cost data, can help in planning for future exercises or crisis actions. In fact, the DD-89 After Action Report (Military Traffic Management Command, Transportation Engineering Agency, 1990) and the MSC cost estimates for DD-89 (Military Sealift Command Atlantic, 1989) are used as a basis for cost estimates in the model presented in this chapter when more current cost data from Desert Sortie is not available.

1.   Steps Required to Employ Seasheds

Before USTRANSCOM planners will consider employing
seasheds, there must be a sealift shortfall identified.
This means unit equipment is required in the deployment
theater by a required delivery date (RDD) and it would not
be delivered without employing seasheds. (Paradise, 1992)

Many conditional decisions are required once it is
determined that seasheds must be employed to meet a RDD or
lift an additional amount of outsize cargo after a shortfall
occurs. These decisions deal with selecting the unit which
will be carried, selecting the best ship from the ones
available, and identifying manpower and equipment needed to
prepare, load, and discharge vessels when needed. Table 7
describes the activities that are required for loading and
discharging a seashed-equipped containership and describes
their precedence relationships with each other.

Some activities are concurrent with others during
their operations which may have different completion times.
There is slack time created by these time differences which
permits predecessor activities to start early, finish early,
start late, or finish late. However, even though some
activities may start before their predecessor activities
finish, they cannot finish before all of their predecessors
are finished.

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Table 7: ACTIVITY/PREDECESSOR LIST FOR SEASHED EMPLOYMENT		
Activity	Description	Immediate Predecessor
A	Identify unit equipment lift shortfall	
B	Identify available ships for seasheds	
C	Identify manpower, equipment for handling seasheds	
D	Move vessel to SPOE-[1]	B,C
E	Strengthen cell guides (if not done previously)	D
F	Transport seasheds to loading dock	E
G	Compute stability of vessel with seasheds and unit equipment	F
H	Install Seasheds	G
I	Move unit equipment to SPOE	A
J	Load unit equipment	H,G,I
K	Movement to POD-[2]	J
L	Offload	K
M	Return for the next load (activity J)	L

-[1]SPOE is the shipping port of embarkation
-[2]POD is the port of debarkation

Source: USTRANSCOM Code (J5-AL)

Military planners must determine the scheduling of these activities to support a deployment of unit equipment employing seasheds when the contingency requires their use. These decisions can become costly when there are avoidable delays or requirements that are not given proper consideration during the deployment planning phase.

The current status of ships available to install seasheds from the list appearing in Appendix B indicates that only one of them has been modified with strengthened cell guides to accommodate seashed installation; Sealand Consumer was the vessel actually employed in DD-89. At $16 per square foot, its conversion cost is the lowest of all the estimates and it is less than one-third of the $57 estimated cost of the Sealand Producer, a vessel in the same class.

Every other vessel listed will require a full conversion and will incur conversion costs in addition to the chartering costs. These conversion costs are for a one time basis, and if the seashed installation is used repeatedly, the conversion cost per charter is incrementally decreased with each voyage. (Corkrey, 1993) The conversion costs specified in Appendix B may be three to four times too high, given the disparity between the actual experience with Sealand Consumer and the estimates for Sealand Producer. Estimates in the model presented in the next section are

based on actual costs from Sealand Consumer in DD-89 and Mallory Lykes during Desert Sortie whenever possible.

2. A Planning Approach Using a Decision Support Model

When deployment steps are carefully planned by military planners, the task of scheduling each activity in the proper sequence is more certain once the predecessor activities have been identified and their completion times are estimated. However, real logistics demands require flexibility in the times to meet required due dates (RDDs) or requisitions for sealift square footage in the deployment theater. To achieve this flexibility, military planners must make judicious decisions on whether the RDD can be met using seasheds and make precise estimates of what the cost would be with changing deadlines.

These decisions can be disastrous if they are based on erroneous estimates. But if accurate information is used, a defensible decision can be supported by a logical approach and reasonable estimation of the time and costs involved. The next section presents a proposed decision support method for modeling and solving cost and time requirements when given reasonable estimates for employing seasheds.

C. MODEL PRESENTATION

By using the list of activities described in Table 7 to represent the sequential relationship of tasks involved in

seashed employment, this section establishes a basis for a time line to aid in estimating the duration of loading and discharging a containership enhanced with seasheds for outsize equipment carriage. The activities' relationships are illustrated with a network diagram in Figure 10 which will be useful in reorganizing the resources once the sequence of tasks that take the longest time is identified. That sequence of tasks is commonly referred to as the critical path.

The network construction depicts project activities and their interrelationships graphically, showing their precedent relationships as listed in Table 7. The network has two components:

- Activities are represented by arrows, and labeled alphabetically. They are tasks that consume time and resources and incur costs.

- Events are project milestones, represented by numbered circles, which occur at a point in time when all the activities preceding them are finished. They are connecting nodes where new activities begin.

A dashed line represents dummy activities that are used in constructing the network to ensure that proper precedence is maintained and to avoid having two nodes directly connected by more than one activity. It uses no resources, incurs no costs, and has a time duration of zero.
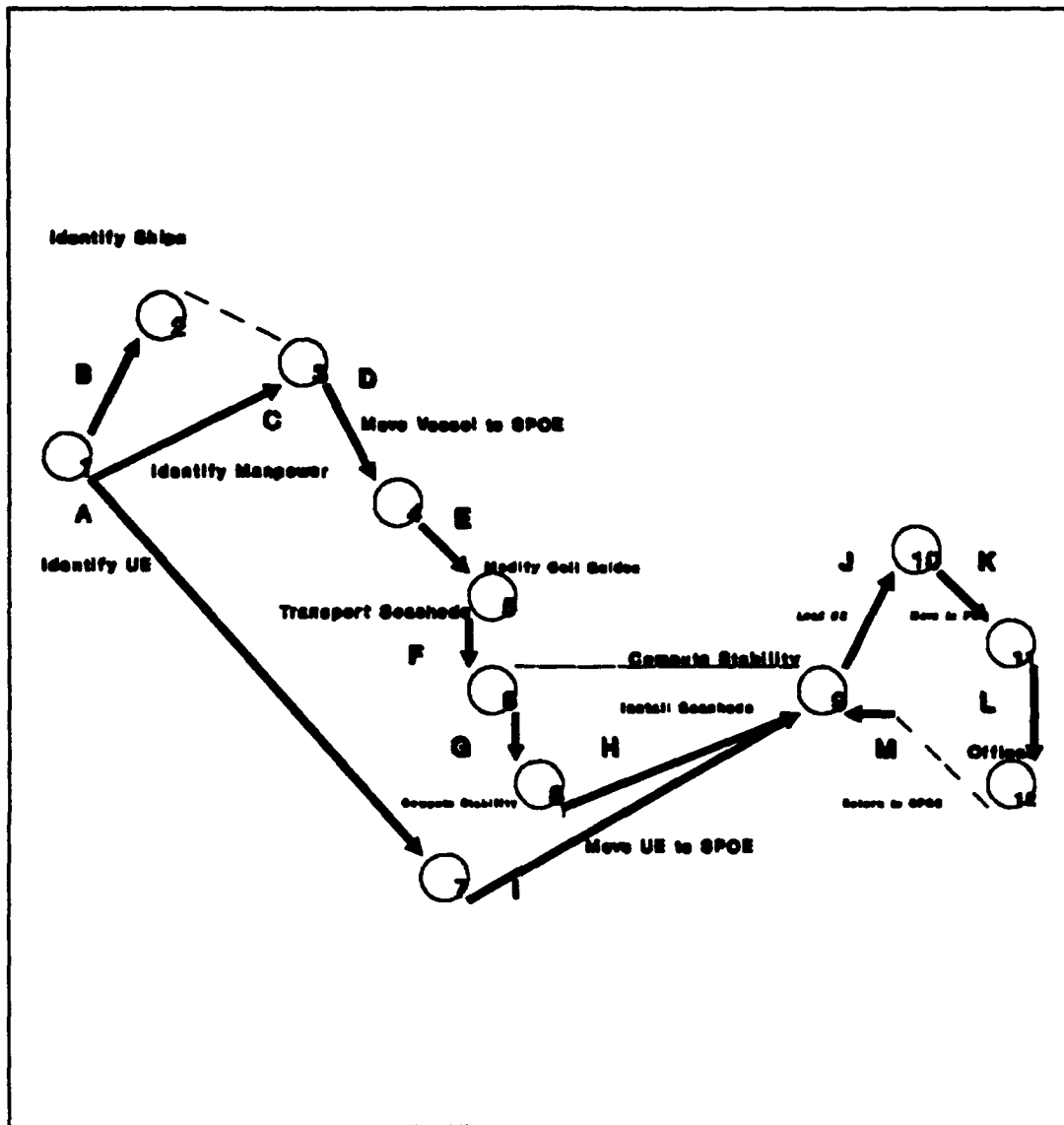
Figure 10 CPM Network for Seashed Employment

1. Model Explanation

CPM is not an optimization technique. It is a descriptive or predictive tool whose value lies in the information it provides through identifying the activities that are critical for on-time completion of the project and determining completion time. When planners have this

information they can work toward completing a project on time and within their budget constraints without gross discrepancies.

When the decision support model's output results are generated, the cost per square foot is calculated to demonstrate how the model may be used to measure the cost effectiveness of a particular alternative with seasheds.

a. *Critical Path Method*

CPM was developed in the late 1950s by the Navy Special Projects Office. (Dennis and Dennis, 1991) It is commonly used in construction projects where time and cost estimates can be made with some degree of certainty.

Since all activities are not completed in series it would be erroneous to simply add up the estimated duration of each time to calculate the time required to complete the project. Some activities occur simultaneously and they are represented on different paths. However, it is possible to compute the completion time by identifying the paths and summing up the lengths of their activities to determine the longest path. That is the critical path.

There are many computer software packages available with this technique and most programs will automatically compute the critical path and project completion times once the activity time data is entered. The QSB Plus software package was used for this research

because it has the capability to automatically compute a cost estimate for a given completion time constraint and predict the cost of the project if a shorter duration of time is required. Additionally, the QSB Plus software package is compatible with the word processing package used for this thesis.

These features can be useful for the planner in controlling an activity's slack times and wisely scheduling activities to keep the project within budget guidelines. Shortening the duration of a project is known as project crashing and is discussed next.

b. The Project Crashing Concept

Controlling the completion time of an activity can be done by controlling the resources used to accomplish the task. Manpower, equipment, and overtime can be used to expedite a task. If additional money is spent to shorten a project duration, it should be done as economically as possible. A cost analysis which looks at the tradeoffs between costs and time can aid in a decision which chooses the specific activities to crash and by how much.

Crashing a project requires sequentially reducing activities on the critical path in such a way that it achieves a maximum reduction of time for each dollar that is spent. The computer application developed for this thesis does that function automatically. When all of the

activities' time lengths and costs are summed by the program it displays the critical path and the total expected cost for the project. What it actually computes is a differential in cost and time for each activity when it is given:

- Cn: Normal cost - the cost to achieve the task under normal circumstances, using the resources required to complete the activity in the normal time.

- Tn: Normal time - the expected activity time under normal circumstances.

- Cn: Crash cost - the cost under expedited or crash circumstance.

- Tn: Crash time - the least possible time it can take to complete an activity.

Cost per unit time may be described in terms of hours, days, or weeks. For the purposes of this thesis the unit time will be expressed in days.

The maximum time reduction (tr) is the difference between normal time and crash time:

$$tr = Tn - Tc \tag{1}$$

Crashing cost per unit time for each activity is calculated as follows:

$$Crashing\ cost/time = \frac{Cc-Cn}{Tn-Tc} \tag{2}$$

Hence, the equation used to calculate crashing cost for an activity is expressed:

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$$Crashing\ cost/time = \frac{Cc-Cn}{tr} \qquad (3)$$

The cost crashing technique can be repeated
until there is no slack remaining in the time, and no
further reduction in time can be made by crashing any
activity time. In other instances, a planner may reach a
point where the maximum budget constraint is reached before
the project's shortest crashing time is reached. Either
situation is possible, and the deployment planner's decision
may depend on whether more time is available or more funds
must be spent to meet th RDD commitment.

For comparison purposes, using the seashed data
presented in this thesis, once the total normal cost is
determined by the program it will be converted into cost per
square foot. Then, cost per square foot will be computed
for the total crashing cost.

c. **Model Validation**

The criteria for employing seasheds is
established by USTRANSCOM. USTRANSCOM only considers
employing seasheds when there is no roll-on/roll-off vessel
available, RDD cannot be otherwise achieved, and a shortfall
of unit equipment will occur in the deployment theater as a
consequence of not using seasheds. It has been confirmed by
USTRANSCOM Code (J5-AL) that the list presented in Table 7

includes the activities that must occur when the decision is made to employ seasheds. (Paradise, 1993)

D. MODEL APPLICATION WITH SEASHEDS

An input was generated based on the activities in Table 7 and costs estimates for normal times and crash times in Table 8. Some estimation of costs was required due to unavailable data. However, actual data was used from Display Determination '89 exercises and Desert Sortie operations to the greatest extent possible in an effort to keep the estimates realistic and conservative.

Input data included cost estimates provided from:

- Military Sealift Command, Atlantic cost estimate from Display Determination '89 (DD-89) loadout;

- After Action report for DD-89 for March 1990; and

- Desert Sortie chartering costs and performance data from Mallory Lykes chartering.

Durations for some of the activities such as G, and H are based on the time required to install a seashed group, which include three seasheds and one CCSA as listed in most cases in Appendix B.

1. Model Assumptions

It is assumed that there is a tradeoff between project completion time and project costs. However, if an alternative permits a faster completion time for the same cost as a slower alternative with the same amount of square

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footage a computerized solution is not needed because the faster alternative is immediately identifiable as the most beneficial decision. This resolves any confusion on situations such as Equation 3, where if tr (= Tn-Tc) equals zero the equation is not defined, because the most economical decision is to choose the normal cost if there is no time reduction when crash time is used. The software application makes allowance for that situation, too.

Table 8: ESTIMATED NORMAL TIME, CRASH TIME, NORMAL COST, AND CRASH COST FOR SEASHED EMPLOYMENT

Activity	Normal Time (days)	Crash Time (days)	Normal Cost	Crash Cost
A	1/4	1/4	$2000	$2000
B	1/2	1/4	$2000	$3000
C	1/2	1/4	$2000	$3000
D	2	1	$800,000	$1,000,000
E	2	0	$60,000	$80,000
F	1	0	$184,000	$220,000
G	1/2	1/2	$1,000	$1,000
H	3	0	$475,000	$550,000
I	3	2	$800,000	$1,000,000
J	3	2	$185,000	$220,000
K	1	1	0	0
L	3	2	$800,000	$1,000,000
M	0	0	0	0

2. Simulation of Seashed Employment Using Cost Crashing Technique

Table 8 provides the estimates of normal cost, normal times, crash cost, and crash times used as input data for the activities described in Table 7 and Figure 10.

The primary cost and time estimates are based on DD-89 conversion costs and chartering costs for Sealand Consumer. The estimate does, however, substitute the time charter rates from Mallory Lykes chartering during Desert Sortie as a basis for estimating time charter expenses ($1,600,000 total per charter) in activities D and L because the estimates are available, more current, and realistically based on an actual charter expense for normal costs. For activities D, I, J and L, crash costs and crash time estimates are arbitrarily estimated as 20% higher for one day gained due to insufficient data available on manpower required, overtime, and completion times.

3. Analysis of Cost Crashing Simulation

The purpose of the program application is to examine whether savings in time and expenses could occur if seasheds were pre-boarded on vessels. This is simulated by having the time duration of activities E (cell guide strengthening), F (transporting of seasheds), and H (seashed installation) crashed to zero after the normal time and costs are computed. These three activities were chosen to

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be crashed to zero because they would require zero time if there were seasheds pre-boarded on the vessel selected for chartering.

Table 8 costs and times are used as input data for the simulation of seashed employment. The simulation takes the data and determines the critical path and normal cost for that critical path. Then, the time constraints are shortened to find the cost of the employment with shortened time constraints by using the computer program's project crashing technique.

It is important to note that the activities that are not unique to seasheds' loading and unloading times are set to zero for their normal time and crash time. These activities are the ones that involve factors unique to the ship's speed, the line haul distance, and whether a backhaul to the POE is required. They are unknown random variables whose analysis is beyond the scope of this thesis. However, in a real exercise or military contingency these factors would be known by planners and could be applied with the model using reasonable estimates. For example, to avoid mixing in the impact of ship's speed, represented by the linehaul times from SPOE to POD, activities K and M are set to zero but they are listed to show their precedence relationship with the others. Since activity M is conditional as an option to return for loading more unit

equipment, it is not included in the computer analysis at all.

a. Results of Computer Analysis

The computerized CPM analysis results of the network are presented in Appendix C. The normal expected time to load and discharge a containership by installing a seashed enhancement is 15 days. The total cost of the normal seashed employment using the input data in Table 8 is $3,311,000.

The results display two critical paths for the network, which means that both paths are equal in duration:

- Critical path # 1 is C- dummy 1 - D-E-F-G-H-J-K-L.
- Critical path # 2 is B-D-E-F-G-H-J-K-L.

These two paths are identical except for the first activity where one path includes ship identification and the other includes manpower identification. Both critical paths includes loading time, unloading times, and merging unit equipment and vessel at the SPOE. The seashed employment CPM network computed the cost using the normal times and normal costs only.

The project crashing technique was applied by finding the shortest feasible duration that the project could be completed within. The program computed seven days

as the shortest time and a new total cost of $3,679,000.
The recommended crash activities were as follows:

- Crash activity B to ¼ day; incremental cost = $1,000.
- Crash activity C to ¼ day: incremental cost = $1,000.
- Crash activity E to 0 days: incremental cost = $20,000.
- Crash activity F to ¼ day: incremental cost = $27,000.
- Crash activity H to 0 days: incremental cost = $75,000.
- Crash activity I to 2¾ days: incremental cost = $50,000.
- Crash activity J to 2 days: incremental cost = $35,000.
- Crash activity L to 2 days: incremental cost = $200,000.

A third critical path appears with the first two when the crashing technique is performed. Critical path number three is A-I-J-K-L. These results will be discussed and interpreted next.

b. Interpretation of Results

With the exception of the recommendation for activity F, all of the recommended crash durations were used. Activity F could not realistically be crashed to one-quarter of a day. If the seasheds were pre-boarded there would be zero time required to transport them to the loading docks. Therefore, a zero was entered for activity F, and the resulting total time was computed as seven days by the program. With those inputs the costs for the seven day

completion was lowered to $2,779,000 for loading and unloading pre-boarded seasheds.

Since the input data is based on the costs for a conversion of Sealand Consumer from Appendix B, the value of 35,200 total square feet is used to convert costs into cost per square foot. The total cost per square foot based on the results of the seashed employment CPM network output is $94 per square foot ($3,311,000/35,200 square feet) and would require 15 days to complete the project using the normal time and normal cost input data.

If the crashing network eliminated three-quarters of a day by crashing activity F the cost per square foot would have been $104.50 per square foot ($3,679,000/35,200 square feet) and would require seven days. However, a more realistic approach by planners would be to shorten activity F to zero and the total cost would be $78 per square foot ($2,779,000/35,200 square feet) which would still require seven days for completion. The only critical path remaining in this crashed network is A-I-J-K-L.

The reason that the program computed a lower cost given the shorter time is because the activities and delays associated with modifying vessels and installing seasheds are avoided in its network analysis because the pre-boarding activities would require no time and their costs would have already been paid.

When the computerized crashing recommendations were applied in the model, the total crashed activities cost more than the normal activities by $368,000 ($3,679,000 - $3,311,000). The planner would save eight days for that increased cost.

When the contingency includes pre-boarded seasheds, the results show that a savings of eight days can be achieved with an accompanying cost saving of $532,000 ($3,311,000 - $2,779,000). This author hastens to add that the actual conversion costs when pre-boarding seasheds is not incurred in that computation. In the case of the Sealand Consumer the cost was $558,315 as listed in Appendix B. Therefore, the cost savings with pre-boarded seasheds, in this case, is not an actual savings but it is a rather slight increase in cost of $26,315 ($558,315 - $532,000) above the normal costs without seasheds boarded on the vessel.

When comparing the crash cost using pre-boarded seasheds with the crash cost using an unmodified vessel, the former options costs $900,000 ($3,679,000 - $2,779,000) less than the latter. Yet, both options require seven days for completion. These results are interpreted to mean that pre-boarding seasheds is a more economical decision than attempting to crash activities on an unmodified vessel. It is assumed, however, that when meeting the RDD is a high priority, planners will not be concerned with these

potential savings opportunities because they have not been proven and they are not yet an option available to them.

Overall, the results are interpreted to mean that the time saving of eight days is the significant benefit of pre-boarding seasheds. As stated before, the conversion cost per vessel is decreased each time the pre-boarded seasheds are used, and therefore that cost would be negated after the seashed enhanced vessel completes a few charters.

The next chapter summarizes the potential for seashed employment, discuss its strengths, and weaknesses and make recommendations regarding further research of seashed employment.

VI. SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

A. SUMMARY

The consequence of not employing seasheds for contingency operations is forfeiture of a range of cost-effective military options which are currently available. There is a strong need to ensure that strategic sealift capability is not lost as a result of a U.S.-flag civilian fleet which is incompatible with military lift requirements. As the number of ships considered militarily useful continues to decline, DOD's exposure to the risk of a sealift shortfall during a crisis situation will continue to increase. MARAD's purchase of used RO/RO vessel's for the RRF is a sure step toward reducing the potential shortfall in unit equipment carriage capability. However, RO/ROs and containerships were useful in the Persian Gulf primarily because of the modern deep-water port facilities available in Saudi Arabia. The concrete wharves and Saudi ground transportion systems made ship offloading time minimal and cargo accumulation on the dock negligible. (Ackley, 1992) The usefulness of RO/ROs and containerships is not significantly better than seashed-enhanced containerships in undeveloped ports.

Seasheds would be most useful in a contingency, such as Operation Restore Hope in Somalia, with underdeveloped ports which necessitates logistics-over-the shore (LOTS) operation. For LOTS operations, ships are required to offload in-stream from an anchorage at sea, and the unit equipment is transported ashore by a variety of lift assets such as causeways, landing craft, or aircushioned landing craft. Seasheds are considered effective enhancements in LOTS operations; however, they have not been employed in exercises or contingencies where they can be tested as effective LOTS assets.

Maintaining an adequate sealift capability and using the resources that are available provide military planners the option to enhance the readiness of sealift assets, reduce costs, and save time in a crisis situation.

> To successfully benefit from the use of enhancement features, strong support is required from within the shipping industry. Without considering the views of shipbuilders/owners/operators, any program initiated for such an endeavor will fail. (MARAD Report No. 840-90015, 1990)

Seasheds' ability to increase the sealift capacity of containerships by including unit equipment cargo carrying capability has been effectively demonstrated during Display Determination '89 and Operation Desert Sortie. However, the addition of seashed enhancement features could have the impact of either enhancing or detracting from commercial

shipping operations, depending on the hull type or intended trade. (MARAD Report No. 840-90015, 1990)

This thesis has presented a decision support model which, if given accurate cost and time estimates for activities involved, aids in determining realistic total costs and time requirements when seasheds are selected for hauling unit equipment on containerships. The indications from the model's simulation, when using the project crashing technique and critical path method, demonstrate that the major advantage to DOD, with preboarded seasheds, is the decreased loading time and unloading time when compared with the normal time and costs. The simulation's results suggest that the substantial amount of time saved with preboarded seasheds would require minimal additional costs in loading and discharging cargo. Costs were not significantly increased for the preboarded seashed scenario compared with the normal operation.

B. CONCLUSIONS

The U.S. Merchant Marine's severe decline has had serious ramifications for national security. According to General Johnson, during Desert Shield/ Desert Storm "availability and timeliness of unit equipment capable ships from both US and worldwide commercial fleets were not adequate to meet the supported CINC's [Commander in Chief's] surge requirement." To meet the requirement, the command used virtually every roll-on/roll-off (RO/RO) it could find: all 17 in the Ready Reserve Force (RRF), 47 US flag charter, and 41 foreign flag charter. Competition among allies exacerbated the problem. For example, in late November, as USTRANSCOM prepared for surge deployment, the United Kingdom was contracting for

22 RO/ROs to move its 4th Mechanized Brigade the Persian Gulf. It was during that time that the danger in the situation became most apparent. From late December 1990 to the end of the war, foreign flags carried nearly 40% of US unit cargo. In General Johnson's words, "it worked okay this time but what if foreign governments don't go along with operations [next time]? After all, only the United Kingdom supported our raid on Qadhafi in 1986. France would not let us fly overhead." (Matthew and Holt, 1992)

Seasheds have military utility but no practical commercial viability. Economic incentives for containership operators have not been sufficient to encourage serious consideration of seashed enhancement installations. The government takes the risk of placing military planners in the unenviable position of waiting for a crisis to arise before choosing the sealift mix, which has tended to include foreign flag ships before using seashed enhanced U.S.-flag containerships. Such a policy saves short term costs but reduces commerce for U.S.-flag operators who would be chartered for DOD movements and U.S. shipyards that would perform conversions because time constraints and their cost are incongruent with current fiscal constraints.

A major hindrance to the use of seasheds for military contingencies has been the unrealistically high cost estimates reported to military planners. Seasheds were authorized, built, and stockpiled in the 1980's. Their advantages and disadvantages should be considered based on

historical performance and non-speculative estimates of costs.

C. RECOMMENDATIONS FOR FURTHER STUDY

1. Even if sealift requirements could be met with seashed enhancements installed, could containership carriers still meet worldwide commitments without permanently losing liner trade routes to foreign competitors?

2. What opportunities exist to acquire aging containerships for the Ready Reserve Force for the purpose of preboarding seasheds?

3. If classes of combination container/breakbulk ships are not profitable for shipowners, would there be a better, more economical arrangement for the shipowners to preboard seasheds and carry only breakbulk cargoes on their vessel?

4. What has been the performance of seasheds in military operations requiring logistics-over-the-shore (LOTS) and joint-logistics-over-the-shore (JLOTS) operations?

5. If the decline in militarily useful U.S.-flag fleet ships continues (from 168 in 1990 to an estimated 35 in the year 2005), should seasheds be employed more often in the future as a sealift enhancement feature (SEF)?

6. How can U.S. strategic sealift assets be developed to provide a sealift capacity large enough to meet military

contingencies without interfering with international

commercial shipping?

CLASS (VESSEL CLASS)   NUMBER OF SEASHEDS
NUMBER OF CCSA

HATCH COVER

CELL
GUIDE

CENTER LINE   CELL GUIDE REINFORCED
FOR POTENTIAL STORAGE
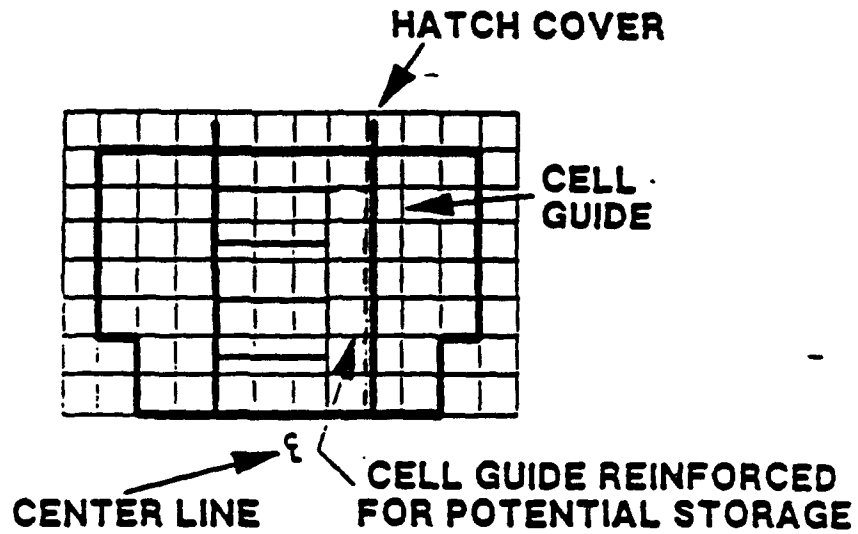
ALTERNATE SEA SHED STORAGE
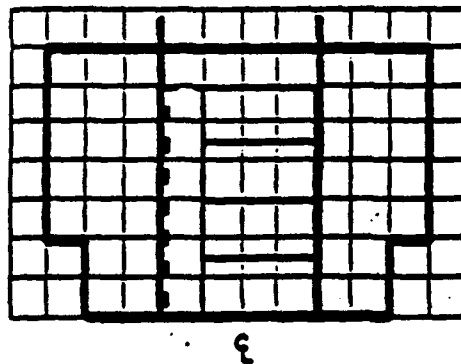
Class: C5-S-73B

Number of Seasheds: 24
Number of CCSA: 8

Hold 1 Fwd
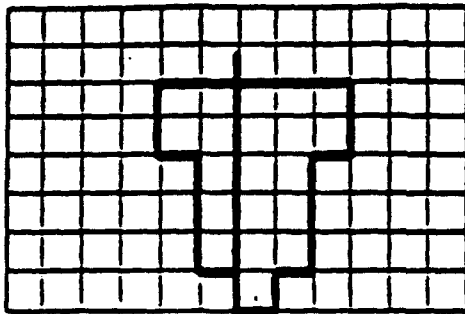
Hold 1 Aft

Hold 2 Fwd
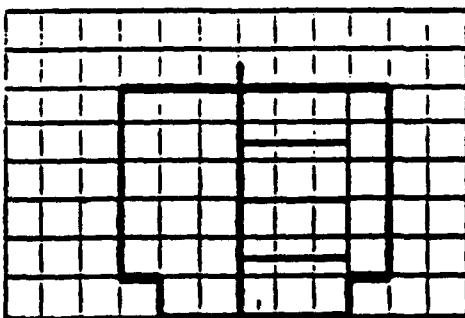
Hold 2 Aft

Hold 3 Fwd
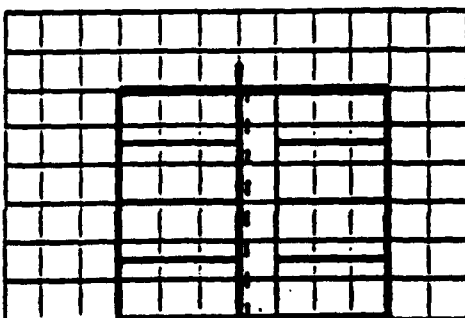
Hold 3 Aft

Hold 4 Fwd
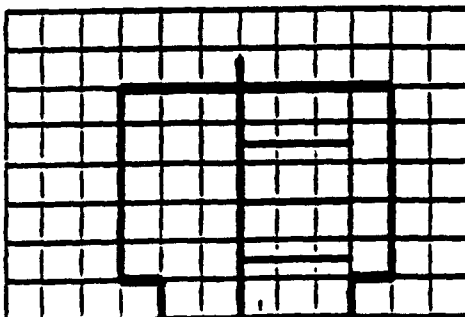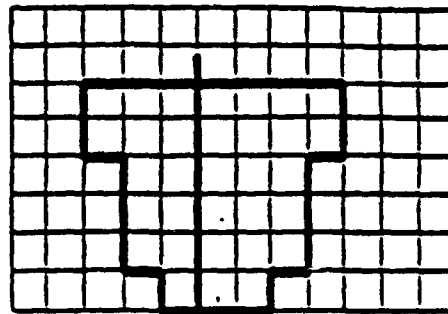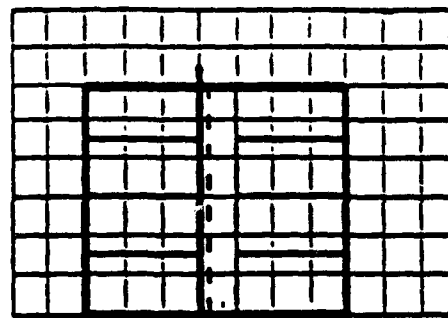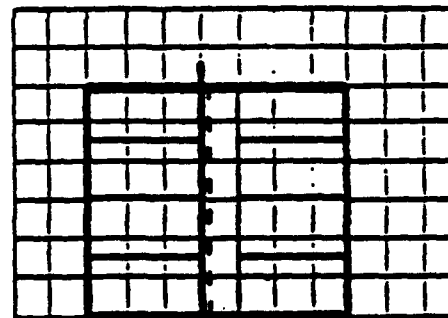
Hold 4 Aft
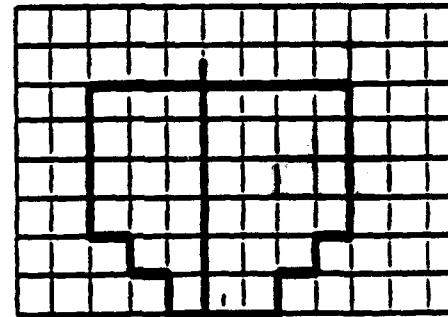
* Hold 5 for 20' containers only

91

Class: C6-M-146A

Number of Seasheds: 24
Number of CCSA: 8
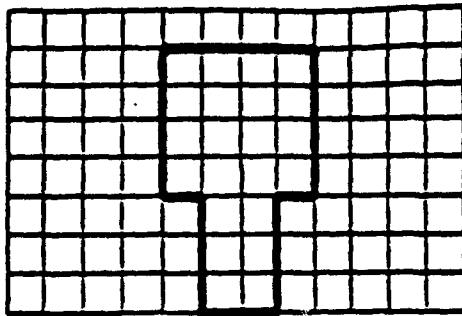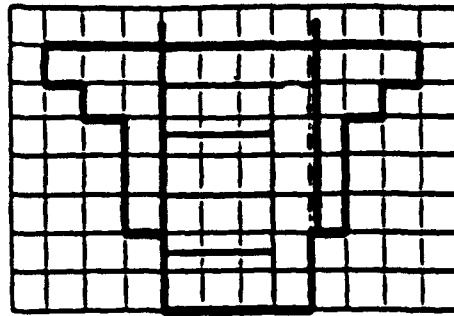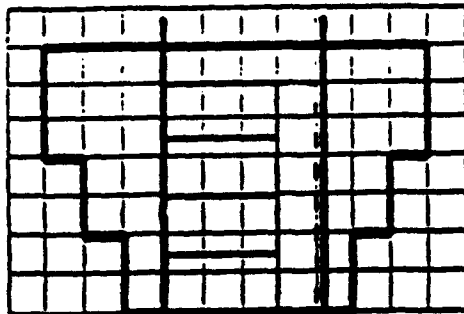
Hold 1
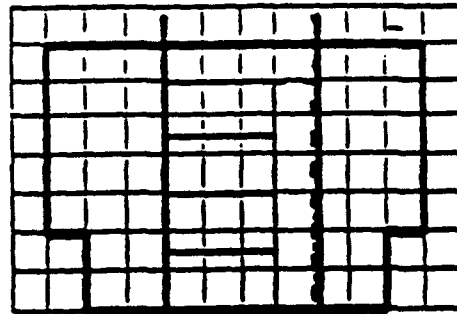
Hold 2

Hold 3

Hold 4

Holds 5 thru 8 have same hold
configuration
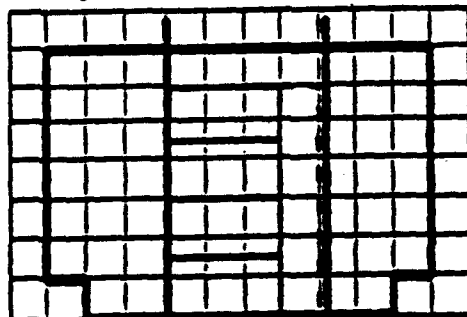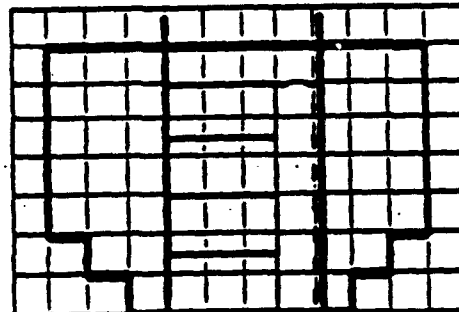
Hold 9
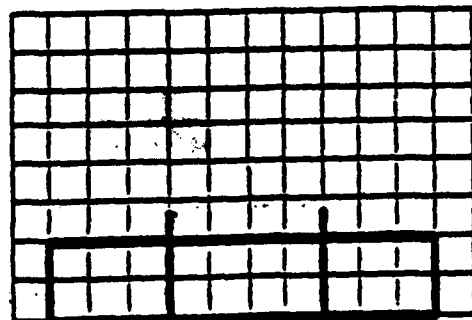
Hold 10

Class: C6-M-F147A

Hold 2 Aft
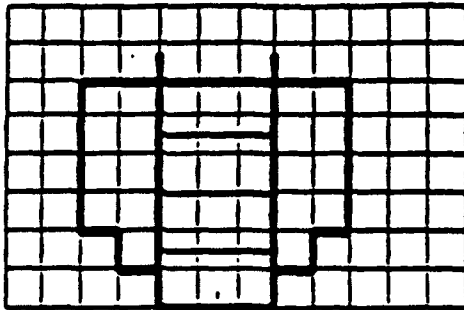
**Hold 3 Fwd, Hold 5 Fwd, & Hold 5 Aft
have same hold configuration**
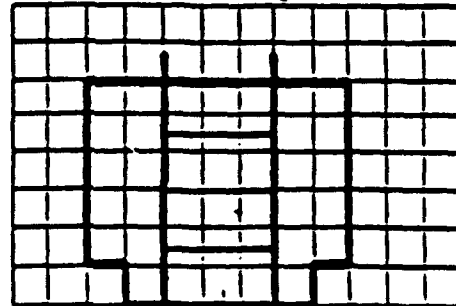
Hold 3 Aft
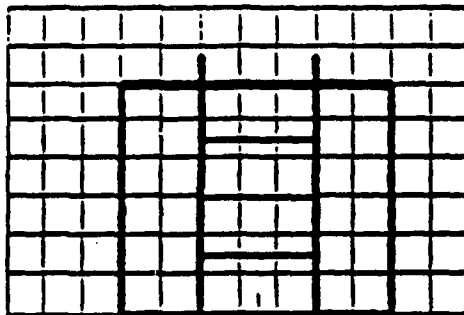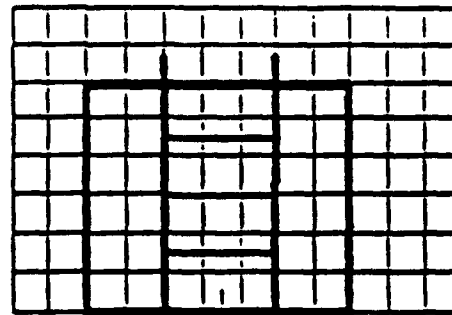
Hold 4

* Hold 1 & Hold 2 Fwd for 20' containers only

93

Class: C6-S-1XA C

Number of Seasheds: 5
Number of CCSA: 3

Hold 3
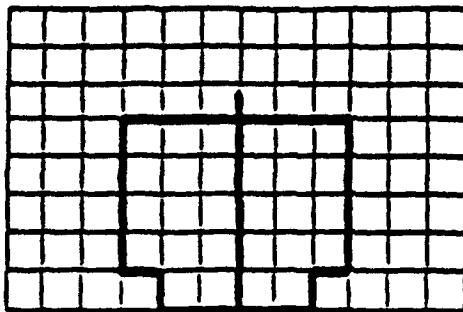
Hold 4
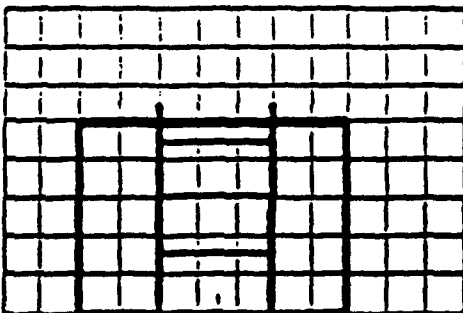
Hold 5

Hold 8

Hold 9
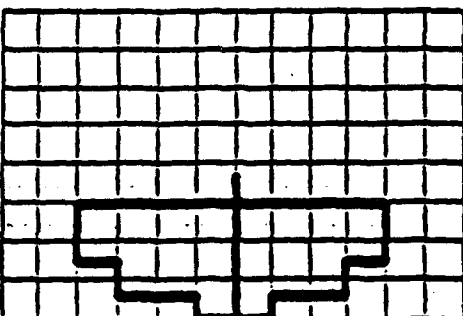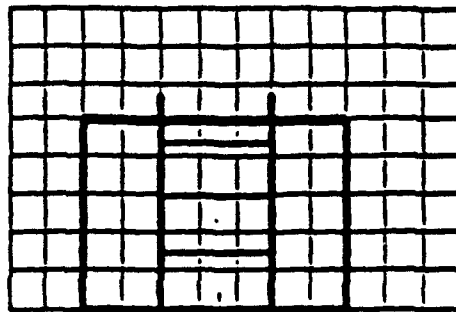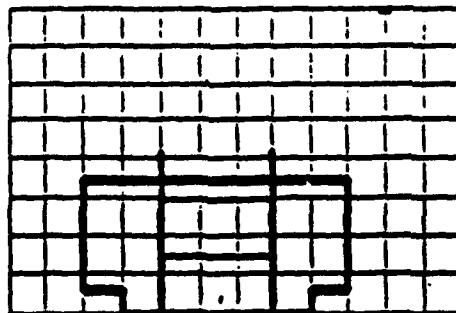
* Holds 1, 2, 6, & 7 for 20' containers only

Class: C6-S-69C C

Number of Seasheds: 12
Number of CCSA: 6

Hold 1
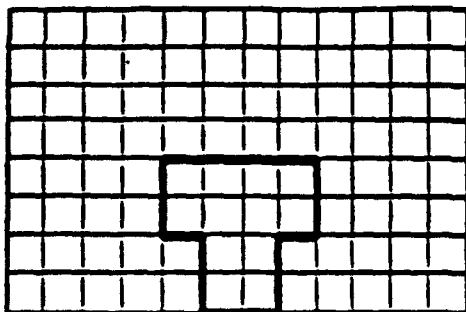
Hold 2

Hold 3 Fwd
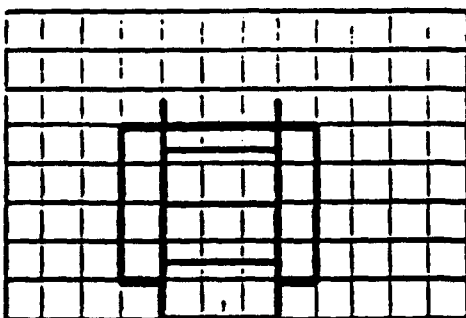
Hold 3 Aft

Hold 4 Fwd, Hold 4 Aft, & Hold 5 Fwd, have same hold configuration
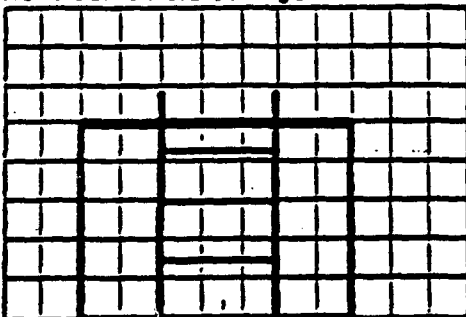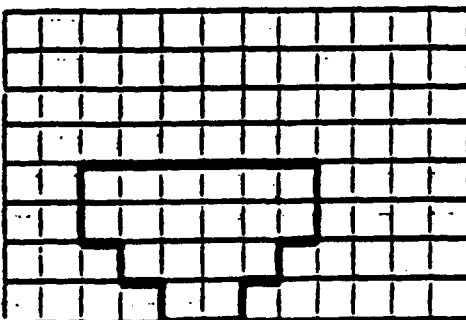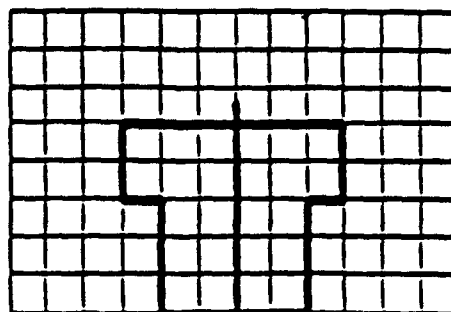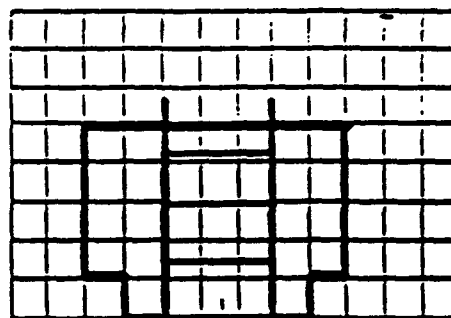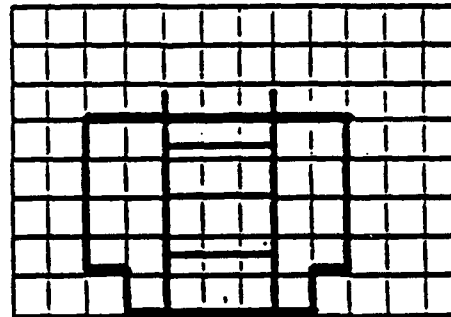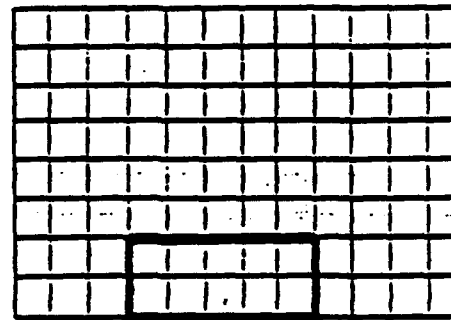
Hold 5 Aft

Hold 6

Hold 7

95
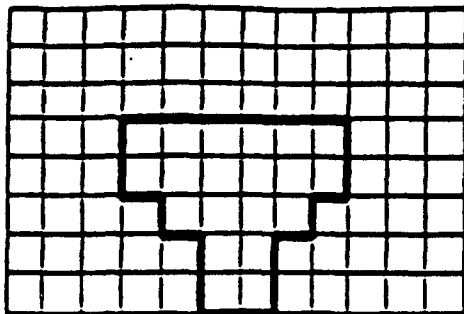
Class: C6-S-85A

Hold 1

Hold 2
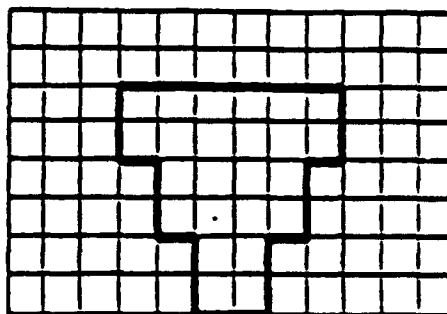
Hold 3
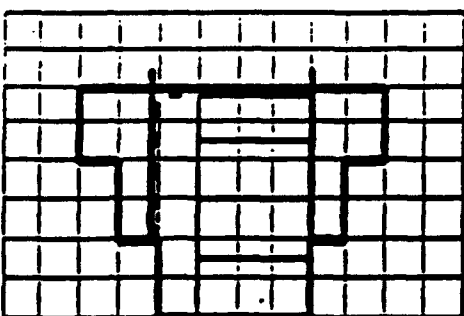
Holds 4 & 8 have same hold
configuration
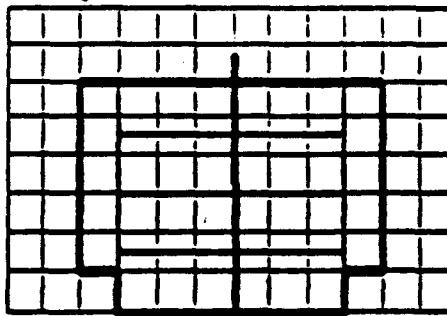
Holds 5 thru 7 have same hold
configuration
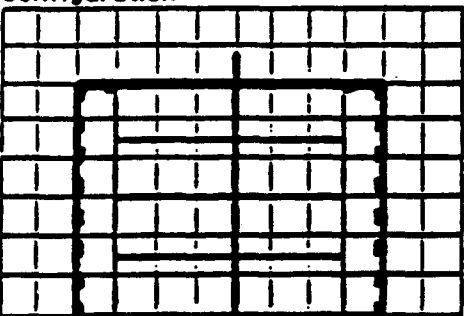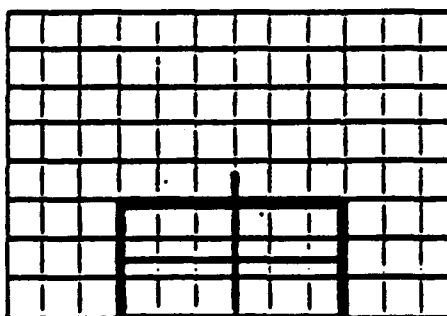
Hold 9

* Hold 10 for 20' containers only

Class C6-S-85B

Hold 4 & Hold 8 have same hold configuration
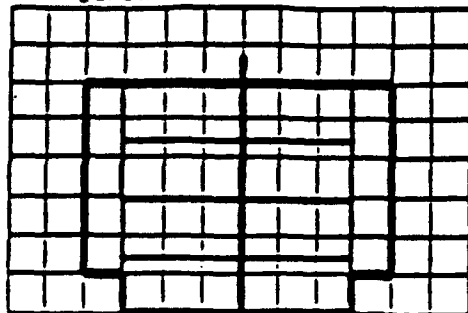
Holds 5 thru 7 have same hold configuration
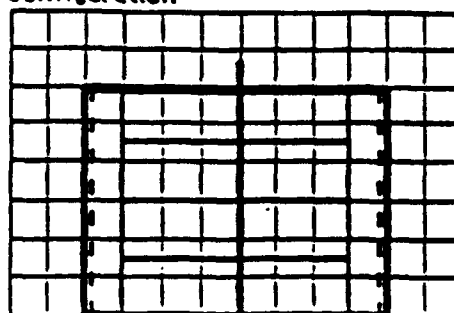
Hold 9 Fwd
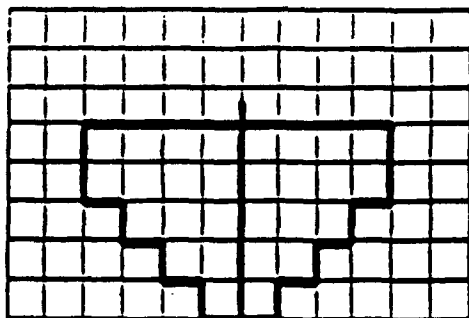
* **Holds 1, 2, 3, & 9 Aft for 20' containers only**

Class: C7-M-88A

Number of Seasheds: 28
Number of CCSA: 14

Hold 1
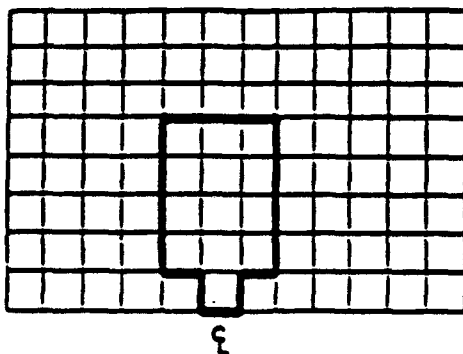
Hold 2
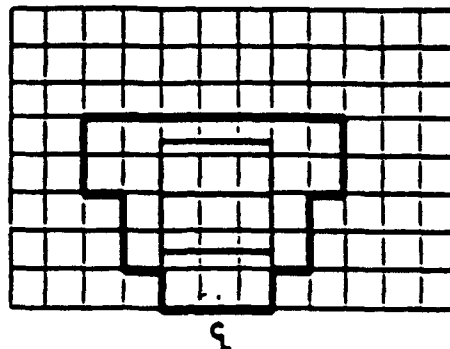
Hold 3
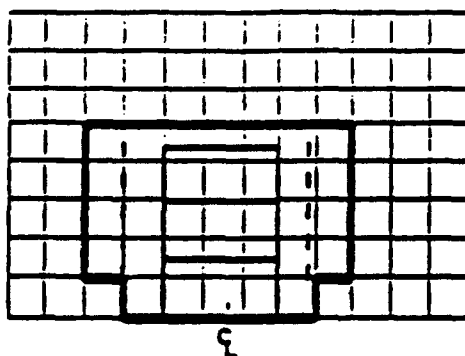
Holds 4 thru 9 have same hold configuration
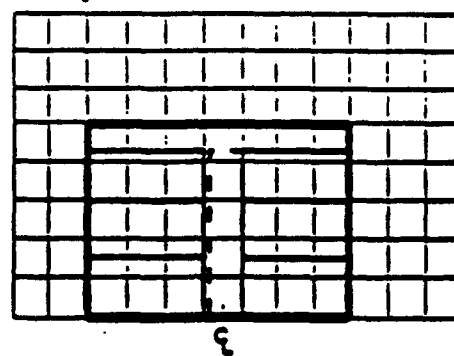
Hold 10
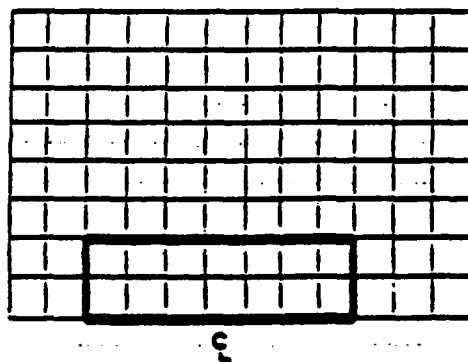
* Hold 11 for 20' containers only

98

Class C7-S-68C,D,E

Number of Seasheds: 30
Number of CCSA: 10

Holds 4 thru 8 have same hold
configuration.
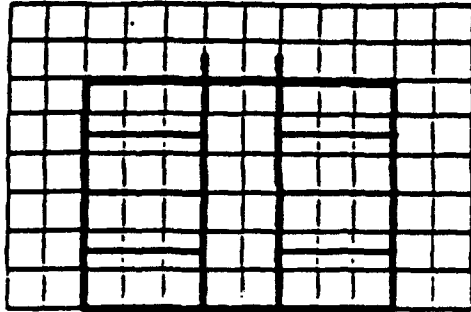
* Holds 1 thru 3 & Holds 9 thru 11
for 20' containers only

Class C7-S-88A

Number of Seasheds: 33
Number of CCSA: 11

Hold 2
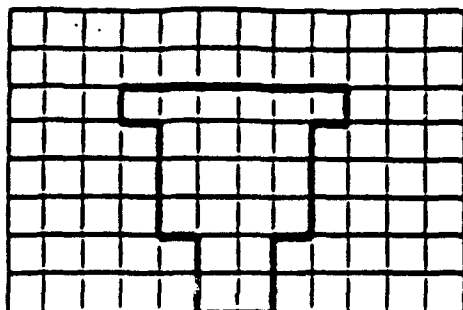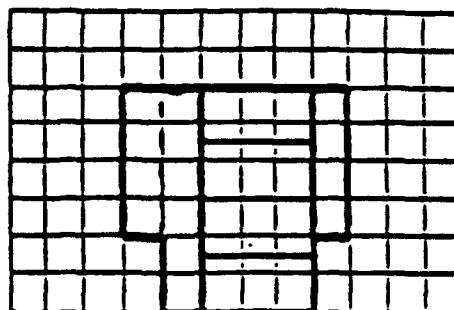
Hold 3

Hold 4
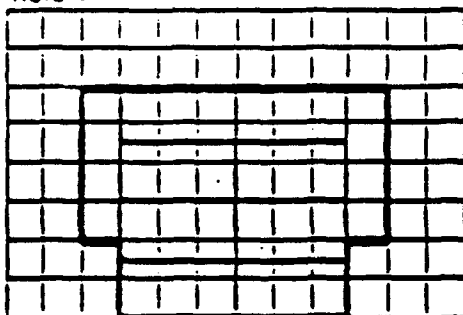
Holds 5, 6, 8, & 9 have same hold configuration
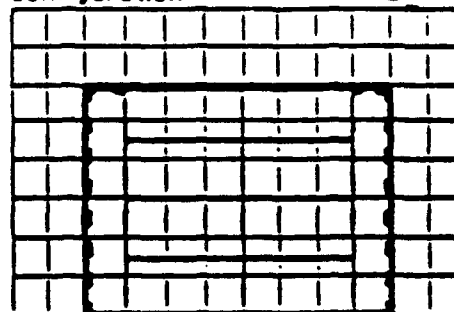
* Hold 1 for general cargo only
Holds 7 & 10 for 20' containers only

100
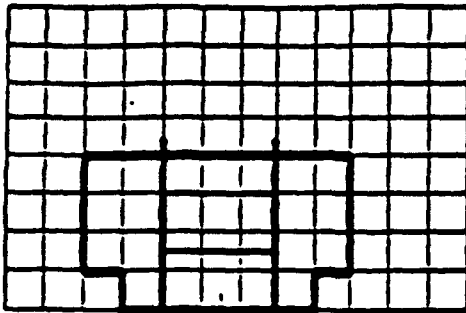
Class: C8-S-81E

Hold 1 Fwd

Hold 1 Aft

Hold 2 Fwd

Hold 2 Mid

Hold 3 Mid

Hold 3 Aft

Hold 5 Fwd

Hold 6 Aft

* Hold 1 Mid, Hold 2 Aft, Hold 3 Fwd, Hold 4 Aft, Hold 5 Aft, & Hold 6 Fwd
for 20' containers only

Hold 4 Fwd is machinery space

101

Class: C8-S-85C,D

Number of Seasheds: 48
Number of CCSA: 16

Hold 1 Fwd
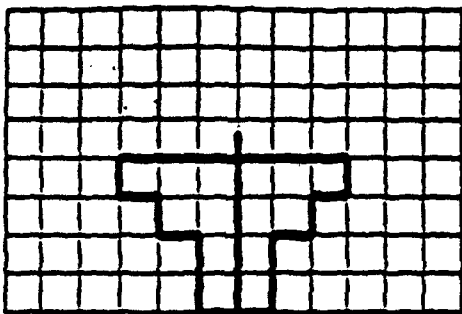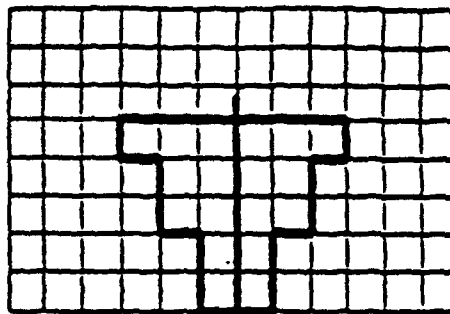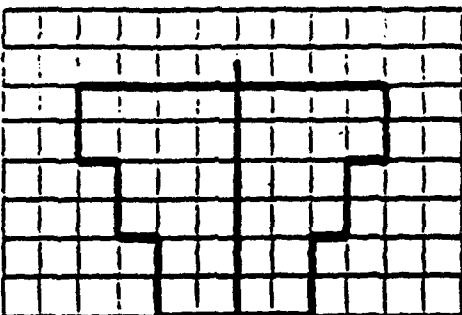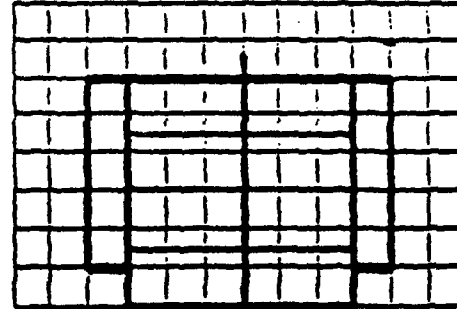
Hold 2

Hold 3

Hold 4

Holds 5 thru 10 have same hold configuration
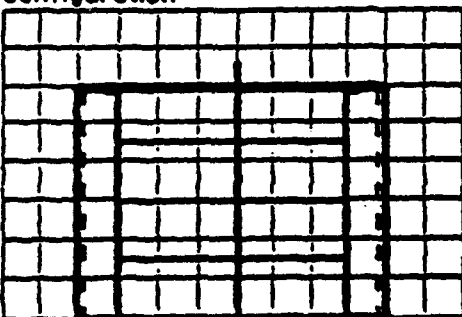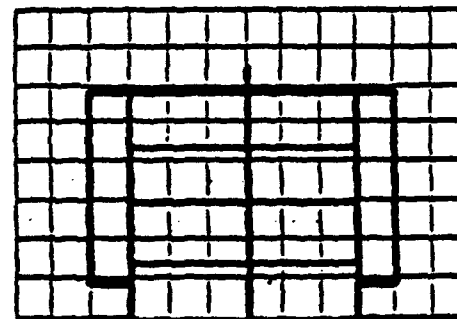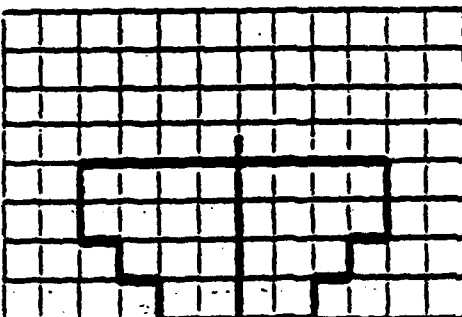
Hold 11

Hold 12

* **Hold 1 Aft for 20' containers only**

Class: C9-M-132B

Number of Seasheds: 39
Number of CCSA: 15

Hold 1 Fwd

Hold 2 Fwd

Hold 2 Aft

Hold 3 Fwd

Hold 3 Mid

Hold 3 Aft

Hold 4 Fwd

Hold 4 Aft

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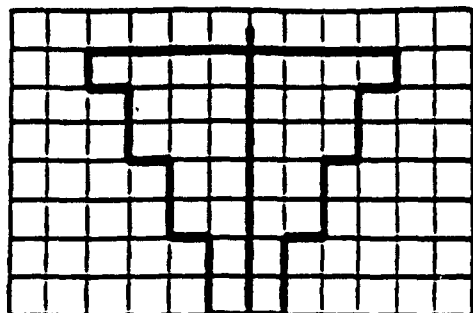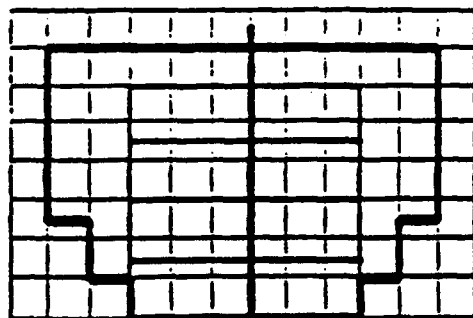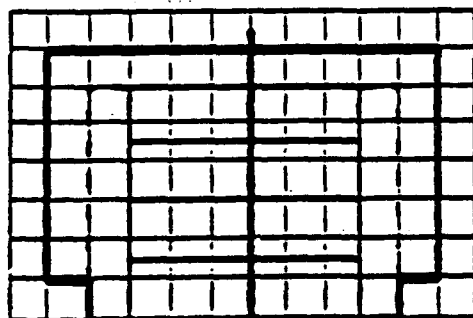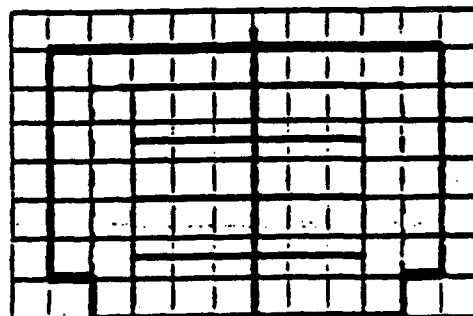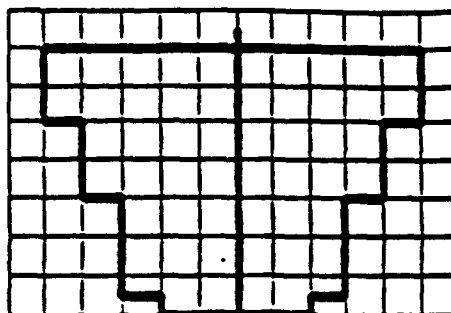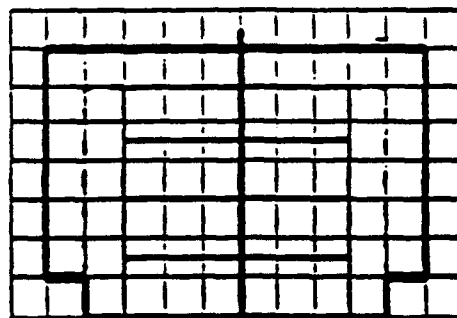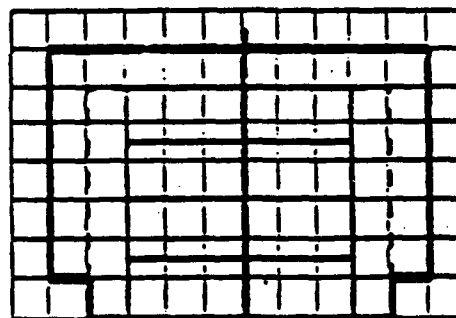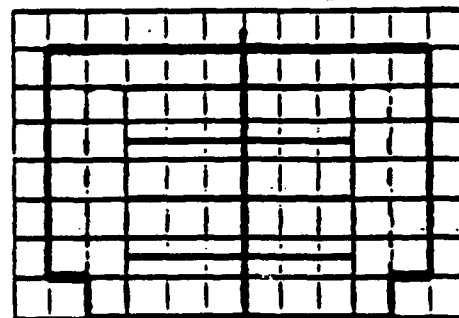
Class: C9-M-132B (cont'd)

Hold 5 Fwd

Hold 5 Aft
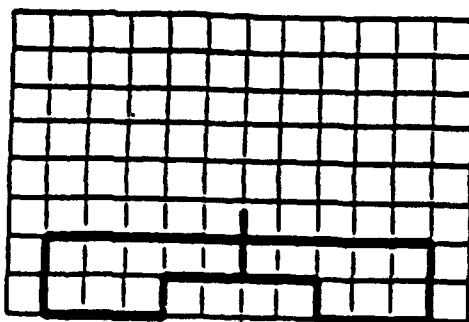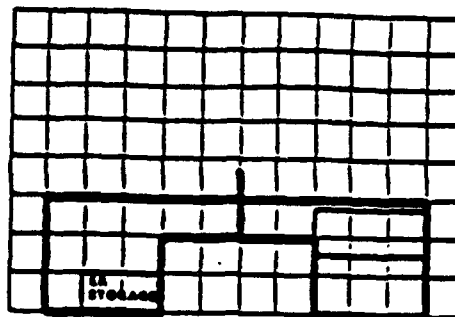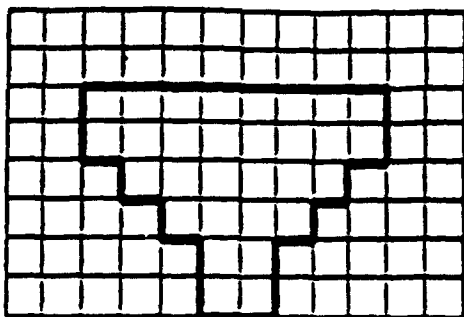
Hold 6 Fwd
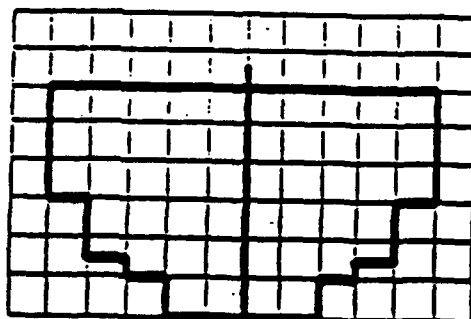
Hold 6 Aft
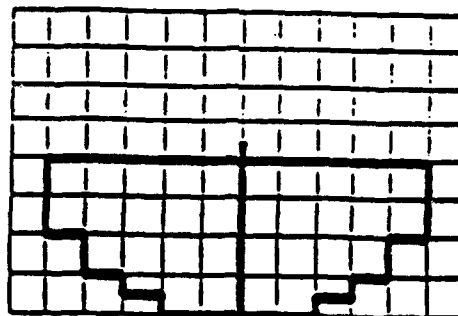
Hold 7 Fwd
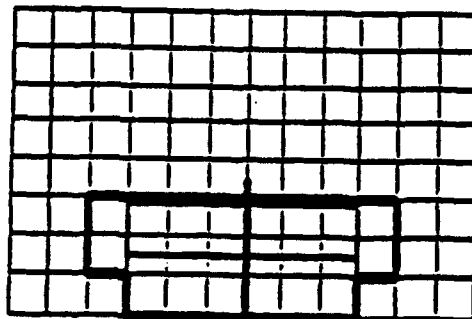
*** Hold 1 Aft for 20' containers only
Hold 7 Aft is machinery space**

Class: C9-M-F141A

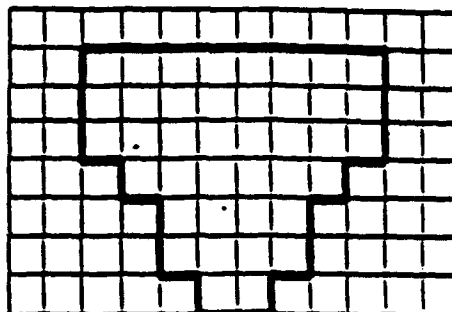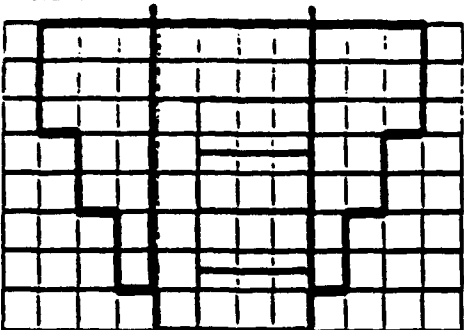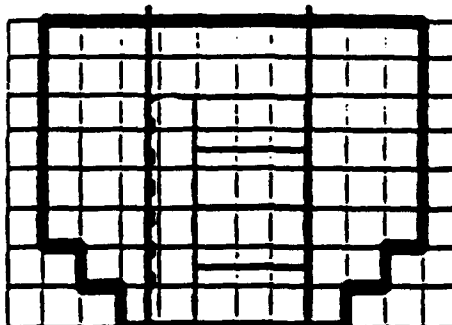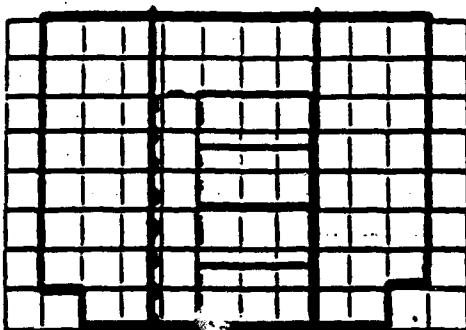Number of Seasheds: 105
Number of CCSA: 35

Hold 1

Hold 2

Hold 3

Hold 4
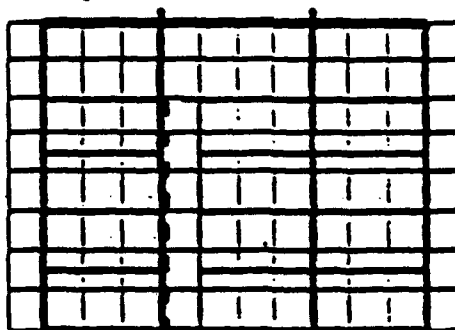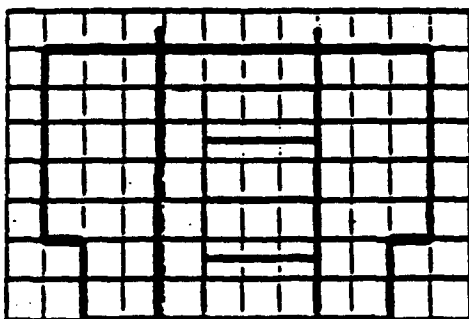

Hold 5

Holds 6 thru 15 have same hold configuration
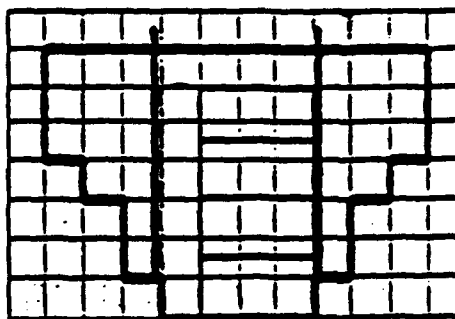
Hold 16

Hold 17

Class: C9-M-F141A (cont'd)

Hold 18
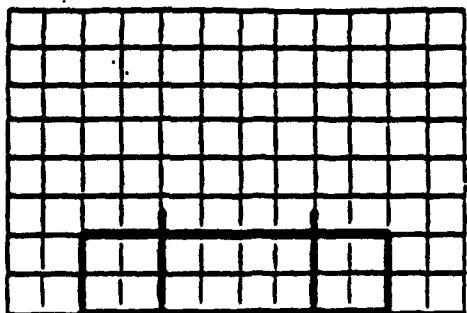
* Hold 18 for machinery space

Class: C9-M-F148A J

Number of Seasheds: 23
Number of CCSA: 9

Hold 1 Aft
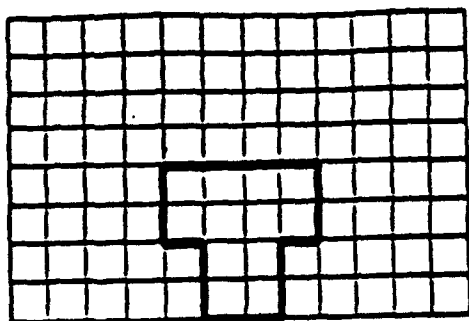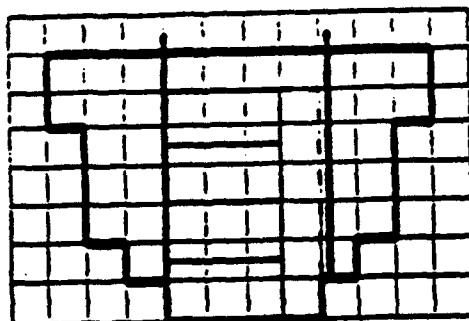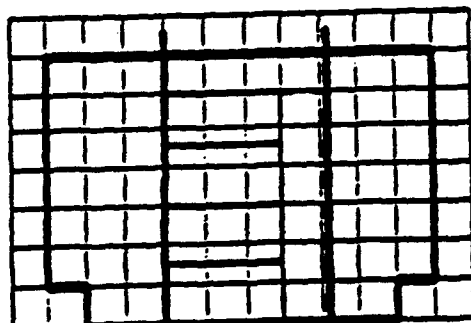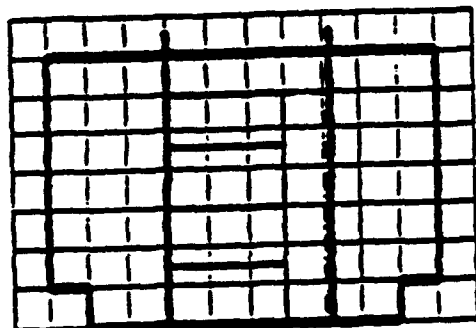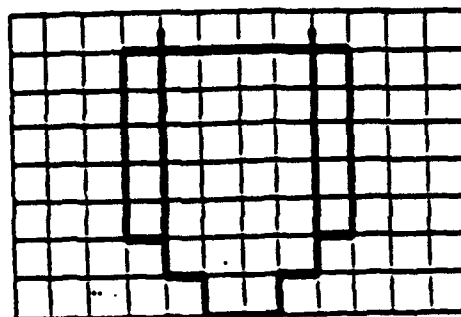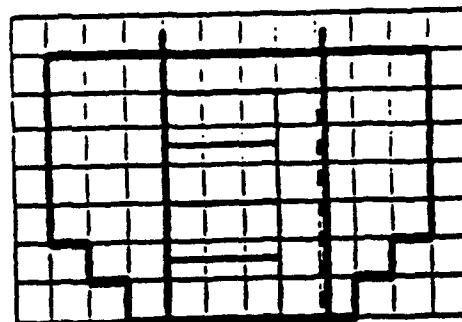
Hold 2 Aft

Hold 3 Fwd

Hold 3 Aft

Hold 4 Fwd, Aft

Hold 4 Aft, Fwd

Hold 4 Aft, Aft
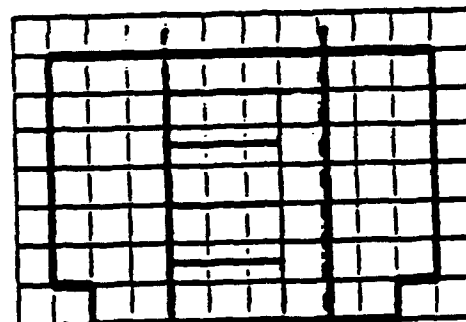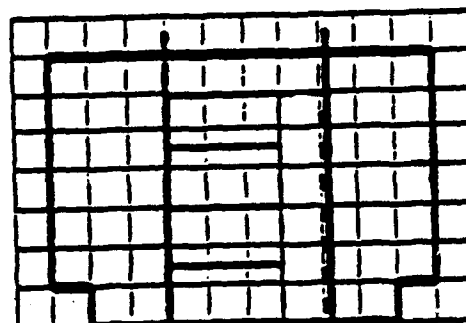
Hold 5 Fwd

Hold 5 Aft
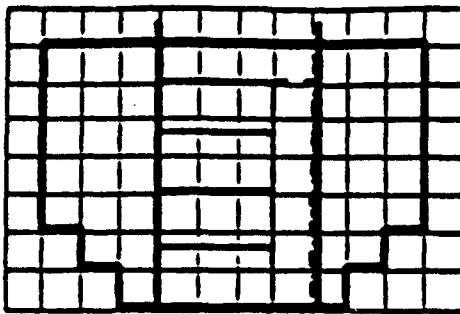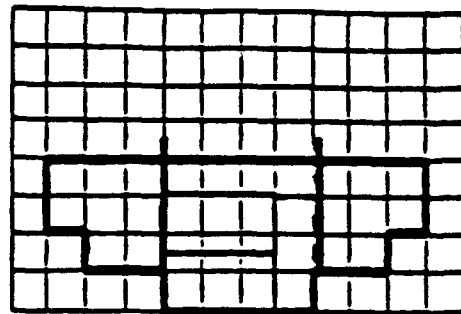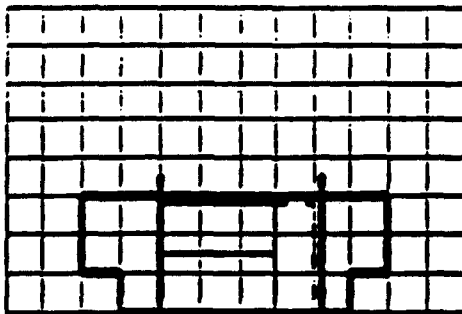
Hold 6 Fwd

Hold 6 Aft

* Hold 1 Fwd, Hold 2 Fwd,
& Hold 4 Fwd, Fwd for
20' containers only

Class: C9-M-F151A

Hold 1 Fwd

Hold 1 Aft

Hold 2 Fwd

Hold 3 Fwd

Hold 4 Fwd

Hold 5 Fwd

Hold 5 Aft

Hold 6 Fwd

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Class: C9-M-F151A (CONT'D)

Hold 6 Aft
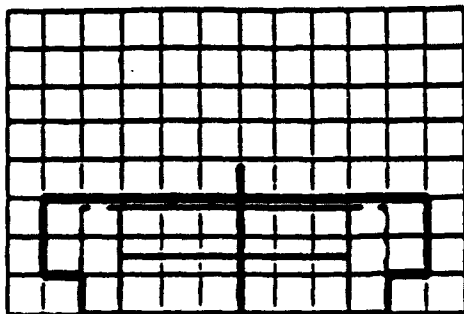
* Hold 2 Aft, Hold 3 Aft, & Hold 4 Aft
for 20' containers only

Hold 1
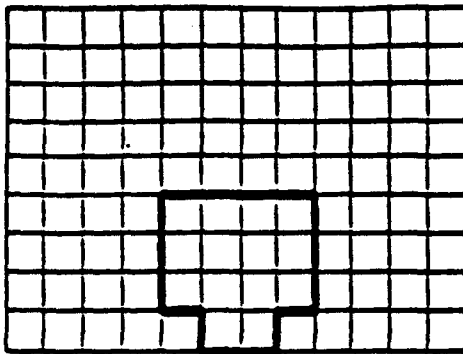
Hold 2 Fwd
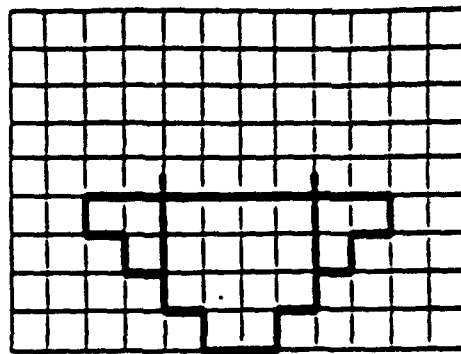
Hold 3 Fwd
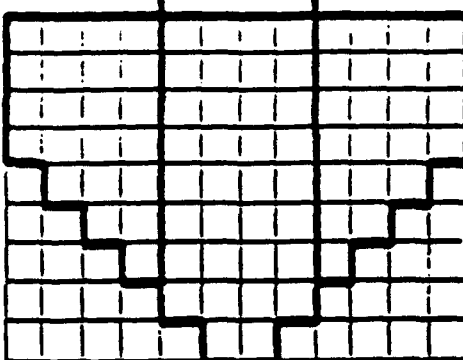
Hold 3 Aft
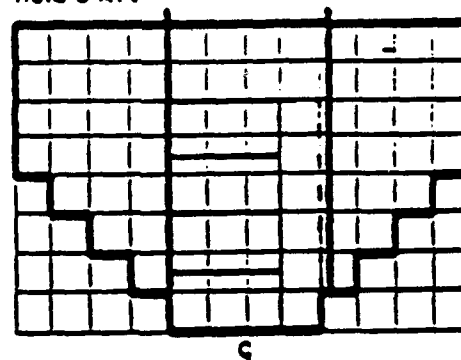
Hold 4 Fwd
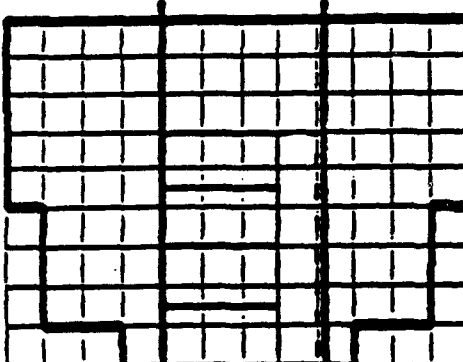
Hold 5 Fwd, Hold 5 Aft & Hold 6 Fwd have same hold configuration
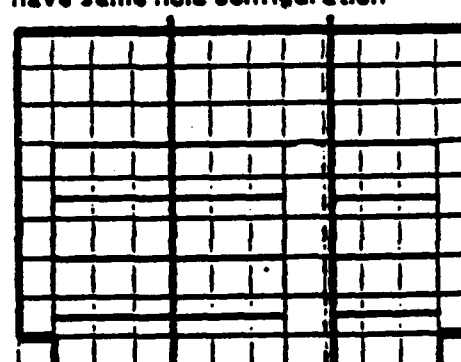
Hold 6 Aft
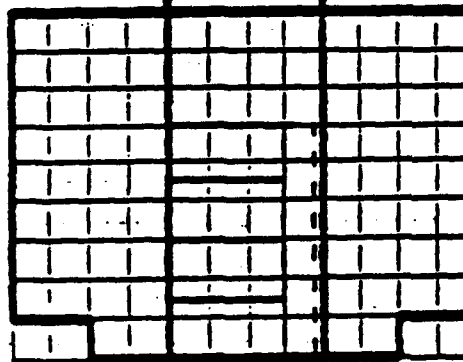
Hold 7 Aft
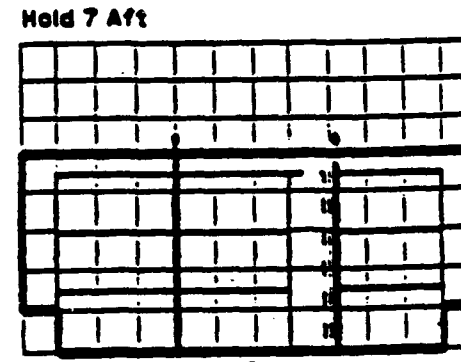
Class C9-M-F150A (cont'd)

Hold 8 Fwd
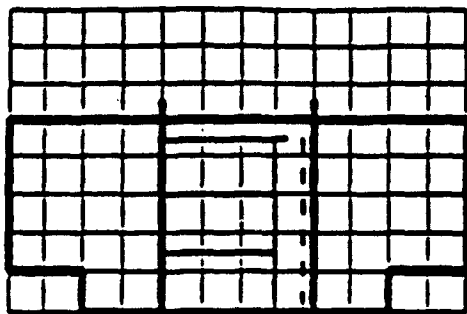
Hold 9 Aft
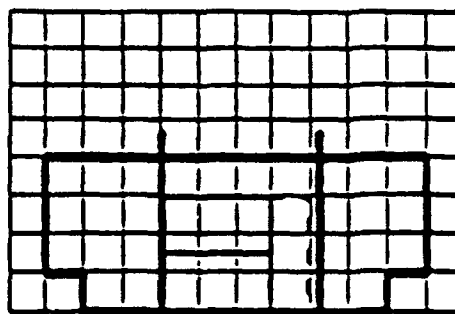
* Hold 2 Aft & Hold 4 Aft for 20' containers only
Hold 7 is machinery room

Class: SL-D6

Hold 1
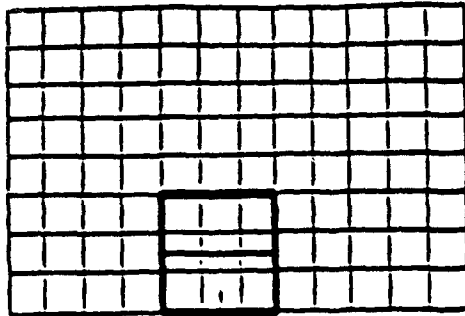
* Holds 2 thru 11 for
20' containers only

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Seashed Conversion Costs

VESSEL NAME	CLASS NUMBER	SEA SHEDS	CCSA's	COST PER VESSEL	TOTAL SQ. FEET	COST PER SQ. FOOT
AMERICAN RESOLUTE	C5-S-73B	24	8	1147795	25600	$45
ARGONAUT		24	8	1147795	25600	$45
EXPORT FREEDOM		24	8	1109440	25600	$43
EXPORT PATRIOT		24	8	1109440	25600	$43
CHESAPEAKE BAY	C6-M-146A	24	8	1099175	25600	$43
DELAWARE BAY		24	8	1099175	25600	$43
ADABELLE LYKES	C6-M-F147A	18	6	801190	19200	$42
CHARLOTTE LYKES		18	6	801190	19200	$42
MARGARET LYKES		18	6	801190	19200	$42
SHELDON LYKES		18	6	801190	19200	$42
PRESIDENT WILSON	C6-S-1XA C	5	3	420295	6400	$66
ALMERIA LYKES	C6-S-69C C	12	6	861575	14400	$60
HOWELL LYKES		12	6	861575	14400	$60
MASON LYKES		12	6	861575	14400	$60
PRESIDENT TAFT		12	6	861575	14400	$60
SEALAND EXPEDITION	C6-S-85A	35	13	1652640	39400	$43
SEALAND HAWAII		35	13	1652640	39400	$43
PRESIDENT JEFFERSON	C6-S-85B	30	10	1447005	32000	$45
PRESIDENT JOHNSON		30	10	1447005	32000	$45
PRESIDENT MADISON		30	10	1447005	32000	$45
PRESIDENT PIERCE		30	10	1447005	32000	$45
SEALAND ANCHORAGE	C7-M-88A	28	14	1657295	33600	$49
SEALAND TACOMA		28	14	1657295	33600	$49
SEALAND KODIAK		28	14	1657295	33600	$49
HUMACAO	C7-S-68C	30	10	1403715	32000	$44
SEALAND CHALLENGER		30	10	1403715	32000	$44
MAYAGUEZ	C7-S-68D	30	10	1469090	32000	$46
SEALAND CRUSADER		30	10	1469090	32000	$46
SEALAND DISCOVERY		30	10	1469090	32000	$46
CAROLINA	C7-S-68E	30	10	1425090	32000	$45
GUAYAMA		30	10	1425090	32000	$45
NUEVO SAN JUAN		30	10	1425090	32000	$45
SEALAND CONSUMER	C7-S-88A	33	11	559315	35200	$16
SEALAND PRODUCER		33	11	2017595	35200	$57
PRESIDENT GRANT	C8-S-81E	19	8	966930	21600	$45
PRESIDENT HARRISON		19	8	966930	21600	$45
PRESIDENT HOOVER		19	8	966930	21600	$45
PRESIDENT TYLER		19	8	966930	21600	$45
SEALAND NAVIGATOR	C8-S-85C&D	48	16	2224790	51200	$43
SEALAND TRADER		48	16	2224790	51200	$43
SEALAND ENTERPRISE		48	16	2224790	51200	$43
SEALAND PACIFIC		48	16	2224790	51200	$43
PRESIDENT LINCOLN	C8-M-132B	39	15	2172345	43200	$50
PRESIDENT MONROE		39	15	2172345	43200	$50
PRESIDENT WASHINGTON		39	15	2172345	43200	$50
PRESIDENT EISENHOWER	C8-M-149AJ	23	9	1291715	25600	$50
PRESIDENT ROOSEVELT		23	9	1291715	25600	$50

Seahed Conversion Costs

GALVESTON BAY	C9-M-F141A	105	35	4995935	112000	$45
NEDLLOYD HOLLAND		105	35	4995935	112000	$45
NEDLLOYD HUDSON		105	35	4995935	112000	$45
NEWARK BAY		105	35	4995935	112000	$45
RALEIGH BAY		105	35	4995935	112000	$45
SEALAND ACHIEVER		105	35	4995935	112000	$45
SEALAND ATLANTIC		105	35	4995935	112000	$45
SEALAND COMMITMENT		105	35	4995935	112000	$45
SEALAND PERFORMANCE		105	35	4995935	112000	$45
SEALAND QUALITY		105	35	4995935	112000	$45
SEALAND VALUE		105	35	4995935	112000	$45
PRESIDENT ADAMS	C9-M-F150A	45	17	2420210	49600	$49
PRESIDENT JACKSON		45	17	2420210	49600	$49
PRESIDENT KENNEDY		45	17	2420210	49600	$49
PRESIDENT POLK		45	17	2420210	49600	$49
PRESIDENT TRUMAN		45	17	2420210	49600	$49
PRESIDENT ARTHUR	C9-M-F151A	28	12	1995590	32000	$62
PRESIDENT BUCHANAN		28	12	1995590	32000	$62
PRESIDENT GARFIELD		28	12	1995590	32000	$62
PRESIDENT HARDING		28	12	1995590	32000	$62
SEALAND ADVENTURER	SL-D6	1	1	137360	1600	$86
SEALAND LEADER		1	1	137360	1600	$86
SEALAND PACER		1	1	137360	1600	$86
SEALAND PIONEER		1	1	137360	1600	$86
SEALAND DEVELOPER	SL-D9 J	27	9	1164825	28800	$40
SEALAND FREEDOM		27	9	1164825	28800	$40
SEALAND PATRIOT		27	9	1164825	28800	$40
SEALAND DEFENDER	SL-D9&D9 C	27	9	1160025	28800	$40
SEALAND ENDURANCE		27	9	1160025	28800	$40
SEALAND EXPLORER		27	9	1160025	28800	$40
SEALAND EXPRESS		27	9	1160025	28800	$40
SEALAND INDEPENDENCE		27	9	1160025	28800	$40
SEALAND INNOVATOR		27	9	1160025	28800	$40
SEALAND MARINER		27	9	1160025	28800	$40
SEALAND VOYAGER		27	9	1160025	28800	$40
SEALAND LIBERATOR		27	9	1160025	28800	$40
TOTAL		3100	1098	$153,299,950	3358400	3997.066058

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|-------------------------------------------------------------------------|
|               CPM Analysis for Seashed Employment     Page  1           |
|-------------------------------------------------------------------------|
   Activity   |     Activity     |Earliest| Latest |Earliest| Latest |  Slack
   No.   Name |Exp.Time Variance| Start  | Start  | Finish | Finish |  LS-ES
|----------+----------+--------+--------+--------+--------+--------|
1    a      |+0.25000  0      |0       |+5.75000|+0.25000|+6.00000|+5.75000
2    b      |+0.50000  0      |0       |0       |+0.50000|+0.50000|Critical
3    c      |+0.50000  0      |0       |0       |+0.50000|+0.50000|Critical
4    dummy1 |0         0      |+0.50000|+0.50000|+0.50000|+0.50000|Critical
5    d      |+2.00000  0      |+0.50000|+0.50000|+2.50000|+2.50000|Critical
6    e      |+2.00000  0      |+2.50000|+2.50000|+4.50000|+4.50000|Critical
7    f      |+1.00000  0      |+4.50000|+4.50000|+5.50000|+5.50000|Critical
8    g      |+0.50000  0      |+5.50000|+5.50000|+6.00000|+6.00000|Critical
9    h      |+3.00000  0      |+6.00000|+6.00000|+9.00000|+9.00000|Critical
10   dummy2 |0         0      |+5.50000|+9.00000|+5.50000|+9.00000|+3.50000
11   i      |+3.00000  0      |+0.25000|+6.00000|+3.25000|+9.00000|+5.75000
12   j      |+3.00000  0      |+9.00000|+9.00000|+12.0000|+12.0000|Critical
13   k      |0         0      |+12.0000|+12.0000|+12.0000|+12.0000|Critical
14   l      |+3.00000  0      |+12.0000|+12.0000|+15.0000|+15.0000|Critical
|-------------------------------------------------------------------------|
       Expected completion time = 15 days    Total cost = $3,311,000
|-------------------------------------------------------------------------|
```

Critical paths for Seashed Employment with completion time = 15 days   Total
cost = $3,311,000

CP # 1 : c - dummy1 - d - e - f - g - h - j - k - l

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Activity No.	Name	Activity Exp.Time	Variance	Earliest Start	Latest Start	Earliest Finish	Latest Finish	Slack LS-ES
1	a	+0.25000	0	0	0	+0.25000	+0.25000	Critical
2	b	+0.25000	0	0	0	+0.25000	+0.25000	Critical
3	c	+0.25000	0	0	0	+0.25000	+0.25000	Critical
4	dummy1	0	0	+0.25000	+0.25000	+0.25000	+0.25000	Critical
5	d	+2.00000	0	+0.25000	+0.25000	+2.25000	+2.25000	Critical
6	e	0	0	+2.25000	+2.25000	+2.25000	+2.25000	Critical
7	f	+0.25000	0	+2.25000	+2.25000	+2.50000	+2.50000	Critical
8	g	+0.50000	0	+2.50000	+2.50000	+3.00000	+3.00000	Critical
9	h	0	0	+3.00000	+3.00000	+3.00000	+3.00000	Critical
10	dummy2	0	0	+2.50000	+3.00000	+2.50000	+3.00000	+0.50000
11	i	+2.75000	0	+0.25000	+0.25000	+3.00000	+3.00000	Critical
12	j	+2.00000	0	+3.00000	+3.00000	+5.00^00	+5.00000	Critical
13	k	0	0	+5.00000	+5.00000	+5.00000	+5.00000	Critical
14	l	+2.00000	0	+5.00000	+5.00000	+7.00000	+7.00000	Critical

Expected completion time = 7 Days   Total cost = $3,679,000

Critical paths for try with completion time = 7 Days   Total cost = $3,679,000

CP # 1 : c - dummy1 - d - e - f - g - h - j - k - 1

CP # 2 : b - d - e - f - g - h - j - k - 1

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|-----------------------------------------------------------------------------|
|              CPM Analysis for Crashing Seashed (Pre-Boarded) Page 3         |
|-----------------------------------------------------------------------------|
| Activity  |     Activity    |Earliest| Latest |Earliest| Latest |  Slack    |
| No.   Name |Exp.Time Variance| Start  | Start  | Finish | Finish |  LS-ES    |
|------------+-----------------+--------+--------+--------+--------+-----------|
|1    a      |+0.25000  0      |0       |0       |+0.25000|+0.25000|Critical   |
|2    b      |+0.25000  0      |0       |+0.25000|+0.25000|+0.50000|+0.25000   |
|3    c      |+0.25000  0      |0       |+0.25000|+0.25000|+0.50000|+0.25000   |
|4    dummy1 |0         0      |+0.25000|+0.50000|+0.25000|+0.50000|+0.25000   |
|5    d      |+2.00000  0      |+0.25000|+0.50000|+2.25000|+2.50000|+0.25000   |
|6    e      |0         0      |+2.25000|+2.50000|+2.25000|+2.50000|+0.25000   |
|7    f      |0         0      |+2.25000|+2.50000|+2.25000|+2.50000|+0.25000   |
|8    g      |+0.50000  0      |+2.25000|+2.50000|+2.75000|+3.00000|+0.25000   |
|9    h      |0         0      |+2.75000|+3.00000|+2.75000|+3.00000|+0.25000   |
|10   dummy2 |0         0      |+2.25000|+3.00000|+2.25000|+3.00000|+0.75000   |
|11   i      |+2.75000  0      |+0.25000|+0.25000|+3.00000|+3.00000|Critical   |
|12   j      |+2.00000  0      |+3.00000|+3.00000|+5.00000|+5.00000|Critical   |
|13   k      |0         0      |+5.00000|+5.00000|+5.00000|+5.00000|Critical   |
|14   l      |+2.00000  0      |+5.00000|+5.00000|+7.00000|+7.00000|Critical   |
|-----------------------------------------------------------------------------|
|         Expected completion time = 7 days   Total cost = $2,779,000         |
|-----------------------------------------------------------------------------|
```

Critical paths for Crashing Seashed with completion time = 7 days   Total cost
= $2,779,000

CP # 1 : a - i - j - k - l

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