A RAND NOTE

Fast Sealift and Maritime Prepositioning Options for Improving Sealift Capabilities

Myron Hura, Richard Robinson

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PREFACE

This Note identifies and describes several fast sealift and maritime prepositioning ships and evaluates their performance in terms of speed and the ability to make cumulative cargo deliveries to developed and underdeveloped theaters. The aim of this work was to screen a range of ships in order to identify attractive candidates for assessment in a subsequent integrated distribution system analysis that is part of an effort to formulate a conceptual design for a DoD Future Materiel Distribution System. Other parts of the study are aimed at analyzing alternative concepts for the distribution of unit-related cargo in conjunction with the mobilization and deployment of forces, and at examining (a) trends in the civil transportation systems on which DoD will rely in a major contingency, (b) the transportability of military equipment, and (c) the affordability of future distribution system alternatives.

The impetus for the overall project arose from correspondence between the Under Secretary of the Army and the Under Secretary of Defense for Acquisition (USDA). In acknowledging the former's concerns about likely problems in mobilization and deployment, the USDA called for a "blueprint" for a materiel distribution system to serve the entire U.S. military. RAND was asked to formulate this conceptual design for the future distribution system, along with a plan to guide the transition to the new system.

Reports issued to date by the distribution study are as follows:

Zale Anis et al., *Role of the Civil Sector in Deployment and Resupply,* Transportation Systems Center, U.S. Department of Transportation, Cambridge, Massachusetts, September 1989.

I. K. Cohen et al., *Issues in Materiel Distribution: A Background Note,* RAND, N-2791-P&L, September 1989.

S. Carroll, R. Worley, and G. B. Crawford, *Alternative Concepts for Managing the Distribution of Resupply Cargo,* RAND, N-3249-DAG/P&L, 1991.

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SUMMARY

Until recently, the privately owned U.S. flag merchant fleet provided sufficient numbers of dry cargo ships to transport military unit equipment (u/e). In the past decade, however, the number of dry cargo ships in this fleet decreased by approximately one-third, from more than 300 to about 200. Equally important, the direct military utility of this fleet decreased substantially because of the increased proportion of container ships. Today, the fleet includes about 94 pure container ships, which without special cargo modules cannot carry the vast majority of Army u/e. If these trends continue, DoD will no longer be able to simply requisition a large number of privately owned U.S. flag ships and employ them without modification to deliver u/e.

This Note, which is the result of research conducted between January 1988 and March 1990, addresses two questions: (1) To what extent can future U.S. flag merchant ships and existing government sealift programs support potential force deployment requirements? (2) If fast sealift ships (FSSs) and maritime prepositioning ships (MPSs) for Army equipment are needed, what kinds of ships should be built and in what operating regime should they be maintained?

FUTURE CIVIL-SECTOR SEALIFT CAPABILITIES

Existing civil shipping trends suggest that by the year 2010, the privately owned U.S. flag dry cargo fleet may decrease to fewer than 100 ships, with about two-thirds of them operating in the commercial sector and the remainder under government charter. The majority of the ships operating in the commercial sector are projected to be engaged in the "liner" trade, delivering cargo to specific ports on well-established schedules. These ships offer fast, safe, and timely delivery, allowing commercial freight forwarders to coordinate ship, rail, and truck schedules efficiently.

The liner trade is principally composed of container ships, the design of which is not as useful as earlier ship designs for carrying military u/e. Container ships carry cargo in open cells typically designed for 20- or 40-ft by 8-ft standard commercial containers. The vast majority of military equipment does not conform to these measurements or cannot be packaged into the standard containers. Container ships also do not have multiple decks, so they require modification to carry vehicles.

Most liner trade ships are nonself-sustaining ships (NSSs), which means they are not equipped with cranes for loading and unloading cargo. They normally operate into well-developed seaports and rely on shore cranes to load and unload cargo. Unencumbered with cranes, these ships can carry more cargo than comparable self-sustaining ships.

To compensate for the limitations of container ships and NSSs, DoD is pursuing two adaptation programs. The first is the Flatrack and Seashed program, which modifies container ships to carry u/e.[1] The second is the Auxiliary Crane Ship program, which is designed to provide loading and unloading services where shore-side cranes are unavailable. In parallel with these options, DoD might be able to design future military equipment to fit commercial containers, thereby increasing the transportability of military forces.

An expansion of the Flatrack and Seashed program offers the potential for increasing the u/e lift of the privately owned U.S. flag dry cargo fleet in the very near term. However, since these ships are essential for the transport of commercial products, DoD cannot expect ready access to them in anything short of a major conflict. Further, even if they can be requisitioned, the process of inserting Flatracks and Seasheds consumes time and delays military equipment deployments. Finally, DoD already counts on container ships to carry resupplies. In light of these drawbacks, an expanded Flatrack and Seashed program should be considered at best as a way to provide increased u/e lift for large-scale conflicts that do not require immediate response or early resupply.

FUTURE GOVERNMENT SEALIFT CAPABILITIES

Several government sealift programs have the potential, with proper support, to provide substantial u/e lift capabilities well into the future. The most important are the Ready Reserve Force (RRF), FSSs, and MPSs.

The RRF consists of deactivated merchant ships, most of which are projected to be ready within five days of an activation order. The RRF might be maintained at its current level or slightly increased if the government purchases used, privately owned dry cargo ships in the U.S. flag merchant fleet as they are replaced with new-construction ships. In

[1] Flatracks and seasheds are cargo-carrying modules that are inserted into container ship cells. They are used to carry equipment and materials that do not fit into standard commercial containers.

the future, this hypothetical RRF might be able to lift approximately 300,000 to 325,000 short tons (stons) of u/e.

Adding the lift capacity of the FSS and MPS forces to that of the projected RRF, we estimate that ships in military sealift programs will be able to lift about 475,000 stons of u/e in the future. This number implies that by the year 2010, the existing government and privately owned U.S. flag merchant ships might be able to lift on the order of 785,000 stons of u/e. This projected lift capacity is equal to the current capability, which is estimated to be 700,000 to 900,000 stons of u/e. Moreover, it is approximately 20 percent less than the existing goal of 1 million stons of u/e.[2]

In addition to the capacity problem, the current and projected sealift force may be unable to provide timely delivery because of the ships' slow speeds. The speed of the dry cargo ships in the U.S. flag merchant fleet is in the range of 17 to 25 knots, and there is no apparent demand in the commercial sector to increase this speed in the future. Assuming an average speed of 20 knots and a week for the activation, call-up, and loading of government and privately owned U.S. flag merchant ships, the hypothetical year-2010 fleet will not be able to deliver large quantities of u/e to Europe in less than 17 days or to Southwest Asia in less than 34 days. Therefore, if the United States has to deploy large forces by sea to Europe in two weeks or less, or to Southwest Asia (without access to the Suez Canal) in less than one month, the current and projected strategic sealift capability would be categorized as inadequate. Options for enhancing future U.S. sealift capabilities need to consider both increased capacity and higher speed.

FAST SEALIFT AND MARITIME PREPOSITIONING SHIP CANDIDATES

We examined several ship designs and ship operating modes by constructing equal-cost forces and evaluating their initial cargo delivery times and cargo throughput to Europe, Southwest Asia, Zaire, and Thailand under different warning time and ship attrition considerations. The performance of the candidates across scenarios is the measure we used in determining which candidates merit further consideration.

We defined three fast sealift candidates: a baseline T-AKR, an improved T-AKR, and a surface effect ship (SES). The two T-AKRs are conventional monohull ships with

[2]General George B. Crist, *Statement Before the Defense Policy Panel of the House Armed Services Committee on the Status of the United States Central Command*, March 17, 1987, p. 52. The goal was set before the recent dramatic changes in the security environment and will undoubtedly be reexamined in light of these changes.

maximum sustained speeds of 33 knots, capable of carrying 8000 and 12,000 stons of u/e, respectively. The SES is an advanced conceptual design ship that rides on a cushion of air. It has a sustained operating speed of 55 knots and carries 5000 stons of u/e.

Our analysis indicates that the preferred conventional monohull FSS candidate is the 33-knot improved T-AKR, which outperforms the baseline T-AKR in all tested scenarios. In reduced operating status, the improved T-AKR can deliver its first cargo to Europe in 12 days, to Southwest Asia in 22 days, to Zaire in 14 days, and to Thailand in 17 days. It can also deliver more cargo than all of the other candidates over 45-, 60-, and 90-day periods.

The improved T-AKR also outperforms the SES in all but the most time-critical situations, the SES being able to deliver first cargo three to seven days earlier than the improved T-AKR. The improved T-AKR provides greater capacity than the SES and can be built with current technology. The SES provides the faster response time, but offers substantially less capacity and requires an R&D program to develop unproven technologies. Given these different capabilities, it is clear that a policy decision must be made between these two options.

An alternative approach for improving unit deployment times is to preposition Army equipment on ships specifically designed to store such equipment. We defined three MPSs for storing Army u/e (MPS (A)s): the standard, the new-design, and the high-capacity ship. These candidates are combination container, breakbulk, and roll-on and roll-off (Ro-ro) ships; they are also conventional displacement monohull ships. The standard has an operational speed of 25 knots; the other two are capable of 33 knots.

Our analysis of the three MPS(A) candidates suggests that the preferred one is the high-capacity MPS(A). Given zero warning time, the high-capacity MPS(A) can deliver initial cargo two to ten days earlier than the SES. There is a penalty for this rapid response, however: the added cost of maintaining the ship in an active operating regime and the cost of procuring an extra set of u/e for storing on board. These added costs mean that fewer high-capacity MPS(A)s than improved T-AKRs or SESs can be built for the same amount of money, which translates into substantially less cargo delivered over 90 days.

Policy decisions are needed to discriminate between the two faster options, the SES and the high-capacity MPS(A). The SES provides the greater flexibility of the two because it is not preloaded and thus can pick up the best-suited military cargo for a given

contingency. Moreover, it delivers more cargo over time than the high-capacity MPS(A). However, because the SES is only in the conceptual design phase, it requires an extensive R&D program to become a reality, which brings in the question of whether there will be sufficient funding. Last, the SES does not make the earliest delivery; this distinction belongs to the high-capacity MPS(A).

THE CHANGING GEOSTRATEGIC ENVIRONMENT

Policy recommendations can only be made within a political and military context. Recent events in Eastern Europe, the Soviet Union, and the Persian Gulf region make it likely that U.S. military planning scenarios will change. For the large European scenario, warning time will probably increase because of the redistribution of forces under way in the Soviet Union and the dissolution of the Warsaw Pact alliance. For the same reasons, the possibility of a large U.S.-Soviet confrontation in the Southwest Asian scenario is called into question. Non-NATO, non-Soviet scenarios will loom larger in the minds of defense policymakers; as of yet, however, it is difficult to judge which scenarios will be perceived as the most important. Finally, the defense budget may shrink over the next few years. All of these considerations will certainly affect the size and structure of future unit deployment and resupply capabilities.

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ACRONYMS AND ABBREVIATIONS

APS	Afloat prepositioning ship
bhp	brake-horsepower
CMMD	Commission on the Merchant Marine and Defense
C-day	Day deployment operations commence
CFE	Conventional Forces in Europe
D-day	Day hostilities or contingency operations begin
DoD	Department of Defense
FSS	Fast sealift ship
ft	foot
LACV	Lighter air cushion vehicle
LARC-LX	Lighter amphibious resupply cargo vehicles
LASH	Lighter aboard ship
LCU	Conventional landing craft
LOTS	Logistics over the shore
MARAD	Maritime Administration
M-day	Day mobilization is declared
MEB	Marine expeditionary brigade
MPS	Maritime prepositioning ship
MPS (A)	Maritime prepositioning ship for Army unit equipment
MSC	Military Sealift Command
MTMC	Military Traffic Management Command
NDRF	National Defense Reserve Fleet
nmi	nautical mile
NSS	Nonself-sustaining
NTPF	Near-term prepositioning force
OM&S	Operating, maintenance, and support
Panamax	Ship whose beam exceeds the navigation width of the Panama Canal locks
POMCUS	Prepositioning of materiel configured in unit sets
Ro-ro	Roll-on and roll-off
ROS	Reduced operating status
RRF	Ready Reserve Force
SES	Surface effect ship
shp	shaft-horsepower
SLOC	Sea lines of communication
SPOD	Seaport of debarkation
SPOE	Seaport of embarkation
stons	short tons (2000 pounds)
SWA	Southwest Asia
T-AKR	Fast sealift ship
TEU	twenty-foot equivalent unit
TOE	Table of Organization and Equipment
u/e	unit equipment

I. INTRODUCTION

BACKGROUND

Political and economic realities since World War II have kept the United States from forward basing sufficient forces and equipment to counter potential military threats in all areas of strategic importance. In concert with its allies, the United States has relied on a strategy involving rapid deployment of military forces based in the United States to regions of potential conflict. Though dramatic changes in geopolitics are taking place, a robust mobility posture is likely to remain central to U.S. national security planning. Consequently, strategic mobility forces will continue to be essential in future defense planning.

The three components of strategic mobility are airlift, sealift, and prepositioning. Airlift provides rapid response but is limited in capacity because of its high cost. Sealift provides high capacity but is limited in response time because of its slow speed. Prepositioning of materiel reduces the total movement requirement and, along with airlift, provides very quick response. However, for prepositioning to be successful, policymakers must correctly guess what materiel will be required and where.

Each of these three components has been used to meet strategic mobility requirements. Airlift has been used extensively in such diverse operations as the resupply of Marine forces at Hue during the Vietnam War, the deployment of Army airborne forces to Grenada, and more recently the deployment of Army airborne and light infantry forces to Panama. Sealift has historically accounted for the majority of all military cargo transport requirements. Land prepositioning has been used in both Europe and the Pacific theater, one of the most visible examples being the prepositioning of materiel configured in unit sets (POMCUS) in Europe.

DoD's principal source of sealift has historically been the privately owned U.S. flag merchant fleet, which, until recently, had always been sufficient to support military requirements. It was composed primarily of ship classes that had features DoD found useful. For example, many ships had cranes and ramps so that their crews could load and

unload cargo without the assistance of port facilities. Also, many of these ships could carry noncontainerized cargo such as rolling stock or palletized cargo.[1]

Since 1980, the number of dry cargo ships in the privately owned U.S. flag merchant fleet declined by about a third, from over 300 to approximately 200, and it is projected that by the year 2000, this number will decline further, by about 50 percent.[2] Compounding this problem of declining numbers is the decreasing military utility of the remaining ships. In the commercial sector, self-sustaining breakbulk and Ro-ro ships are being replaced by nonself-sustaining (NSS) container ships. These ships do not carry cranes or ramps and therefore must rely on developed port facilities or other ships' cranes to load and unload cargo. Moreover, without modifications, these newer ships cannot be loaded with noncontainerized unit equipment (u/e). Because of these limitations, NSS container ships are generally not considered as useful for transporting u/e.

Because of the changes in the U.S. flag merchant fleet, policymakers have expressed concern that existing and future strategic sealift forces will be unable to support force deployments in the sorts of future conflicts for which they have planned. Some policymakers foresee that the deficiencies experienced today will increase in magnitude over time unless the government intervenes on behalf of the U.S. maritime industries, providing subsidies for ship construction and operation and instituting measures to ensure even-handed competition between U.S. and foreign shipping companies.[3]

Concerns with sealift fall into two categories, lift capacity and response time, and can be expressed as follows:

- Insuring adequate total lift capacity for military needs.
- Insuring that the time taken by ships to begin making cargo deliveries is short enough to meet the theater commander's demands.

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[1]This category of ships includes self-sustaining breakbulk, self-sustaining Roll-on/roll-off (Ro-ro), barge, and multicommodity self-sustaining ships such as combination container/breakbulk and container/Ro-ro ships.

[2]Commission on the Merchant Marine and Defense (CMMD), *Third Report: Findings of Facts and Conclusions*, Washington D.C., September 1988, p. 13.

[3]Ibid., pp. 1–3.

The stated goal for the strategic sealift capacity is 1 million short tons (stons) of u/e.[4] Estimates of present U.S. sealift capacity range from 700,000 to 900,000 stons of u/e, implying that current capabilities fall 10 to 30 percent short of the stated goal. A specific rapid response goal for sealift has not been stated. However, an approximation of this goal may be inferred from DoD's previous policy actions.

Rapid response has two features: the time required to mobilize a ship for military operations and the time required to load, transit, and unload. In the 1980s, DoD initiated two programs to improve the rapid response of sealift for general-purpose forces. The first program established the Ready Reserve Force (RRF), which provides commercial design ships to DoD on short notice, 5 to 20 days. When the program was created, it was a substantial improvement over the previous reserve program, the National Defense Reserve Fleet (NDRF), which called for 60 to 90 days of preparation time. The second program was the acquisition of eight fast sealift ships (FSSs). These are maintained in a readiness condition that allows them to be mobilized on four days' notice. Both programs suggest that a requirement for rapid response is at least perceived. They also suggest that ship mobilization time is important.

Specific criticisms of the sealift response time appear to stem from considerations of political/diplomatic goals that the NATO alliance set for itself and from the possibility of having to deploy to Southwest Asia. In 1978, the U.S. strategic mobility goal for NATO was stated as the ability to have ten divisions on the ground and ready to fight in Europe ten days after a mobilization order.[5] To meet this ten-in-ten goal would require a combination of land-based prepositioning, airlift, and sealift.

The average speed of merchant ships is on the order of 20 knots, so their transit time to Europe (4000 nmi) is about eight days. Adding time for loading and unloading shows that the ten-day goal might be totally consumed by sea shipment time, leaving no time for movement of equipment from forts or depots to seaports of embarkation (SPOEs) or for onward movement in theater. If the ten-in-ten goal is assumed to be the

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[4]General George B. Crist, *Statement Before the Defense Policy Panel of the House Armed Services Committee on the Status of the United States Central Command*, March 17, 1987, p. 52. This goal, which has guided recent sealift planning, will probably be reexamined in light of recent changes in the Eastern bloc and the rapid progress of the Conventional Forces in Europe (CFE) talks.

[5]Recent events in Eastern Europe, changes in the Soviet Union, and prospective agreements over the levels of conventional forces in Europe may lead to a reconsideration of this 12-year-old goal.

requirement, the existing fleet, which at best can deliver a modest amount of u/e in 13.5 days and large quantities (300,000 to 400,000 stons) in 17 days, has inadequate speed.

For U.S. force deployments to Southwest Asia, if the Suez Canal is not used, sealift ships must travel a nominal distance of 12,000 nmi from U.S. to Persian Gulf ports. The existing fleet can deliver large quantities of u/e from the United States to the Persian Gulf region in approximately 34 days. If more rapid deliveries are needed, however, the speed of the existing sealift capability would also be categorized as inadequate.

Recently, contractors have proposed advanced 55-knot surface effect ships (SESs) and 40-knot semiplaning hull ships as a means for improving the response time of strategic sealift. Alternatively, displacement monohull ships with speeds in the range of 30 to 35 knots may be adequate to support future force deployment requirements.

The value of fast transport in improving force closure rates is closely related to force readiness and cargo availability. The personnel and u/e of active duty forces are ready for transport within one or two days after the receipt of deployment orders. For these forces, fast transport greatly reduces fort-to-foxhole timelines and therefore is of high value in short-warning scenarios. However, the personnel and equipment of reserve forces are maintained at lower readiness. For them, sea transit time consumes less than half the deployment time,[6] so fast sealift is of fairly low value. Consequently, decisions on how much to invest in fast sealift must take force readiness postures into consideration.

In proposing fast sealift as a reasonable means of meeting short-warning deployment requirements, proponents of new ship designs point with growing concern to recent government-sponsored fast sealift programs in Japan that are exploring the application of superconductive materials and magnetohydrodynamic propulsion to advanced ship designs. These proponents argue that U.S. reluctance to invest in advanced technology for sealift may lead us to overlook a major breakthrough in sea transport. Thus, DoD has to determine not only if fast sealift is required from a military perspective, but also whether research on advanced ship designs is prudent for the nation given trends in technology development.

In the absence of a clearly stated requirement for fast ships, we examined the capabilities they provide rather than measuring their ability to meet a specific goal.

[6]Unpublished RAND research by David Kassing.

These are issues that need to be considered in formulating a future DoD distribution system.

APPROACH

We first examined important trends in civil shipping industries, concentrating on dry cargo ships because they are the most useful in transporting military u/e. Trends in the civil sector indicate the character of sealift assets DoD will have to work with in the future. In large measure, these trends determine how many ships will be in the merchant fleet, how fast they will be, their capacity, how specialized their cargo-carrying ability will be, and how difficult it will be for DoD to gain access to them in time of need. From the trends, we can project with some confidence the extent to which DoD can count on the civil sector for strategic sealift assets. However, because unforeseen changes in transportation markets and economic activity levels may substantially alter projected trends, we used the trends to establish a framework for defining alternative ship designs, rather than to project specific DoD sealift program requirements.

Next, we reviewed existing DoD sealift programs to establish a baseline from which to construct alternative enhanced sealift options. The major characteristics of these programs were used to develop a framework for examining speed, capacity, availability, ship manning, and life-cycle cost of strategic sealift ships, and the potential contributions of these programs in the year 2010 were estimated.

We then used the first two parts of the analysis as a context in which to construct alternative FSS and maritime prepositioning ship (MPS) designs. We examined several technologies that offer the potential to increase ship speed, as well as ship configurations capable of increasing the capacity for carrying military u/e.

To assess the relative value of candidate ships, equal-cost forces were constructed based on an arbitrary 20-year life-cycle cost limit of 15 billion in 1988 dollars. We then evaluated the performance of equal-cost forces in postulated deployments to Europe, to Southwest Asia, to Zaire, and to Thailand using two performance measures: time to deliver first cargo, and cargo throughput over time. The effect of ship attrition on performance was measured in deployments to Europe and Southwest Asia.

II. IMPORTANT TRENDS IN CIVIL SHIPPING

This examination of the civil sector shipping industry is limited to technologies and trends that are of interest to DoD. We begin with a discussion of intermodal and just-in-time transport, two rapidly maturing logistics concepts that have substantial implications for existing DoD materiel storage and transportation practices. Commercial transportation has evolved to a point where transportation companies have assumed responsibilities well beyond the physical movement of cargoes using a single mode of transport. Integrated logistics companies now provide end-to-end transportation services. Their responsibilities include storage and movement of materiel using multiple types of transport. This evolution will continue to affect the types of ships being built and the availability of those ships to DoD.

INTERMODAL TRANSPORTATION

New, large cargo ship designs, excluding those for bulk cargo carriers, are being driven for the most part by the rapid expansion of intermodal transportation markets.[1] To compete in these markets, many traditional transportation companies that previously provided services along a single mode of transport—i.e., trucks or ships—are now becoming integrated logistics companies that own, lease, or contract for ships, trains, rail services, trucks, and containers. Although the evolution of transport companies began before the invention of standardized containers for shipping, the effect of container shipping on DoD interests has been particularly strong.

The advent of containers provided advantages for both shipping customers (shippers) and shipping suppliers (transporters). For shippers, containers simplified the process for contracting transportation. Rather than supply detailed manifests to transporters, shippers now had only to provide the number, type, and weight of the containers they wanted to ship. With this information plus knowledge of the shipper's

[1]Intermodal transportation refers to any system of transport that allows the cargo to be transferred among different modes of transport such as trucks, trains, and ships without handlers making direct contact with cargo. Standard 20- and 40-ft shipping containers are principal components of the system. Rail cars, truck chassis, ship cells, and associated loading equipment are all designed to accept the standard containers so that transfer from one mode to the other can be accomplished without repackaging.

desired delivery date and location, each transporter could rapidly respond with schedules and prices. The shipper could then work out the best combination of schedule and price to meet his needs.

In the early stages of the container revolution, the impetus to change to containers was simply a reduction in shipment costs. Costs decreased for two immediate reasons: containerization reduced the quantity of cargo lost from damage and pilferage, and it reduced the amount of labor required to load a given amount of cargo. During later stages, additional benefits became apparent. The use of standardized containers reduced the variance in loading times, containerization simplified the task of keeping track of cargo because only the containers had to be monitored, and the containers served as temporary warehouses for shipping customers.

The net result of all these factors was more dependable and timely transportation service, which eventually led shippers to adjust their production procedures. Before containerization, shippers stored large stockpiles of production materiels as a buffer against variations in deliveries of supplies. With the advent of containerization and its attendant reduction in the variance of cargo arrival dates, shippers began to reduce their stockpiles and derive substantial capital savings.

This process of replacing in-plant storage with increasingly predictable transportation services continues. A concept now in vogue is "just-in-time delivery." This concept involves a contract between a single logistics company and a shipper. Because the logistics company has control of multiple modes of delivery and shipping containers, it can guarantee delivery in a specific time window. Today, a Japanese auto parts manufacturer in Yokohama can contract for delivery of parts on a particular day to a Nissan plant in Smyrna, Tennessee. The Nissan plant is willing to pay higher transport fees because the increased costs of transportation are more than offset by the reduction in warehousing costs.

To support intermodal transport of containerized cargo, large transport companies are replacing their breakbulk, Ro-ro, and mixed-cargo ships (i.e., combination container/breakbulk and container/Ro-ro) with large NSS container ships built with a minimum number of decks and transverse bulkheads. Container cells permit containers to be stacked up to ten high. With this configuration, NSS container ships are more efficient for carrying containers than are comparably sized Ro-ros or breakbulks. Similarly, NSS container ships are not encumbered with shipboard cranes or ramps for

loading and unloading cargo, which means they can carry more containers than can breakbulks or other self-sustaining ships of comparable size. They do, however, have to rely on specialized shore-side facilities for loading and unloading.

The recent procurement by American Presidents Lines of five large container ships illustrates the trend. The 903-ft length and 129-ft beam of these ships give them the capacity to carry 4300 twenty-foot equivalent units (TEUs) of cargo in four different containers ranging in size from 20- to 48-ft units.[2] The ships are equipped with large diesel power plants capable of supporting a ship speed of 24 knots. Evergreen and Maersk shipping lines are also interested in similar ship programs.

From a strategic sealift perspective, these ships can be viewed as a mixed blessing. On the plus side, the development of these ships indicates that the U.S. merchant fleet is competitive with the fleets of other countries at least in liner services in which ships arrive and depart from a fixed set of ports on a regular schedule that permits synchronization with other transport modes. A further benefit is that these vessels are very large and so can carry a great deal of cargo. However, these ships depend on shore facilities for loading and unloading and are so large that they cannot use the Panama Canal and many medium and small ports around the world. Moreover, they are designed to carry containers, and only a fraction of present military u/e can be containerized. Finally, these ships operate in a very competitive market, so DoD cannot expect to use them in anything short of a major conflict without paying a substantial premium.

The trend toward increased use of intermodal transportation will continue to reduce the number of breakbulk, Ro-ro, and combination cargo ships in the U.S. merchant fleet. Given these circumstances, DoD either has to fund programs to preserve ship classes that are no longer commercially attractive or has to adapt to containerization.

REDUCTION OF PRIVATELY OWNED U.S. FLAG MERCHANT FLEET

The decline of the privately owned U.S. flag merchant fleet is the result of both market forces and foreign government intervention. The U.S. flag merchant fleet finds it difficult to compete because of differences in wage scales and material costs and because of the lack of U.S. government support for maritime industries. Since the early 1980s, the U.S. government has reduced some shipping subsidies and eliminated others.

[2]The ships are generally referred to as Panamax because their beams exceed the maximum possible width for the Panama Canal.

Meanwhile, other nations continue to use a variety of devices to sustain their shipping industries, some of the most apparent being subsidies, tax incentives, and cargo reservation systems that exclude U.S. transporters.

These factors, combined with increased reliance on intermodal transportation, have for the most part shaped the character of the privately owned U.S. flag merchant fleet. By 1987, the number of privately owned U.S. flag dry cargo merchant ships had declined to 199. Of these, 29 were chartered to the Military Sealift Command (MSC), 12 were in the afloat prepositioning force, and 13 were MPSs. Two hospital ships and two aviation support ships were also under the control of the MSC.

Table 1 lists the U.S. flag dry cargo ships that were in the commercial sector in 1987, gives their lift capacity, and projects how many will exist in 2010. Ninety-four of the 1987 ships were pure container ships, which cannot carry noncontainerized military u/e without first being modified, and three were container/passenger ships, also not suited to carry u/e. Thus, approximately 57 percent of these ships were not useful for carrying military u/e.

Table 1

U.S. FLAG DRY CARGO FLEET
(commercial sector)

Ship Class	1987	2010
Breakbulk	7	0
Barge carrier	14	0
Container/breakbulk	25	5
Container/Ro-ro	7	5
Ro-ro	20	10
NSS container	87	40
Self-sustaining container	7	0
Container/passenger	3	0
Car carriers	0	4
Number of ships	170	64
Lift capacity (stons u/e)		
without flatracks/seasheds	325,000	110,000
with flatracks/seasheds	370,000[a]	310,000[b]

[a]This number reflects the use of existing DoD-owned flatracks and seasheds on NSS container ships to carry u/e.

[b]This total includes the procurement of sufficient flatracks and seasheds to outfit all projected NSS container ships to carry u/e.

Military u/e consists of items that vary considerably in weight, size, and volume, and ships vary substantially in size and cargo storage facilities. To estimate precisely how much military u/e the commercial fleet can carry requires a detailed loading analysis of each ship with regard to specific items of u/e. However, representative u/e and ship characteristics can be used to establish reasonable estimates of fleet lift capacity. The aggregate dimensions of the u/e for a representative Army armored division are 70,885 stons and 1.18 million sq ft.[3] We load this notional u/e using average ship area characteristics and stowage factors defined by the Military Traffic Management Command (MTMC).[4] With this approach, we estimate that the privately owned U.S. dry cargo fleet, not including pure container ships and ships under MSC control, can lift approximately 325,000 stons of u/e.

Table 1 also projects what the privately owned commercial fleet might look like in the future based on the CMMD projection of the number of dry cargo ships for the year 2000 and our assumption that this projection will remain valid for the year 2010. Thirty privately owned merchant ships chartered to DoD for military sealift programs are not included in the data. Moreover, the projection assumes that current government maritime policies will continue into the future, implying no construction differential subsidies in the future and no new construction of large dry cargo ships in U.S. shipyards. Replacement ships, for those in the commercial sector that wear out and for those that are bought by the government for the RRF, will be purchased from foreign sources. If this projection holds true, the privately owned dry cargo fleet will consist of only 20 militarily useful ships by current definition, with a total lift capacity of about 110,000 stons of noncontainerized u/e.

In these circumstances, DoD will have to consider using all of the container ships to carry u/e. To derive a reasonable estimate of the lift that these ships can provide, we hypothesize that in 2010 the average NSS container ship, with flatracks or seasheds, will carry 5000 stons of u/e.[5] If this assumption is realized, we estimate that the lift capacity of the dry cargo ships in the privately owned U.S. flag merchant fleet will be 310,000 stons of u/e.

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[3]These are Transportation System Center estimates derived from the Army's (TRADOC) October 1986 TOE Master File and the January 1987 COMPASS Equipment Characteristics File.

[4]Military Traffic Management Command Transportation Engineering Agency, *Logistics Handbook for Strategic Mobility Planning*, Newport News, Virginia, January 1986.

[5]The use of flatracks and seasheds for deploying u/e is discussed in Sec. III.

How many of the container ships will actually be available to carry u/e will depend on the magnitude of early ammunition and resupply requirements. Currently, DoD plans to use the majority of container ships in resupply operations. Therefore, in conflicts with large early ammunition or other resupply requirements, only a small fraction of the container ships will be available for u/e deployment.

III. EXISTING MILITARY SEALIFT PROGRAMS

Since the end of World War II, the United States has stored and maintained a large number of ships in the NDRF. In times of conflict, these deactivated ships may be reactivated to support military lift requirements. A recent such use was during the Vietnam War, when many of the ships transported materiel. Today, there are about 125 militarily useful dry cargo ships in the NDRF. However, most of them are over 40 years old and in questionable condition. To achieve operational status, they require substantial refurbishment, which may include drydocking. Projected activation times are in excess of 60 days. Because of these factors, these ships are not counted toward force deployment capability, but rather as replacement ships for resupply operations later in a war. By the year 2010, most of the ships currently in the NDRF will have been scrapped.

In the late 1970s and early 1980s, DoD confronted the aging of the NDRF and the continuing decline of the merchant fleet by starting several strategic sealift enhancement efforts. Among the most important of these were

- Establishing the RRF.
- Initiating the Flatrack and Seashed program.
- Beginning the Auxiliary Crane Ship program.
- Procuring FSSs.
- Creating the MPS program.

The important characteristics of these programs are discussed next.

READY RESERVE FORCE

The primary objective of the RRF program is to maintain an adequate and timely sealift capability for delivering u/e. Under this program, DoD purchases ships from the merchant fleet that are either commercially inactive or in the process of being scrapped. Because the ships are no longer commercially useful, DoD has been able to acquire them at fairly low cost, on the order of $5–10 million per ship. The initial plan was that the RRF would consist of approximately 30 ships. However, because the U.S. flag merchant fleet declined more rapidly than expected, DoD procured many more than 30 ships.

Currently, 83 cargo ships are in the RRF: 17 Ro-ro and combination container/Ro-ro ships, 58 general dry cargo ships, and 8 auxiliary crane ships (four additional conversions are planned). There are plans to increase the number of dry cargo ships to 104. Most of the time, RRF ships are kept at one of three locations: James River, Virginia; Beaumont, Texas; or Suisun Bay, California.[1] They are maintained under Maritime Administration (MARAD) contracts in one of three readiness conditions for underway operations: 5, 10, and 20 days. Approximately 70 percent of the fleet is kept in the five-day category.[2] The average annual cost of maintaining a ship in the RRF is roughly $1.5 million.

To derive a reasonable estimate of the RRF's u/e lift capability, we again used MTMC average ship area characteristics and cargo stowage factors, and loaded the ships with the u/e of an Army armored division. We estimate that the current RRF, not including the auxiliary crane ships, can lift approximately 290,000 stons of u/e.

We also estimated the RRF's response time. Assuming that the RRF ships can be activated and loaded in seven days, they will deliver the u/e for approximately four armored divisions to Europe in roughly 17 days or, without access to the Suez Canal, to Southwest Asia in 34 days. These are substantial lift capabilities.

The RRF faces several difficulties in the future: the availability of personnel trained to man the ships, the availability of replacement ships for those that are scrapped, and the capacity of repair facilities to support RRF activation. This analysis examines the first two of these problems.

The decline of the U.S. merchant marine raises serious questions on the future availability of personnel trained to man RRF ships. The Navy Merchant Marine Manpower Study[3] conducted in 1986 estimated that by 1992 there will be a shortage of roughly 8100 trained personnel if all RRF ships are activated. At the time of the study, 3200 personnel were required to man the RRF fleet. Four alternatives were suggested to address the RRF problem:

- Maintain a larger active U.S. flag merchant fleet.

[1]Military Sealift Command, *Ship Register*, January 1989.

[2]Estimate based on the status of the RRF on 16 September 1988.

[3]S. Turver, "Sealift Manning: Critical Period, Critical Choices," *Armed Forces Journal International*, July 1987, pp. 30–38.

- Require commercial firms maintaining RRF ships to develop contingency manning plans.
- Expand the merchant marine reserve.
- Establish naval reserve units to man the RRF.

The first alternative is more of a global solution to both commercial and defense sealift problems than a specific program to remedy manning shortfalls. The second alternative places the burden for maintaining sufficient crews on the commercial sector. Commercial firms would clearly have to hike existing maintenance contract prices if they were asked to maintain a labor pool as well. The commercial firms do not have any particular advantage in developing and maintaining a reserve pool. In fact, the government may do better in this area because of its experience with reserve programs and its ability to offer nonfinancial rewards for participation.

Cost estimates for the merchant marine reserve and the naval reserve concepts ranged from $10–50 million per year.[4] These figures imply an additional cost to the RRF of $120,000 to $600,000 per year per ship, which represents an increase in cost of 8 to 40 percent per ship per year.

Since the focus of our study is on options for improving sealift capabilities for the year 2010, we examined how the RRF might look at that time. Of particular concern is the age of the ships in the RRF. Table 2 shows the current ages of RRF ships. Assuming that an ongoing investment in maintenance allows the ships to remain in the RRF until they reach the age of 40, only 21 ships now in the RRF will remain. They will be able to lift approximately 115,000 stons of u/e.

Table 2

CURRENT AGE OF RRF SHIPS

Age of Ships (years)	General Dry Cargo	Ro-ro	Auxiliary Crane
30+	2	0	0
20+	49	3	8
10+	7	14	0

SOURCE: Military Sealift Command, *Ship Register*, January 1989, pp. 35–51.

[4]Ibid., pp. 36–37.

One option for increasing the RRF's lift capacity in the future is the phased procurement of additional ships as replacements for those that are scrapped. A review of the January 1989 inventory of the privately owned U.S. merchant fleet shows that there are 64 militarily useful cargo ships by current definition. (This number does not include the 13 privately owned MPSs operating under government charter.) Thirty-six of the 64 ships are less than 20 years old.[5] If these 36 ships are eventually purchased for the RRF, they would provide an estimated lift capacity of approximately 210,000 stons of u/e. The RRF in the year 2010 thus may be able to lift roughly 325,000 stons, or about ten percent more than our estimate of current capabilities.

A second option is for DoD to procure militarily useful ships from the world fleet. If DoD is authorized to make such a purchase, the RRF could be maintained at roughly its current size or increased by continuing to invest as has been done in the recent past. In this case, the RRF might also be able to lift on the order of 325,000 stons of u/e in the future.

Our size, capacity, and cost estimates for a hypothetical future RRF are useful in thinking about the RRF's potential sealift contribution in the future. They are not, however, predictions of what the RRF will actually look like in the year 2010.

FLATRACK AND SEASHED PROGRAM

The Flatrack and Seashed program is designed to make container ships more useful for carrying military u/e. This program was undertaken because container ships are an increasing percentage of the U.S. merchant fleet and only a small fraction of military u/e can be placed in standard containers.

A flatrack is basically a standard open-top, open-sides container used to carry cargo that does not fit in standard closed-van containers. Commercial flatracks come primarily in two standard lengths, 20 and 40 ft. They are 8 ft wide and have end vertical frames that range in height from 7 to 9 ft. The typical commercial 40-ft flatracks can carry roughly 30 stons. Commercial shippers use flatracks to carry vehicles, lumber, and large metal products in standard container ship cells. The flatracks fit directly into the cells and are compatible with intermodal loading equipment and transport vehicles. To carry heavy items that do not fit into standard containers, shippers use platforms (flat metal structures) to configure container ships with temporary decks.

[5]Military Sealift Command, *Ship Register*, January 1989, p. 13.

The outside dimensions of large military vehicles—such as helicopters, tanks, trucks, and motorized artillery pieces—exceed those of most commercial flatracks. Moreover, the weight of some of these vehicles exceeds the maximum carrying weight of individual flatracks. To overcome these problems, flatracks can be designed with heavier decks and extendable vertical support frames. The heavier decks increase to 60 stons the maximum weight that individual flatracks can support. Several flatracks placed in adjacent container ship cells can create false decks for loading large military vehicles. The extendable support frames (7 to 17 ft) provide added overhead clearance for larger vehicles and allow multiple stacking of flatracks in container ship cells. An analysis found that flatracks with similar dimensions were a preferred option for carrying all the equipment of a mechanized infantry division.[6]

A seashed is a large module (40 ft long, 25 ft wide, and 12.5 ft high) with an open top and a hinged floor. Seashed dimensions do not quite match those of container ship cells, so container ships must be modified to allow the seasheds to be fit into the cells. The needed modifications have been estimated to cost approximately $1.5 million per ship.[7]

Because their outside dimensions exceed those of truck chassis and railcars, seasheds are not readily transportable by intermodal systems. As a consequence, they are used almost exclusively to carry military cargo. The major advantage of seasheds over flatracks is their hinged floor construction, which permits quick access to cargo in lower holds without the entire module having to be lifted. Another advantage is that once seasheds are inserted into ship cells, they can remain in place, which enables cargo to be unloaded faster than it would be from flatracks.

There are three major drawbacks to using NSS container ships outfitted with flatracks or seasheds to carry u/e. First, insertion of the flatracks and seasheds into the ship cells before heavy military vehicles are loaded increases the loading time and requires multiple crane lifts. Second, the use of ships in u/e transport precludes their participation in resupply operations. Third, NSS container ships require shore-side or floating-crane facilities to unload cargo. These three drawbacks make programs for increasing u/e lift capabilities less than ideal. However, in the absence of an adequate U.S. flag merchant fleet, the use of NSS container ships should be considered with some priority.

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[6]Military Traffic Management, Transportation Engineering Agency, *A Comparative Analysis of Seashed and Flatrack Systems*, 31 October 1983.

[7]Ibid.

In 1983, DoD initiated a program to acquire enough flatracks and seasheds to outfit 25 container ships. So far, DoD has acquired 1300 flatracks and 850 seasheds, which, when loaded with u/e, can be carried by 12 large container ships. The flatracks can be procured at an average unit cost of $14,000, the seasheds at $140,000. The vast majority of flatracks and seasheds are kept at the military operating terminal in Bayonne, New Jersey, and at the naval weapon station in Charleston, South Carolina.[8]

The importance of an expanded Flatrack and Seashed program will continue to grow. Given that the future privately owned U.S. flag dry cargo fleet may consist primarily of NSS container ships, the U.S. flag merchant fleet hypothesized for the year 2010 (20 militarily useful ships, by current definition) will only be able to lift on the order of 110,000 stons of noncontainerized u/e, or about one-third of the estimated current capacity. A detailed analysis is needed to establish the best program for adapting NSS container ships to carry u/e. Then, sufficient flatracks or seasheds should be procured to outfit NSS container ships to carry on the order of 5000 stons of u/e per ship.

Approximately 83,000 sq ft of surface area is needed for 5000 stons of armored division u/e. Assuming a cargo stowage factor of 0.5, approximately 519 40-ft flatracks are needed to carry this amount of u/e. Alternatively, 166 seasheds could provide the required deck area. This number of flatracks or seasheds should pose no problems for an NSS container ship designed to carry 1000 or more 20-ft-equivalent container units inside its hull.

AUXILIARY CRANE SHIP PROGRAM

Auxiliary crane ships are equipped with two or more heavy lift cranes whose reach is sufficient for loading and unloading cargo from other ships. The Auxiliary Crane Ship program seeks to resolve three sealift problems. The first is that even though most modern ships are NSS, not all ports to which DoD may have to deploy will have enough cranes available to unload the ships in a timely manner. The crane ships may prove useful in this case. The second problem is that military sealift unloading operations may take place at anchorages, in which case crane ships will accelerate in-stream unloading if sea state permits them to moor alongside other ships. Finally, the crane ships can handle such nonstandard cargo as tanks, whose weight may exceed the lift capacity of pier cranes.

[8]Military Sealift Command, Letter 4620, Serial N521, April 27, 1990.

As the trend toward intermodal transport continues, the requirement for auxiliary crane ships may lessen. That is, more countries are likely to equip their ports with container-handling equipment, so a greater number of ports will be ready to handle NSS ships. Nonetheless, auxiliary cranes will continue to be useful for in-stream unloading and handling heavy u/e.

To date, the Auxiliary Crane Ship program has converted eight merchant ships, all built in the 1960s, into crane ships at a cost of $200 million and plans to convert four more ships. Before deploying to theaters of operation to perform their primary missions, these ships can be loaded with military cargo. The average crane ship has approximately 44,000 sq ft available for carrying u/e. Assuming all crane ships are loaded before leaving the United States, we estimate that they can lift approximately 16,000 stons of u/e.

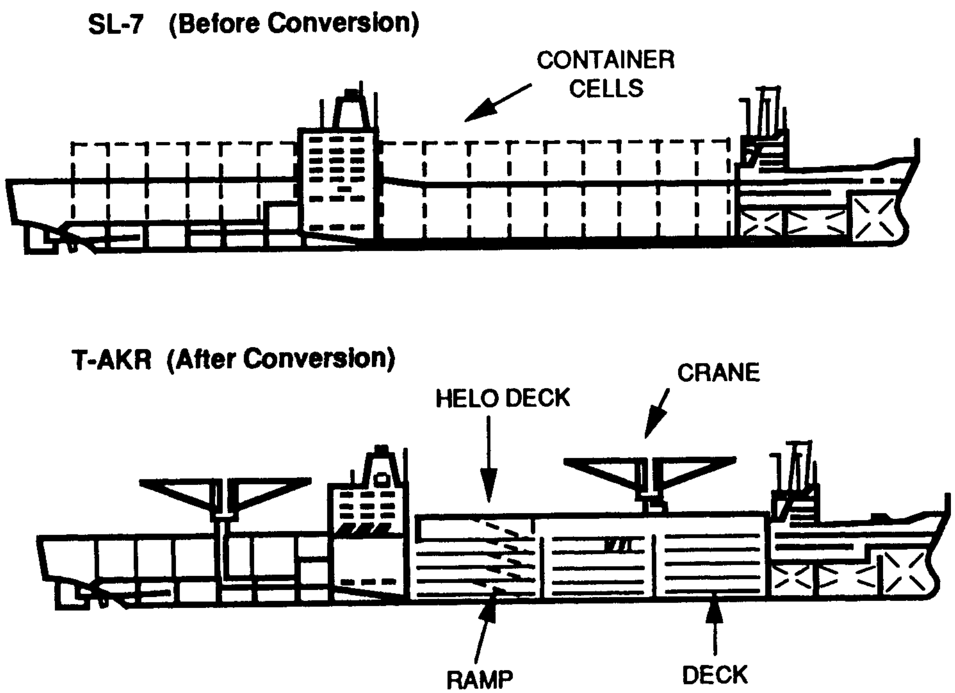
EXISTING FSSs

DoD's existing fast sealift force consists of eight FSSs (T-AKRs), which can operate at a sustained speed of 30 knots. Built in European shipyards in the early 1970s as large NSS container ships for Sea-Land Shipping Lines, they were originally called SL-7s. Their steam turbine propulsion plants, the largest ever built for cargo ships, are designed to generate 120,000 shaft-horsepower (shp).

Because of their large and unique power plants, these ships proved to be very expensive to operate and maintain. In fact, at higher fuel costs, they could not compete in commercial trade with the slower, more efficient conventional container ships. For that reason, additional ships of comparable size and speed have not been built for commercial use. DoD thus cannot look to the world merchant fleet to expand this capability.

In 1983, DoD purchased the SL-7s from Sea-Land at an average cost of $35 million per ship and then converted them to container/Ro-ro ships. Renamed T-AKRs, these ships were each outfitted with two twin cranes to enable autonomous unloading to shore facilities or lighters. They were also provided with a helicopter pad and helicopter storage deck, and with ramps for unloading the Ro-ro areas. The conversions were performed in U.S. shipyards at an average cost of roughly $65 million per ship.

As Fig. 1 shows, the ship's midsection was completely reconfigured. Multiple decks were added to carry vehicles, and internal ramps were provided to permit Ro-ro



T-AKR	
Cargo (stons)	
U/e	8000
Ammunition	16,000
Speed (knots)	30 (33 when new)
Dimensions (ft)	946x105.5
Draft (ft)	29.9–36.6
Propulsion (shp)	120,000 (steam turbine)

Fig. 1— SL-7 conversion to T-AKR

operations. The after section was only partially modified to carry seasheds and permit lift on and off operations with flatracks, seasheds, and containers. Each T-AKR can carry 8000 stons of u/e or approximately 16,000 stons of ammunition.

The conversions of the SL-7s to T-AKRs were constrained by cost objectives and did not maximize vehicle storage or provide optimum vehicle loading and unloading capabilities. If the primary objective of the conversion had been to maximize vehicle storage, the after section of the ship would have been configured with multiple decks and access ramps. In this configuration, we estimate that the T-AKRs would be able to carry approximately 30 to 40 percent more u/e. Similarly, the ships could have been equipped with stern and bow Ro-ro ramps, in addition to side ramps, to permit flow-through loading and unloading of vehicles. With this modification, the average time for loading or unloading would be one day rather than two or four days. The net result would be a much more efficient ship for transporting u/e.

Despite these constraints, the existing T-AKR force provides a substantial sealift capability. The ships can lift 64,000 stons of u/e. Because of their speed advantage, the T-AKRs can deliver cargo to Europe three days earlier than the average 20-knot RRF ships. This advantage grows with distance so that in a deployment comparison to Southwest Asia, the T-AKRs deliver cargo eight days earlier than the average 20-knot RRF ships.

Estimates provided by the MSC indicate that the cost of a T-AKR in full operating status is roughly $14.6 million per year. To minimize operating, maintenance, and support (OM&S) costs, they are maintained in a reduced operating status (ROS). In this status, the ships are kept in U.S. ports and maintained so that they can get under way four days after orders are issued. The annual OM&S cost of a T-AKR in ROS is roughly $4.5 million. This figure does not include the cost of breaking out one or two T-AKRs from ROS for military exercises.[9]

MARITIME PREPOSITIONING

Currently, two distinct maritime prepositioning concepts are employed to support force deployments and resupply operations: the afloat prepositioning ship (APS) program and the MPSs. Many of the ships in the APS program were originally part of

[9]These estimates were derived from information provided by the Budget Division of the MSC.

the near-term prepositioning force (NTPF), which was formed during the Carter administration to support the Rapid Deployment Joint Task Force. Ships assigned to the NTPF were loaded with equipment and supplies to support primarily the deployment of a Marine expeditionary brigade (MEB) to Southwest Asia. In the mid-80s, this material was unloaded and transferred to the MPSs, and the role of the APS program was substantially changed.

Afloat Prepositioning Ship Program

Ships in the APS program carry primarily ammunition and other consumable supplies for Army, Air Force, and Navy forces. The APS program consists of a dozen ships, 11 of which operate in the vicinity of Diego Garcia to support military contingencies in Southwest Asia. The remaining ship operates in the Mediterranean. There are several classes of dry cargo ships in the program, including breakbulk, Ro-ro, and barge ships. The barge ships carry equipment for clearing channels and establishing port facilities, and military supplies aboard preloaded barges. The barges can be unloaded to make cargo deliveries in austere ports. Once the barges and lighters carried by these ships are themselves unloaded, they can receive more cargo from nonbarge ships. Thus, barge ships are both a cargo-carrying system and an unloading system for the rest of the ships.

The estimated lift capacity of an APS is approximately 75,000 stons of u/e. The ships in the APS force are owned and operated by commercial firms under DoD charters. The average OM&S cost to DoD for an APS is approximately $8 million per year.[10]

MPSs

The MPS force consists of 13 ships, organized into three squadrons, each carrying u/e and supplies to support an MEB of 16,500 men for 30 days. One squadron, assigned to support operations in Southwest Asia, operates out of Diego Garcia, one operates in the Atlantic, and one in the Pacific theaters. In the event of increasing tensions and at the direction of national authority, the ships proceed to designated areas to unload material. Before that time, the ships can position themselves near the likely points of debarkation. The personnel assigned to each MEB are airlifted to the vicinity of the seaports of

[10]APS force cost estimates were derived from planning information provided by the Budget Division of the MSC.

debarkation (SPODs). The aviation assets assigned to the MEB are not prepositioned on MPSs. They also have to be flown in to complete force closure.

Three classes of ships are in the MPS force. Two of the classes, Cpl. Hauge and Sgt. Kocak, are conversions of combination container/Ro-ro ships originally owned by the Maersk and Waterman Shipping Lines. The third class, Lt. Bobo, was specifically designed and built for prepositioning military u/e. As shown in Table 3, the ships have large Ro-ro areas and carry substantial quantities of additional cargo. The Lt. Bobo class ships, although smaller in overall dimensions, have larger Ro-ro capacity and therefore can carry more u/e. None of the ships is capable of speeds in excess of 20 knots.

All MPSs are owned and operated by commercial firms. They are provided to DoD on 25-year leases; upon expiration of the leases, the ships revert to the owners. Commercial firms operate the ships with merchant crews under DoD charters. The annual charter costs per ship average $12 million, and the OM&S costs average $12.3 million.[11] Under the existing arrangement DoD spends roughly $316 million per year to maintain the MPSs.

Cost estimates for equipment and supplies currently stored aboard the MPS force are difficult to establish. According to the Naval Audit Service, the Marine Corps spent $946 million from the beginning of the program through FY 1987 on procurement of equipment and supplies for the MPS.[12] This figure is a reasonable lower limit.

Table 3

MPS CHARACTERISTICS

	Ship Class		
Characteristic	Cpl. Hauge	Sgt. Kocak	Lt. Bobo
Cargo capacity			
Ro-ro (sq ft)	120,000	152,000	162,500
Number of containers	332	540	493
Dimensions (ft)	755 × 90	821 × 106	671 × 105
Draft (ft)	33	32	29
Speed (knots)	17	20	18
Propulsion	Diesel	Diesel	Diesel

[11]Estimates were derived from information provided by the Budget Division of the MSC.

[12]Naval Audit Service, *Logistics Planning for the Maritime Prepositioning Ships Program*, January 28, 1989, p. 1, exhibit B.

Discussions with knowledgeable individuals indicate that more equipment has been added since 1987 and that the actual value of stored equipment and materiel may be on the order of $2 billion.

The primary advantage of MPSs over other government-controlled sealift programs is their potential for very quick response. If properly positioned and loaded, they can begin to deliver cargo in one to two days. This assumes that sufficient intelligence is available to move them to the vicinity of ports in areas of potential conflict. Based on the Ro-ro areas of the ships in the MPS force, and assuming a 0.75 cargo stowage factor, the current MPS force could carry roughly 85,000 stons of u/e of the notional Army armored division.

U.S. FLAG COMMERCIAL AND MILITARY SEALIFT CAPABILITIES

The examination of commercial shipping indicated that if the trend to containerization and the use of intermodal transport continues, the future privately owned U.S. flag dry cargo fleet will consist primarily of large container ships with speeds in the range of 20 to 25 knots. Only a small number of ships will be capable of carrying military u/e without adaptations. Unless there are dramatic and unexpected changes in shipping markets, DoD will not be able to rely directly on the privately owned U.S. flag merchant fleet to carry u/e. To use the private fleet, DoD needs to consider an expanded Flatrack and Seashed program. With such a program, we estimate that the privately owned U.S. flag dry cargo fleet in the future might lift roughly 310,000 stons of noncontainerized u/e, or about 60,000 stons less than the current fleet with existing DoD owned flatracks and seasheds (see Table 4).

The trend to increased use of container ships also has implications for the future of existing military sealift programs. Despite no new ship construction in U.S. shipyards and current political limitations that prevent the procurement of used ships from the world fleet, RRF and APS force ships will still need to be replaced. By the year 2010, the existing military sealift programs will have to rely on ships that are over 30 years old. We estimate that these ships can lift approximately 475,000 stons of u/e. Adding this total to that of the privately owned fleet, we estimate that the hypothetical U.S. flag merchant fleet might lift about 784,000 stons of u/e in 2010. This estimate falls within the range of estimates for current capabilities, which recent analyses consider inadequate to support major force deployments of the sort previously envisioned. Moreover, new sets of military requirements for the 1990s and beyond may emerge.

Table 4

ESTIMATED SEALIFT CAPABILITIES
(stons)

	1987	2010
Privately owned U.S. flag fleet		
W/o flatracks/seasheds	325,000	110,000
With flatracks/seasheds	370,000[a]	310,000
Military sealift programs		
RRF	290,000	115,000
With replacements		325,000
Crane ship program	16,000	—
T-AKRs	64,000	64,000
APS	75,000	—
MPS	85,000	85,000
Total (with flatracks/seasheds and RRF replacements)	900,000	784,000

[a]With existing DoD flatracks and seasheds.

The combination of these factors argues for consideration of new DoD strategic sealift initiatives. In the next section, we develop alternative candidates for each of the basic enhanced sealift categories—FSSs and MPSs. We address not only ship speed but also u/e lift capacity.

IV. CHARACTERIZATION OF FUTURE CONCEPTS

An alternative maritime concept, whether FSSs or MPSs for Army u/e (called MPS(A)s), includes a specific ship design, a ship operating regime, and a ship procurement option. These attributes determine ship capabilities and life-cycle costs of alternative FSS and MPS(A) concepts.

SHIP DESIGN

The following characteristics define specific ship designs:

- Speed
- Size
- Range
- Cargo capacity
- Loading and unloading considerations
- Survivability

The first four characteristics are fixed by the technologies and hull forms selected for building the ships. Loading and unloading times are partially determined by design, but are also affected by scenario-imposed variables such as pier space and handling facilities. For example, unloading times for Ro-ros will vary as a function of pier configuration and the number of ramps available. Similarly, unloading times for NSS container ships will vary as a function of the type and number of cranes at assigned berths.

Survivability is partially a function of ship characteristics such as speed, compartmentation, signature, and installed defensive systems. It is also a function of the type of threat that the ship is likely to encounter. The threat in turn varies as a function of enemy capabilities, attack strategies, and priority assigned to the disruption of sea lines of communication (SLOC). Soviet naval and air forces, if dedicated to SLOC interdiction, are likely to pose the most serious threat to strategic sealift ships in open ocean in the future. They can employ a variety of weapon systems, including ships and

submarines with torpedoes, mines, or cruise missiles, and long-range bombers with antiship cruise missiles. If they assign high priority to strategic sealift, they will probably use weapons that take into account specific ship vulnerabilities. For example, against high-speed ships with relatively small underwater hull areas, which reduce ship vulnerability against submarine-launched torpedoes, they are likely to use cruise missiles, which have little difficulty in acquiring the large radar cross sections of sealift ships.

Similarly, instead of attacking the strategic sealift ships, the enemy may choose to concentrate his efforts on the much more vulnerable replenishment ships, which are needed to support high-speed candidates. Consequently, candidates that require at-sea refuelings to complete transits to theaters of interest may be viewed as more vulnerable than those that do not. Section V examines the effects of attrition on the candidate FSS and MPS(A) ships.

SHIP OPERATING REGIMES

Ships can be maintained in three general operating regimes: active service, reduced operating status, and inactive reserve. The operating regimes determine how quickly ships become available to support military lift requirements. Active ships engaged in DoD operations, such as MPSs or APSs, have the quickest start-up times, on the order of one day. They have full crews and routinely conduct operations in various parts of the world. As a consequence, they have high OM&S costs.

Ships in reduced operating status are kept in U.S. ports with small core crews that perform routine maintenance. They have the next best start-up, estimated as four days. Their OM&S cost is roughly one-third that of active ships. Obviously, this fraction will vary depending on the number and duration of breakout operations used to test their readiness for underway operations.

The start-up times for ships in the inactive reserve vary substantially. Ships in the RRF have advertised start-up times ranging from 5 to 20 days. NDRF ships require on the order of 90 days for activation. In addition, mobilization orders have to be issued by the National Command Authority before NDRF ships are activated. This requirement may impose additional delays.

SHIP PROCUREMENT OPTIONS

There are several potential procurement options for increasing the number of DoD strategic sealift ships. DoD can purchase used ships from the U.S. or foreign merchant fleets. Alternatively, it can contract for new ships to be built in U.S. or foreign shipyards. The purchase of existing ships can be viewed as a low-cost, near-term alternative for enhancing strategic sealift, assuming that ships with substantial military utility are found to be underemployed in the commercial sector, as was the case when DoD purchased the SL-7s and converted them to T-AKRs. If used ships require considerable modifications to meet military specifications, the cost of this option is likely to be nearly equal to that of new construction, as was the experience with the Maersk and Waterman conversions to MPSs. The capitalized costs per ship were $159 million and $185 million, respectively, whereas they were only $175 million for new construction of the Lt. Bobo class.[1]

Today there are no large cargo ships in the world merchant fleet capable of speeds in excess of 30 knots. Therefore, all FSS and MPS(A) candidates, except 25-knot ships, have to be built new in U.S. or foreign yards. There are great differences in the costs of building ships in U.S. and foreign shipyards. Ships built in Korea and Poland, for example, cost up to 70 percent less than those built in U.S. shipyards. Japan and several Western European countries also build ships for substantially less than the United States.[2] Lower labor and material costs and government support programs for shipbuilding industries are among the most important factors that create these large differences. Favorable ship owner financing with government guarantees, shipbuilding subsidies, favorable tax treatment, and exemption of import duties are some of the kinds of government aid used by foreign countries.[3]

Because of the large cost differences, for the past several years no large ocean-going dry cargo ships have been built in the United States. The shipbuilding industry has been primarily involved in building Navy ships and in ship repair work. Navy ships are built according to military specifications, which substantially increase the cost of construction. As a result, there is a lack of current empirical data for estimating the cost of building large, fast, commercial Ro-ro ships in U.S. shipyards.

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[1]Navy Audit Service, *Logistics Planning for the Maritime Prepositioning Ships Program*, February 1989, p. 1, exhibit A.

[2]D. Todd, *The World Shipbuilding Industry*, St. Martin's Press, New York, 1985.

[3]Shipbuilders Council of America, *Shipbuilding Aid in the World's Leading Ship-Producing Nations*, October 1988.

To establish reasonable cost estimates for building the representative ship candidates in U.S shipyards, we used the following sources: Maritime Administration cost figures for ships built under the construction subsidy program, recent studies of enhanced sealift programs, cost estimates for Navy logistics ships, and current estimates from private contractors. Our cost figures for the representative candidate ships are rough order-of-magnitude estimates that are useful in comparing alternative ship designs. They are not intended to support specific resource allocation decisions.

REPRESENTATIVE FSS CANDIDATES

There is no consensus as to what speed regime defines fast ships. The MTMC classifies ships with maximum sustained speeds in excess of 20 knots as fast. Commercial transporters consider large cargo ships with speeds of 22 to 25 knots as fast. The eight existing T-AKRs, which have a speed of 30 knots, are often used as a primary example of fast sealift. Moreover, advanced ship designs with speeds in excess of 40 knots have been proposed to DoD for strategic sealift.

Our review of civil shipping indicates that there is no apparent demand for large (10,000 or more deadweight tons) cargo ships with speeds in excess of 30 knots. Large cargo ships with maximum sustained speeds in the range of 20 to 25 knots are being built. The American Presidents Lines' new C10 class container ship with a maximum speed of 24.3 knots is an example. These speeds can be achieved with the use of 57,000 shp diesel engines, which are more economical to operate than comparable steam and gas turbine plants.

Government-sponsored fast ship programs in Japan appear to be driven for the most part by research in superconductivity. The successful development of superconductive materials may permit the design of lightweight and efficient motors and associated components for shipboard applications. Such systems offer the potential for reductions of about 20 percent in ship weight.

Successful developments in superconductive materials may also lead to practical magnetohydrodynamic propulsion systems. This type of propulsion is based on the principle that a force is created on a current-carrying conductor in the presence of a magnetic field. For marine propulsion systems, seawater might be used as the conductor. Current passing through water in the presence of a magnetic field generates a force that pushes the water out of the conduit. This force might be used to propel ships through the

water. Such a system would eliminate the use of propellers, the associated shafting, and reduction gears, and would substantially reduce weight.

Both technologies are in the basic research stage and require extensive development programs before they can be applied to fast ship designs. This status is evident in the ongoing work sponsored by the Japan Foundation for Shipbuilding Advancement, which is planning to build a model superconducting electromagnetic ship with a displacement of 150 tons and a speed of 8 knots. Therefore, we believe it is premature to plan U.S. strategic transportation programs for the early 21st century with this technology. However, because of the potentially wide application of superconductivity in other industries, DoD should support an adequate research program in this technology.

In selecting FSS candidates, we examined alternative hull forms, their range and payload characteristics, and the associated propulsion system requirements to achieve speeds in excess of 30 knots. In particular, we examined displacement monohull, semiplaning hull, and SES designs.

Large displacement monohull ships capable of speeds in excess of 30 knots have been built. For example, SL-7s, when new, were capable of a maximum speed of 33 knots. Today, aircraft carriers and other large Navy warships, when required by operational considerations, steam at speeds in excess of 33 knots. The technology is well established.

At high speeds, the semiplaning hullform provides lift, which causes the vessel to ride higher in the water and decreases the wetted hull area. Since the amount of power required to move a ship through water is partly a function of surface drag on the wetted area, large semiplaning hull ships theoretically can attain higher speeds than those with displacement hulls. Small semiplaning hull vessels have speed capabilities in the range of 35 to 40 knots.

An SES rides on a cushion of air and can achieve higher speeds than ships with semiplaning hulls. SESs under 200 tons have speeds in excess of 50 knots. Since the speed characteristics of displacement monohull ships and SESs bracket those projected for semiplaning hull designs, this analysis does not construct a semiplaning hull FSS candidate.

Using the characterization framework described in the previous section, we defined three FSS candidates:

- Baseline T-AKR
- Improved T-AKR
- SES

Each candidate would be built for DoD in U.S. shipyards and maintained in ROS by commercial firms under DoD charters. As shown in Table 5, we use a range of low and high cost for an SES because of the uncertainty about the costs of producing this advanced design ship.

Baseline T-AKR

The baseline T-AKR is a new-construction SL-7, built with a gas turbine propulsion plant with roughly 120,000 shp. The propulsion plant provides the ship with a maximum sustained speed of 33 knots. It is a combination Ro-ro/container ship, with the same u/e cargo capacity as the existing T-AKRs. Its estimated 20-year life-cycle cost of $312 million (FY 1988 dollars) includes an average ship procurement cost of $222 million and a 20-year OM&S cost of $90 million. The 20-year OM&S cost reflects an annual cost of $4.5 million per ship.

Improved T-AKR

The improved T-AKR has the same exterior dimensions as the baseline T-AKR (946 × 105.6 ft). However, it is redesigned as a pure Ro-ro with multiple decks that

Table 5

FSS CANDIDATES

Characteristics	Baseline T-AKR	Improved T-AKR	SES
Speed (knots)	33	33	55
Range (nmi)	8,000	8,000	3,500
Cargo (stons u/e)	8,000	12,000	5,000
Loading/unloading (days)	2	1.6	0.7
Fuel use (tons/hr)	20.4	20.4	50.9
20-year life-cycle cost (million FY 1988 dollars per ship)	312	423	347–547

extend along the length of the ship and access ramps to facilitate travel between decks. To provide increased parking areas, the number of ship compartments and vertical support members is reduced, imposing heavier loads on the hull and the remaining vertical support members. Consequently, the hull, vertical strength members, and decks have to be built with stronger and more costly materials.

The reduced compartmentation detracts from ship capabilities to establish fire and flooding boundaries. To compensate for this lack, the ship's design includes more sophisticated fire and flooding systems. Its electrical system is better insulated and equipped with automatic shut-off devices to prevent electrical fires. Similarly, auxiliary systems (e.g., firemain and potable water) are built with more robustness to prevent flooding.

To facilitate loading and unloading, the improved T-AKR is equipped with stem and bow Ro-ro ramps in addition to midship ramps. With this configuration, we estimate the ship can be unloaded in 1.6 days. To reflect the added features, we estimate that the procurement cost of the improved T-AKR is roughly 50 percent more than that of the baseline, or $333 million (FY 1988 dollars). With OM&S, the 20-year life-cycle cost of the improved T-AKR is $423 million.

SES

The SES is an advanced-design catamaran hull ship outfitted with a lift system that permits the variation of draft (Fig. 2). It is 850 ft long and has a beam of 150 ft. The full load displacement of the SES is over 21,000 stons. Large-capacity fans, powered by gas turbines, generate an air cushion that is contained by two rigid catamaran side hulls and flexible forward and after skirts. This lift system allows the SES to vary draft from 30 to 10 ft. Operating on air cushion, the SES may access shallow ports. Also, the lift system reduces the skin and wave-making drag and permits the SES to attain an average speed of roughly 55 knots. To achieve this speed, the SES requires a propulsion plant capable of generating roughly 240,000 brake horsepower (bhp). With a cargo weight of 5000 stons, it has a range of roughly 3500 nmi.[4]

Since the SES is only a conceptual design, it is difficult to establish a ship procurement cost with a high degree of confidence. Table 6 shows SES cost estimates from one contractor for a hypothetical ten-ship construction program. The cost of the

[4]Ingalls Shipbuilding, Inc., *Surface Effect Fast Supply Ship (SFS) Technology Assessment Report*, Pascagoula, Mississippi, 1987.

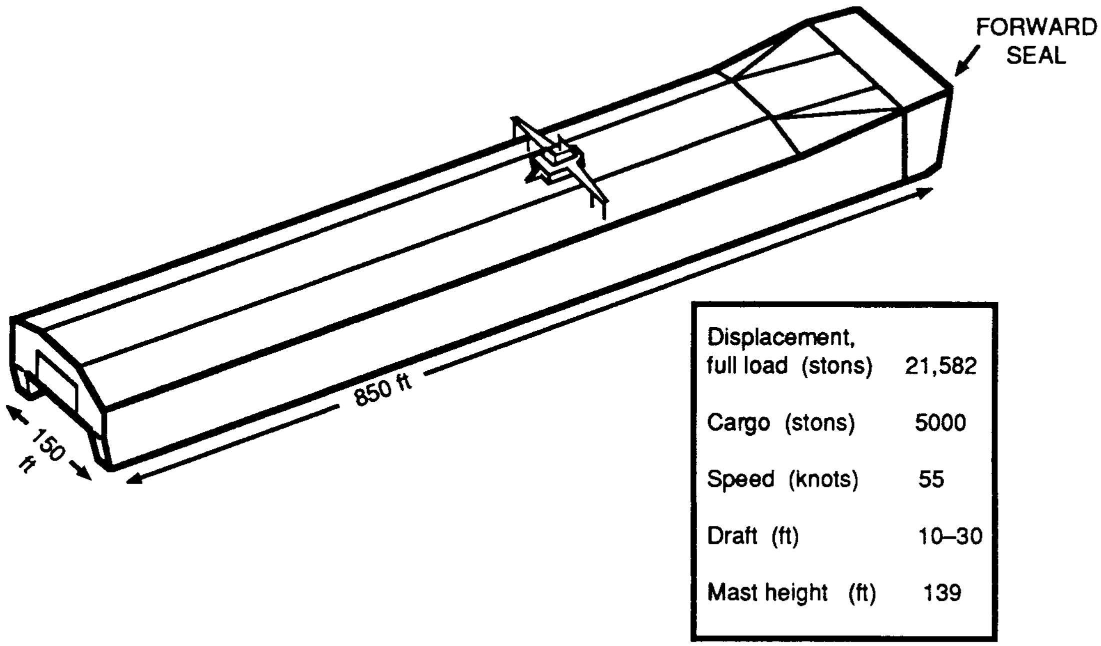

Fig. 2—SES

lead ship, including profit, is $279 million (FY 1987 dollars). The average cost of the follow-on ships is approximately $211 million (FY 1987 dollars). These estimates are based on four assumptions:

- No major R&D program is required.
- Production model is built without any intervening prototypes to validate preliminary designs, reliability, and maintainability.
- Conventional shipbuilding material and techniques are used.
- The ship is built according to commercial ship specification and not to meet military specifications.[5]

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[5]Ingalls Shipbuilding, Inc., *Surface Effect Fast Supply Ship (SFS) Producibility, Cost and Schedule Report*, Pascagoula, Mississippi, 1987.

Table 6

SES COST ESTIMATES
(FY 1987 $ in thousands)

Category	Lead Ship	Follow-on Ships
Hull	47,878	42,775
Propulsion	54,744	52,485
Electric	3,699	3,297
Auxiliary	35,082	33,151
Outfitting	14,837	13,024
Command	1,423	1,334
Integration/engineering	49,970	7,216
Ship assembly/support	27,524	21,385
Ship construction cost	235,157	174,667
Proposed cost of money	2,629	1,904
Proposed profit	41,288	34,459
Total procurement cost	279,074	211,030

SOURCE: Ingalls Shipbuilding, Inc., *Surface Effect Fast Supply Ship (SFS) Producibility, Cost and Schedule Report*, Pascagoula, Mississippi, 1987.

Because of the assumptions, we consider these estimates to be overly optimistic. We thus modified them to define a "low cost" estimate, which includes a substantial R&D program that results in a lead ship cost of $1.5 billion. We assume that the average cost of follow-on ships is $214 million (FY 1988 dollars). In a 30-ship procurement program, the added R&D costs translate to an average SES cost of $257 million. The size of the program is driven by the arbitrary cost limit set in constructing equal-cost forces. With OM&S, the 20-year life-cycle cost of the low-cost SES is estimated as $347 million (FY 1988 dollars).

In our high-cost estimate, we include a large R&D program that increases the cost of the lead ship to $4.4 billion. Recent Navy estimates for an SES development program were in the range of $3.4–4.4 billion. The program included the construction of one or two intermediate-size SESs.[6] In addition, we assume that the average cost of the follow-on ships is $321 million. In a 30-ship procurement program, the added R&D translates to an average ship procurement cost of $457 million. With OM&S, the life-cycle cost of the high-cost SES is estimated as $547 million (FY 1988 dollars).

[6]Naval Sea Systems Command, *Fast Sealift Program Requirements and Technology Assessment Report* (Draft), 1988, p. 10-1.

The hypothetical low- and high-cost SES estimates are not provided as point estimates for different SESs, but rather to illustrate the range of uncertainty associated with building an SES capable of carrying 5000 stons of cargo 3500 nmi at an average speed of 55 knots without refueling.

Technology and Engineering Risk Assessment of SESs

Approximately 400 fairly small SESs are operational in the free world. Only three of these operate in the speed regime of 41 to 50 knots. The largest is the Navy SES 200, with its displacement of approximately 200 tons. The conceptual design proposed for a strategic sealift SES calls for a ship roughly 100 times as large. A scale-up of this magnitude poses development and engineering challenges.

To establish the technology and enginering risks for building a strategic sealift SES, we reviewed the conceptual design proposed by Ingalls Shipbuilding.[7] The principal characteristics of the conceptual design are listed in Table 7. We examined three functional areas—hull, propulsion, and lift/seals—and qualitatively ranked them as low, moderate, or high. We assess technology risks as high if new concepts, materials, components, or systems must be created before a prototype can be built. We characterize risks as moderate if the needed items exist but have to be adapted for ship application; we characterize them as low if the items are available to build an SES prototype.

Engineering risks are high if systems of comparable size (within an order of magnitude) have not been built and the reliability and maintainability of the proposed system designs have to be proved in a prototype before production models can be built. We consider engineering risks moderate if comparable systems have been built and their reliability and maintainability have been proven in other than ship applications. And we consider engineering risks low if comparable ship systems exist and their reliability and maintainability are satisfactory.

The tradeoffs between weight and speed are critical in the design of SESs. Consequently, the weight of the hull must be minimized without compromising static and structural integrity. This requires the use of lightweight and high-strength materials. Model tests have not been performed to validate that HSLA-80 steel, a material

[7] Ingalls Shipbuilding, Inc., *Surface Effect Fast Supply Ship (SFS) Producibility, Cost and Schedule Report*, Pascagoula, Mississippi, 1987.

Table 7

SES CONCEPTUAL DESIGN CHARACTERISTICS

Characteristics	
Dimensions (ft)	
Length	850
Beam	150
Mast height	139
Air cushion area (sq ft)	97,000
Weights (stons)	
Displacement (full load)	21,582
Design cargo load	5,000
Fuel	3,573
Power plants	
Eight gas turbine engines	30,000 bhp per engine
Eight water jet propulsors	30,000 hp per propulsor
Lift power	60,000 bhp
Construction materials	
Hull	Welded HSLA-80 steel
Superstructure	5456 aluminum

employed in the construction of conventional ship hulls, can be used for the large catamaran hull design of the SES without exceeding conceptual design weight constraints or compromising structural integrity. Lightweight and high-strength materials used in other industries may have to be adapted. Consequently, the technical and engineering risks in the hull area are assessed as moderate. Figure 3 compares SES risks with those of building T-AKRs.

The power requirements of the SES, including lift, are on the order of 300,000 bhp, which is more than twice the size of the largest power plant built for commercial ships. Large marine gas turbines are available to support these requirements.[8] However, water jets of the size proposed for SESs have not been developed for ship propulsion systems. Similarly, the novel engine and propulsor arrangement, single engines driving individual water jet pumps, with four such combinations located in each side hull, has not been proven. The technical and engineering risks in propulsion are evaluated as moderate.

[8]LM 2500 gas turbine engines rated at 30,000 bhp are used in Spruance class destroyers. Ten of these would be required for the proposed SES.

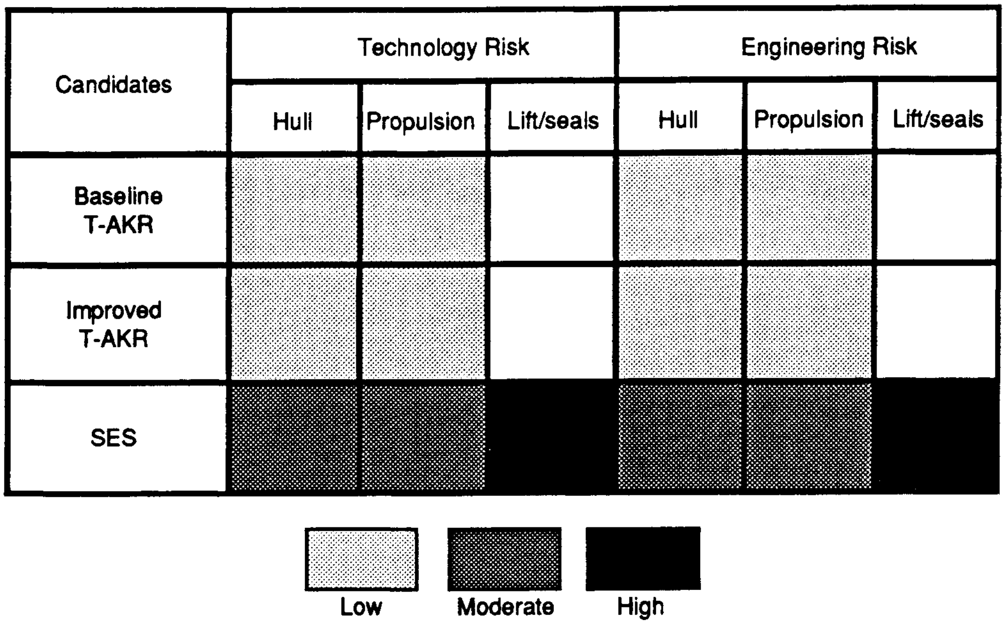

Fig. 3—Technology and engineering risk assessment

Candidate materials and coatings for SES bow seals have been identified, but their structural strength and performance have not been validated. Schemes for attaching the seals to hulls have been postulated, but they have not been adequately tested. A dedicated R&D program is required to build a prototype seal system for SESs. A bag with an attached flexible finger arrangement is envisioned as the seal prototype. Only data based on experience with much smaller seals on existing hovercraft are available to predict the wear and maintainability of this configuration. We consider seals as high technology and engineering risk areas.

REPRESENTATIVE MPS(A) CANDIDATES

MPS(A)s are built to carry and store u/e and large quantities of supplies. They are combination Ro-ro, container, fuel tanker, and breakbulk ships; and their interior designs are substantially different from those of FSSs. They have added internal compartmentation and climate control to support long-term storage of u/e, and they include facilities to support routine maintenance of stored u/e. Their interior configurations provide personnel adequate access to perform routine maintenance operations. As a result, an MPS(A) carries less u/e than an FSS of comparable size.

Unlike FSS candidates in ROS, MPS(A)s routinely operate fully loaded with high-value military equipment. To ensure safe storage under such conditions, they are built to military ship specifications, which require closer framing, added compartmentation to improve firefighting and damage control capabilities, shock mounting of vital equipment, and redundant firemain and emergency electrical systems. These features increase ship construction cost.

For the analysis, we constructed three MPS(A) candidates (see Table 8). All are capable of fast speeds and are intended to perform as FSSs after they unload preloaded cargo. The ships are fully manned and routinely deploy to various locations (active regime). The cost of maintaining them in an active regime is the major factor in their high life-cycle cost.

The standard MPS(A) is a derivative of the Lt. Bobo class currently used for prepositioning Marine Corps equipment. It is faster (25 versus 18 knots) but carries roughly the same amount of u/e. The improvement in propulsion system is estimated to cost $10 million. The average ship cost of the Lt. Bobo class adjusted to 1988 dollars, using MARAD shipbuilding cost factors, is $186 million.[9] Including $246 million for OM&S cost, the 20-year life-cycle cost of the standard is $442 million.[10]

The new design is 8 knots faster and carries roughly 45 percent more u/e than the standard. The length of the new design is roughly that of the T-AKRs. To achieve the

Table 8

MPS(A) CANDIDATES

Characteristics	Standard	New Design	High Capacity
Speed (knots)	25	33	33
Range (nmi)	12,000	8,000	8,000
Cargo (stons u/e)	5,000	7,250	10,000
Loading/unloading (days)	1	1.5	2
Fuel use (tons/hr)	10.2	20.4	20.4
20-year life-cycle cost (million FY 1988 dollars)	442	530	558

[9]MARAD Division of Cost Estimates and Analysis, *Index of Estimated Shipbuilding Cost in the United States*, June 1988.

[10]Estimate based on existing MPS annual OM&S cost of $12.3 million.

postulated speed, the ship is outfitted with a gas turbine power plant roughly the same size as that of the T-AKRs. It has two conventional shafts and associated high-performance reduction gears and propellers. Reflecting the added speed and increased cargo storage capacity, we estimate the procurement cost of the new design as $284 million. Including $246 million for OM&S cost, the life-cycle cost of the new design is $530 million.

The high-capacity MPS(A) has the same speed capabilities as the new design but carries roughly 38 percent more u/e. In constructing this candidate, we kept ship size constant but increased the amount of equipment storage space above the main deck. We assume that this change adds roughly 10 percent to ship cost. As a result, the procurement cost of this candidate is estimated as $312 million. Including $246 million for OM&S cost, the 20-year life-cycle cost of the high-capacity MPS(A) is estimated as $558 million.

V. PERFORMANCE ASSESSMENT OF FSS AND MPS(A) CANDIDATES

This section examines the performance of FSS and MPS(A) candidates to identify the most promising options. To determine ship performance, we consider ship start-up, cargo loading, ship transit from SPOE to SPOD, at-sea refueling, and cargo unloading at SPODs. Using these variables, we calculate the time it takes the candidates to deliver first cargo and cargo throughput over a 90-day period to Europe, Southwest Asia, Zaire, and Thailand.

We first examine the performance of the candidates under a zero warning-time assumption to all four theaters. Warning time is the amount of time that U.S. forces will have to prepare for and deploy to designated locations. Three terms are commonly used to discuss warning time:

- Day mobilization is declared (M-day)
- Day deployment operations commence (C-day)
- Day hostilities or contingency operations begin (D-day)

In the zero warning-time case, M-day, C-day, and D-day are simultaneous. This case is by far the most demanding for U.S. force deployments and strategic mobility forces. It implies that the United States is caught completely by surprise and must mobilize, transport, and fight simultaneously.

Given existing U.S. intelligence capabilities, it is unlikely that major enemy force buildups or preparations for offensive actions would be undetected in major theaters. In response to intelligence warning, the National Command Authority may order early mobilization of forces and the activation of government-controlled sealift ships (those in the RRF and in ROS) before C-day. If this action were to be implemented, government-controlled ships could be ready to depart SPOEs on C-day and possibly arrive in SPODs before D-day. We categorize this situation as a moderate warning-time case. We assess the performance of candidate ships under the moderate warning-time assumptions in force deployments to Europe and Southwest Asia. Requests for assistance from such Third World countries as Zaire and Thailand are more likely to come with little warning.

Consequently, we chose not to specifically assess the performance of candidates in operations to Zaire and Thailand under moderate warning-time assumptions.

For all cases, 10 percent of the sealift ships (rounded to the next highest number) in each equal-cost force were not available because of routine maintenance, repairs, or overhaul. Also, we assumed that cargo is available for loading when ships are.

EQUAL-COST FORCES

To evaluate the performance of candidates, we first constructed equal life-cycle-cost forces. For the purpose of this analysis, an arbitrary 20-year life-cycle total cost limit of $15 billion (FY 1988 dollars) is set for each alternative force. Equal-cost forces include the appropriate number of tankers required to support a 12,000-nmi deployment without relying on shore facilities. This distance is representative of force deployments from U.S. ports to the Persian Gulf without the use of the Suez Canal. In view of the U.S. national interest in this area, it is important to assess how the proposed sealift forces perform without shore support.

The SES carries approximately 3200 tons of fuel. At an average speed (55 knots), it consumes roughly 51 tons per hour. Consequently, in a one-way trip to the Persian Gulf, the SES requires approximately 7900 tons of fuel from replenishment tankers. Because of its speed advantage, the SES requires tankers to be prepositioned at different locations along the route. Assuming equal warning time, this implies that the tankers have to be maintained in an active operating regime. Assuming these tankers have a 24,000 long ton fuel capacity, on the average three tankers are needed to support nine SESs in deployments to the Persian Gulf. We assume that allied or friendly nations in the region provide the shuttle tankers required to keep station tankers supplied with fuel.

T-AKRs and the new-design and high-capacity MPS(A) candidates also require tankers to support their deployments to the Persian Gulf. However, they carry more than twice the amount of fuel of SESs and consume roughly 20.4 tons of fuel per hour. Therefore, they require only one refueling (2466 tons of fuel) per one-way trip to the Persian Gulf. One tanker can support approximately ten T-AKRs or new-design and high-capacity MPS(A)s.

The cost of a tanker with a fuel capacity of approximately 24,000 tons of fuel and port and starboard high-capacity refueling capabilities is $200 million.[1] Adding to this figure $246 million for OM&S, we estimate the 20-year life-cycle cost of a tanker as $446 million. Including tankers as part of the equal-cost forces reduces the number of FSSs that can be built and maintained. Table 9 summarizes the composition of equal-cost fast sealift forces.

MPS(A) equal-cost forces can be constructed with and without including u/e costs. Taking the first approach, we assume that an additional set of u/e has to be procured for prepositioning aboard ships. This implies that all existing u/e sets are either fully employed in training operations, deployed with active duty forces, or prepositioned on land sites. In most circumstances, this rationale is valid, and the cost of maritime prepositioning concepts should include u/e cost. However, there may be opportunities for deploying existing u/e on ships. For example, an extra set of u/e may become available under current DoD plans to demobilize two active divisions. Similarly, a portion of the POMCUS equipment prepositioned in Europe might become available for afloat prepositioning at little or no additional cost. In these circumstances, only u/e maintenance and replacement costs would have to be included.

For this analysis, MPS(A) equal-cost forces were constructed with (Table 10) and without (Table 11) u/e costs included. To reflect the added cost, we calculated the procurement and OM&S cost for 100,000 stons of notional armored division equipment.[2] We used the Army Table of Organization and Equipment (TOE) to establish the cost of

Table 9

EQUAL-COST FSS FORCES

	Candidate Ships			
Number	Baseline T-AKR	Improved T-AKR	Low-Cost SES	High-Cost SES
Ships	41	31	30	20
Tankers	5	4	10	7

[1]Congressional Budget Office, *Issues and Options for the Navy's Combat Logistics Force*, April 1988, p. 9.

[2]U.S. Army Military Traffic Management Command Transportation Engineering Agency, *Deployment Planning Guide*, Newport News, Virginia, September 1989.

Table 10

ALTERNATIVE MPS(A) FORCES
WITH U/E COSTS

	Candidate Ships		
Number	Standard	New Design	High Capacity
Ships	21	16	14
Tankers	0	2	2

Table 11

ALTERNATIVE MPS(A) FORCES
WITHOUT U/E COSTS

	Candidate Ships		
Number	Standard	New Design	High Capacity
Ships	34	26	24
Tankers	0	3	3

individual pieces of equipment. The 20-year life-cycle cost of this prepositioned equipment is estimated as roughly $4.7 billion in 1988 dollars—$4 billion for procurement and $0.7 billion for OM&S. This estimate does not include helicopter assets of an armored division. Typically, these assets are not stored aboard ship, but are part of the fly-in echelon that deploys to SPODs of prepositioning ships.

To reflect the cost of equipment, we add to each alternative MPS candidate a fraction of the cost of equipment based on its cargo capacity. The composition of equal-cost forces shown in Table 10 reflects the estimated cost of u/e. A comparison of the data in Tables 10 and 11 shows the effect of procuring u/e for prepositioning. For example, only 14 high-capacity MPS(A)s can be bought with u/e included, compared to 24 high-capacity MPS(A)s without u/e. But 140,000 stons of additional Army u/e have been procured.

PERFORMANCE OF FSS AND MPS(A) CANDIDATES IN DEPLOYMENTS TO EUROPE

In force deployments to Europe, all cargo is shipped from U.S. ports on the East and Gulf coasts to ports in Germany, Belgium, and the Netherlands. Great circle distances with no evasive maneuvering between specific ports vary roughly from approximately 3200 to 5000 nmi. For the purpose of estimating travel time, we use a nominal distance of 4000 nmi and the maximum operating speeds of the individual candidates.

Since the FSS candidates are in ROS, they require four days to attain active status and commence loading operations in SPOEs. Assuming that there is sufficient port throughput capacity in U.S. East and Gulf coast ports, the loading times for the forces reflect individual ship loading times previously discussed in the characterization of alternative FSSs.

Germany, the Netherlands, and Belgium have large, well-developed port facilities. Hamburg, Amsterdam, Rotterdam, and Antwerp can accommodate more than 350 deep sea ships at any given time. In the event that enemy forces are successful in closing these ports, numerous French and Italian ports may be used as alternative SPODs.[3] In this analysis of cargo deliveries to the European theater, we do not include any time delays due to port access or unloading constraints.

Zero Warning and No Ship Attrition

Taking into consideration ship start-up, cargo loading, travel, enroute refueling, and cargo unloading times, we calculated the performance of equal-cost FSS and MPS(A) forces in deploying to Europe over a 90-day period with zero warning time and no ship attrition (Fig. 4). The improved T-AKR dominates the baseline T-AKR, the low-cost SES dominates the high-cost SES, and the high-capacity MPS(A) dominates the standard and new-design candidates.

For European contingencies, MPS(A) forces are taken to be 2000 nmi from Europe at C-day. This reflects current MPS operations, where one MPS squadron operates in the Atlantic. Under this assumption, the high-capacity MPS(A)s deliver their first cargo, 120,000 stons of u/e, in four days, or approximately five days earlier than

[3]Lloyd's, *Ports of the World, 1989*, Lloyd's of London Press, Colchester, United Kingdom, 1989.

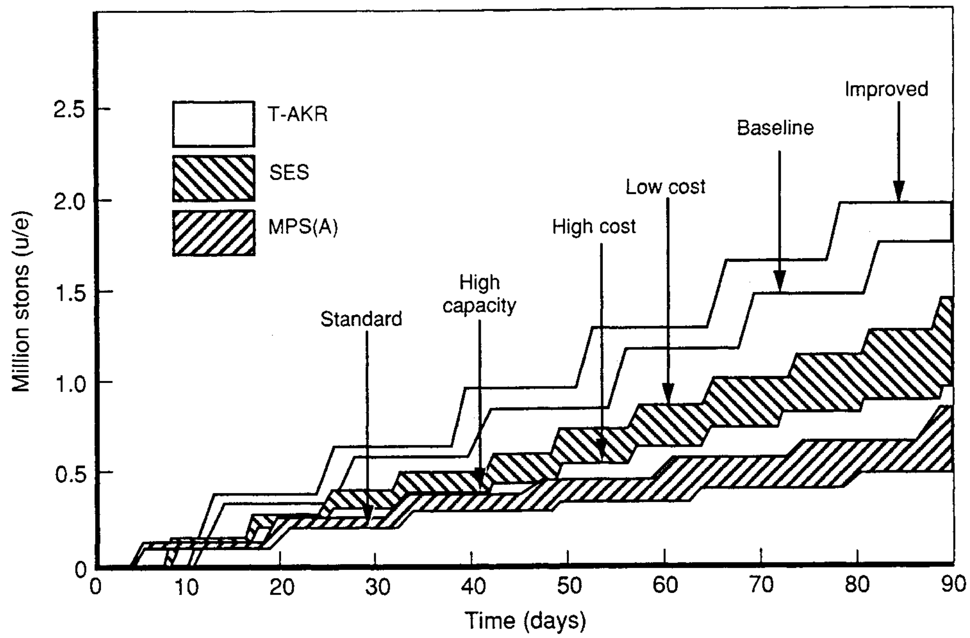

Fig. 4—Performance of FSS and MPS(A) candidates (Europe, zero warning, no ship attrition)

SESs and eight days earlier than T-AKRs. After delivering their first cargo, MPS(A)s are employed as FSSs. Because of the cost penalties imposed by their active regime and the cost of u/e, they are not competitive over time with the low-cost SES and improved T-AKR forces.

The low-cost SES force delivers its first cargo, 135,000 stons of u/e, in nine days. The improved T-AKR force does not deliver its first cargo, 324,000 stons of u/e, until day 12. However, over time, T-AKR forces outperform the MPS(A) and SES forces. For example, over 90 days, improved T-AKRs deliver approximately 1.95 million stons of cargo, compared to 1.49 million stons for low-cost SESs and 0.84 million stons for high-capacity MPS(A)s.

In examining the cargo buildup curve (Fig. 4) for this case and those developed for other cases, one should remember that there are two criteria for assessing the performance of candidates: time to deliver first cargo and cargo throughput over time. The lower left-hand quadrants of the cargo buildup curves show the candidates' performance against time of initial delivery. The middle and right-hand sections of the

buildup curves highlight the candidates' performance against cargo throughput over time. In this screening analysis, we did not establish the relative value of early delivery versus capacity.

Moderate Warning and No Ship Attrition

In a moderate warning-time scenario, along the lines of M-day = D-day – 26 days (denoted as M=D–26) and C-day = D-day – 10 days (denoted as C=D–10), T-AKR and SES forces might be activated and loaded before C-day. Under these conditions, SESs will deliver their first cargo 6 days and T-AKRs 3.5 days before hostilities commence. MPS(A)s can arrive as much as 23 days before D-day. For the analysis, MPS(A)s arrive at SPODs on C-day and begin to unload cargo (Fig. 5). Obviously, to effect these early deliveries, permission from host countries is required to begin unloading operations before hostilities commence. If permission is not obtained, all candidates would be in the vicinity of SPODs to commence unloading operations on D-day.

In the moderate warning scenario, the relative performances of candidate ships do not change from those of zero warning. The improved T-AKR continues to outperform the other candidates in terms of throughput over time. Ninety days into the war, the

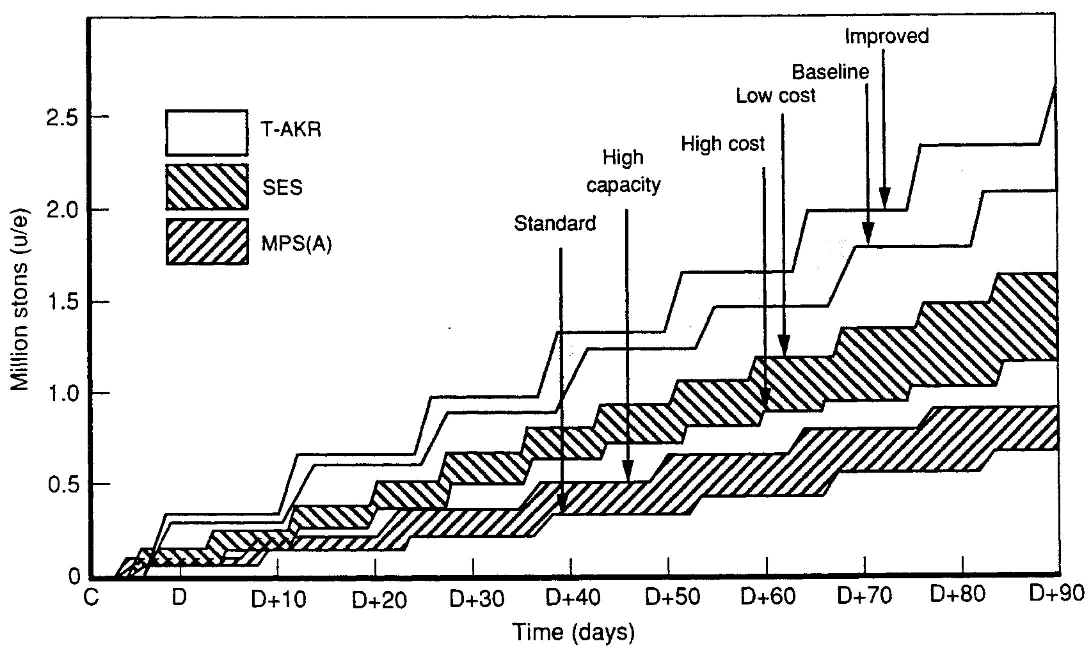

Fig. 5—Performance of FSS and MPS(A) candidates (Europe, M=D–26, C=D–10, no ship attrition)

T-AKRs deliver roughly 2.6 million stons, compared to 1.6 million stons for low-cost SESs and 0.9 million stons for high-capacity MPS(A)s.

With Ship Attrition

The Soviet Union has substantial sea and air capabilities for interdicting SLOCs in the North Atlantic. The forces include diesel- and nuclear-powered submarines equipped with torpedoes, mines, and cruise missiles; and ships and long-range bombers armed with antiship missiles. Assuming that the Soviets maintain some of these capabilities in the future, in the event of a major conflict with NATO they may assign some of these assets to an SLOC interdiction campaign. A detailed analysis, outside the scope of this study, is required to establish the likely outcomes of alternative SLOC interdiction campaigns.

To establish an initial indication of the potential impact of attrition on the performance of FSS and MPS(A) candidates, we assess attrition parametrically using the postulated attrition factors shown in Table 12. To reflect the potential advantage that SESs might have over the other candidates in a torpedo- and mine-dominated threat environment because of their faster speed and smaller underwater hull area, we assumed that they are half as vulnerable per cycle as the other candidates.

During the first cycle, all T-AKR and MPS(A) forces are attrited by a factor of 0.10, all SES forces by a factor of 0.05. These figures correspond to losses of three improved T-AKRs, one high-capacity MPS(A), and one low-cost SES (rounding to the nearest whole number). In calculating the number of candidate ships in subsequent cycles, we simply multiply the remaining number of ships from the previous cycle by the appropriate attrition factor.[4] The decrease in ship attrition factors in subsequent cycles

Table 12

SHIP ATTRITION FACTORS FOR EUROPE
(percent attrition per cycle)

Cycle	T-AKR/MPS(A)	SES
First	0.10	0.05
Second	0.03	0.15
Subsequent	0.01	0.005

[4]If these calculations result in losses of less than one ship during the cycle, we continue to use the number of ships in the previous cycle while carrying the fractional loss until it is greater than 0.5. At that point, we round off to the next lower number.

reflects the increased effectiveness of U.S. military forces for protecting sealift ships against enemy antishipping efforts.

Using the preceding procedure, we calculated the cumulative cargo deliveries over a 90-day period for the improved T-AKR, low-cost SES, and high-capacity MPS(A) (Fig. 6). Ship attrition did not change the relative performance of the candidate forces. Over 90 days, SESs cycle roughly twice as many times as the other candidates and consequently are exposed to the threat more often. Over time, the improved T-AKRs continue to deliver more cargo than the other candidates.

Ship attrition does substantially reduce cargo deliveries to Europe for all candidates. Over a 90-day period, the improved T-AKR delivers roughly 14 percent less cargo, the low-cost SES delivers 8 percent less cargo, and the high-capacity MPS(A) delivers 16 percent less cargo than in the case of no ship attrition.

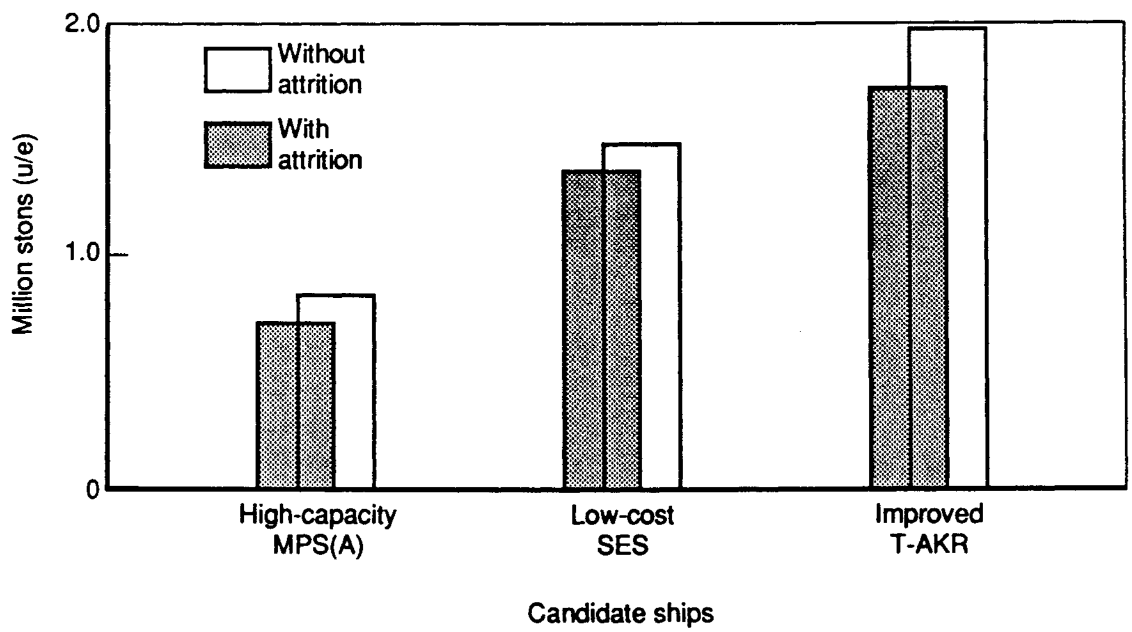

Fig. 6—Cumulative cargo deliveries over 90 days (Europe, zero warning, with and without ship attrition)

PERFORMANCE OF FSS AND MPS(A) CANDIDATES IN DEPLOYMENTS TO SOUTHWEST ASIA

The hypothetical Southwest Asia (SWA) scenario used in comparing the performance of FSS and MPS(A) candidates is one that involves U.S. assistance to Saudi Arabia and Kuwait to repel an invasion by Iraq. In this scenario, U.S. sealift ships have the option to deliver cargo to ports in Saudi Arabia, Kuwait, Bahrain, Qatar, and the United Arab Emirates. There are at least ten ports (Fig. 7) on the southern littoral of the Persian Gulf, with more than 100 berths that can accommodate ships of the size and draft of the largest FSS and MPS(A) candidates. Many of these berths have specialized facilities to handle Ro-ro and container ships. Consequently, for the analysis of cargo deliveries to SWA, we assume that there are no port constraints. This would not be the case if Iranian ports were to be used for debarkation.

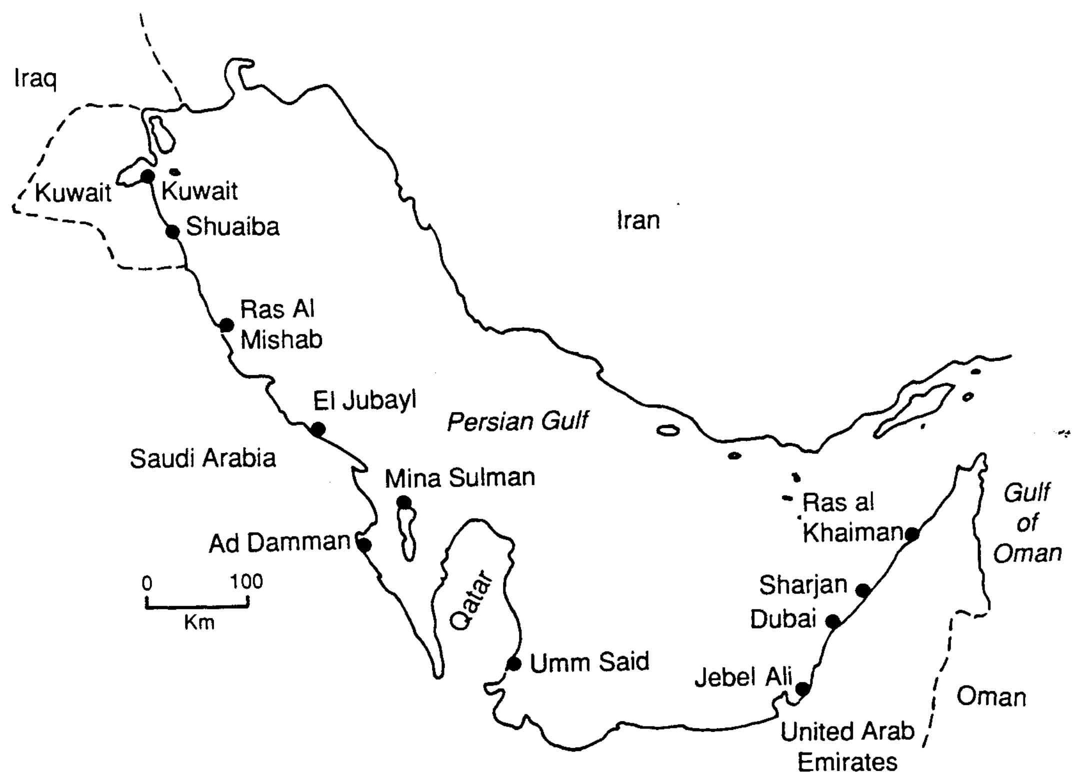

Fig. 7—Major Persian Gulf ports

The distances from U.S. East and Gulf coast ports to specific ports in the Persian Gulf via the Suez Canal vary from approximately 8000 to 9000 nmi. If the Suez Canal is not used, ships based on the East Coast have to travel around the southern tip of Africa to reach the Persian Gulf. The distances then range from approximately 11,000 to 12,000 nmi. The distances from continental U.S. West Coast ports to the Persian Gulf vary from approximately 10,500 to 11,500 nmi. For calculations of travel time of SESs and T-AKRs to SWA, a notional distance of 12,000 nmi is used. MPS(A)s operate in the vicinity of Diego Garcia, at a distance of 2500 nmi from SPODs.

To travel the large distances in this scenario, all candidate ships except the standard MPS(A) require at-sea refuelings. SESs have to refuel six times per round trip; T-AKRs and the other MPS(A)s have to refuel only twice. These requirements translate to a penalty per cycle of roughly two days for the SES and two-thirds of a day for the other ship candidates.

Zero Warning and No Ship Attrition

Under a zero warning scenario, the high-capacity MPS(A) force delivers its first cargo, 120,000 stons of u/e, to SWA in five days (Fig. 8), the low-cost SES force in ROS delivers 135,000 stons in 15 days, and the improved T-AKR force in ROS delivers 324,000 stons in 22 days. As in the European scenarios, the improved T-AKR dominates the baseline T-AKR, the low-cost SES dominates the high-cost SES, and the high-capacity MPS(A) dominates both the standard and new-design MPS(A)s.

Over time, the improved T-AKR force outperforms all other candidates. In 90 days, it delivers 0.81 million stons of u/e, compared to 0.54 million stons for the low-cost SES force and 0.36 million stons for the high-capacity MPS(A) force. As shown in Fig. 8, MPS(A)s are competitive with SESs during the first 60 days, but cannot compete over time with the other candidates because of the penalty imposed by the cost of their active operating regime and the cost of u/e.

Moderate Warning and No Ship Attrition

In a moderate warning scenario (M=D–26 and C=D–10) the order of first cargo deliveries does not change: MPS(A)s deliver first, followed by SESs and T-AKRs. Similarly, the improved T-AKR continues to outperform the other candidates (Fig. 9) in terms of cargo deliveries over time. Ninety days into hostilities, T-AKRs deliver 0.97 million stons of u/e, compared to 0.675 million stons for low-cost SESs and 0.36 million stons for high-capacity MPS(A)s.

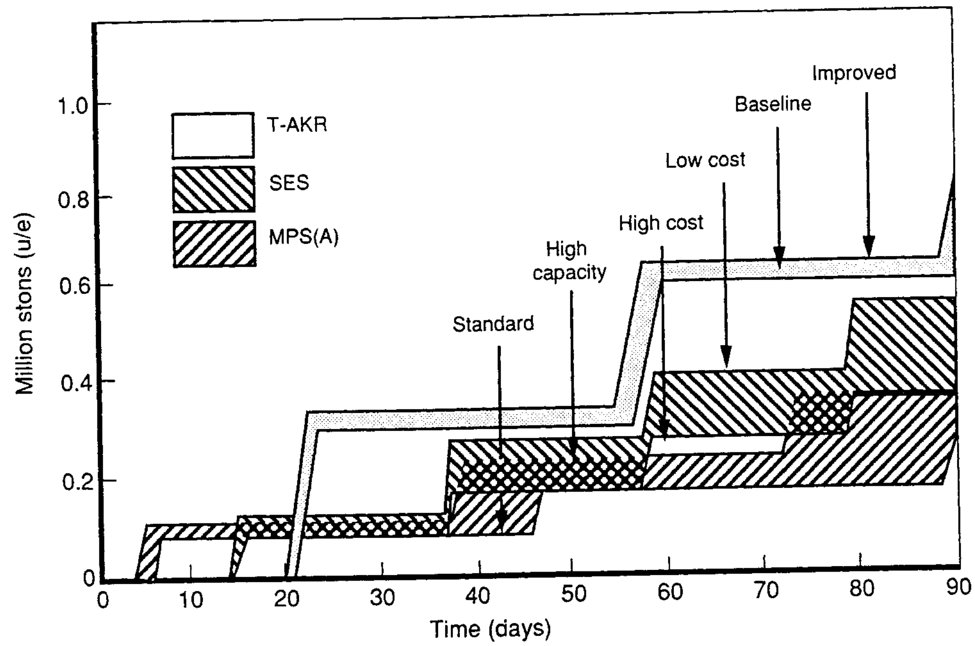

Fig. 8—Performance of FSS and MPS(A) candidates (SWA, zero warning, no ship attrition)

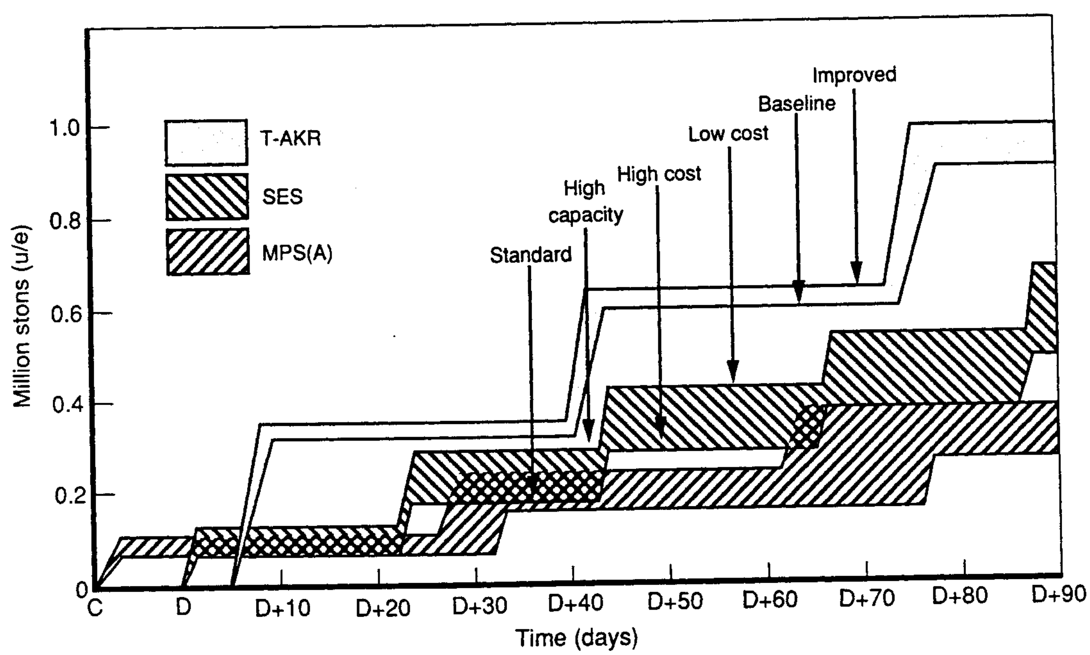

Fig. 9—Performance of FSS and MPS(A) candidates (SWA, M=D-26, C=D-10, no ship attrition)

With Ship Attrition

The military forces of Iraq have limited capabilities to attack sealift ships outside the Persian Gulf. In the future, they might be able to conduct very limited attacks against ships in the western end of the Gulf with air launch missiles and mines. Therefore, we do not include any ship attrition due to Iraqi military actions.

The Soviets currently have limited support facilities for their naval and air forces in the vicinity of the Persian Gulf. They are unlikely to expand these capabilities in the future. In the event of their involvement in the invasion of Saudi Arabia, it is unlikely that they would gain additional support. Consequently, they would have to institute heroic measures to maintain a substantial force of submarines in the area for SLOC interdiction. With potential U.S. air superiority in the region, they are unlikely to conduct a sustained air offensive against sealift ships. These factors argue for fairly low ship attrition in force deployments to SWA. The ship attrition factors listed in Table 13 are used to calculate the effect of attrition on cargo deliveries of the FSS and MPS(A) candidates. As in the European scenario, we postulate that SES attrition is half that of the T-AKR and MPS (A).

As shown in Fig. 10, the relative performance of the candidates does not change from the no-attrition case. Improved T-AKRs continue to deliver more cargo over time than the other candidates. The effect of attrition in SWA deployments is not as severe as in the European case. Over 90 days, improved T-AKR, low-cost SES, and high-capacity MPS(A) forces deliver, respectively, about 2, 1, and 3 percent less cargo than they do in the case of no ship attrition.

Table 13

SHIP ATTRITION FACTORS FOR SWA
(percent attrition per cycle)

Cycle	T-AKR/MPS(A)	SES
First	0.02	0.01
Second	0.005	0.0025
Subsequent	0.0025	0.0012

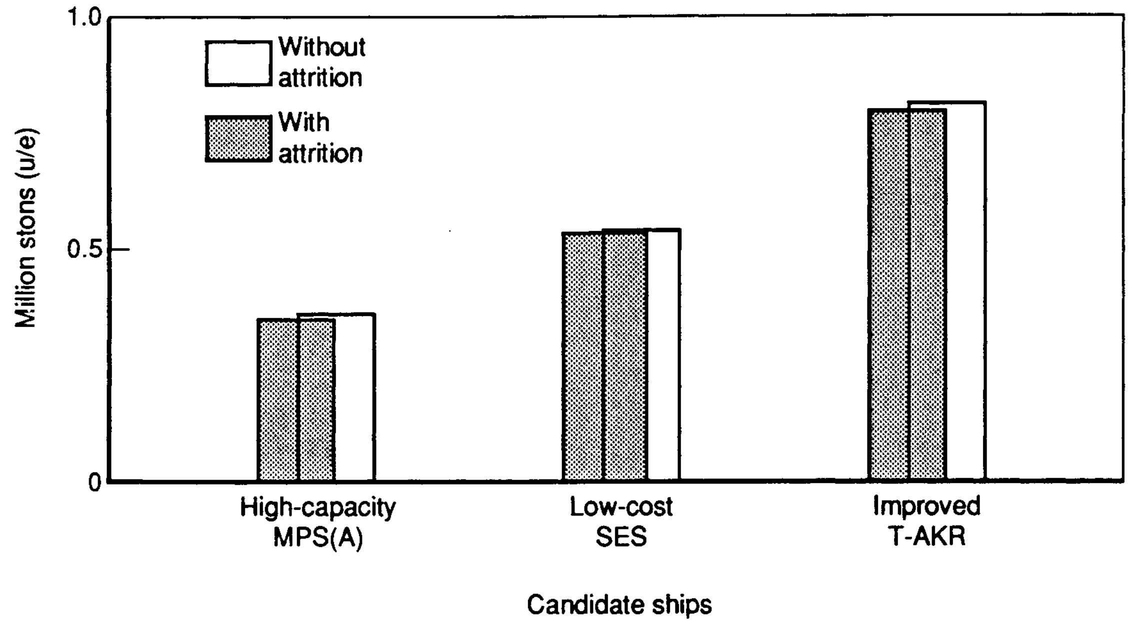

Fig. 10—Cumulative cargo deliveries over 90 days (SWA, zero warning, with and without ship attrition)

PERFORMANCE OF FSS AND MPS(A) CANDIDATES IN DEPLOYMENTS TO ZAIRE

In the hypothetical Zaire scenario, the United States is asked to support local forces with moderate amounts of u/e and forces to assist in putting down an insurgency against the government. The u/e is delivered by FSSs from U.S. East and Gulf coast ports. The distance from these ports to the vicinity of Zaire is roughly 5400 nmi. As previously discussed, MPSs normally deploy in the North Atlantic, in the vicinity of Diego Garcia, and in the Pacific. They are unlikely to be in the vicinity of Zaire under a zero warning scenario. To reflect this condition, we assume that MPS(A) candidates are operating in the North Atlantic in the vicinity of the U.S. East Coast when called to deliver cargo.

Zaire has only three ports: Banana, Boma, and Matadi. Banana is a small port, located just north of the mouth of the Congo River, and cannot accommodate large ships. The other two ports are located approximately 50 and 80 nmi up the Congo River. Navigation of the river is very difficult for large ships because channels are poorly marked and limited in depth and width, there are shifting riverbanks and islands, and

river flows and currents vary widely. The largest ships that routinely travel up the Congo River are less than 600 ft long and draw less than 30 ft of water. Consequently, it is unlikely that any of the FSS and MPS(A) candidates will be able to use these ports to conduct pier-side unloading operations.

In force deployments to Zaire, FSS and MPS(A) forces have to rely on logistics over the shore (LOTS) operations to unload and transfer cargo to shore locations. Typically, LOTS operations require a wide range of equipment, most of which is cumbersome to transport. The major equipment includes

- Calm-water Ro-ro discharge facilities for unloading tracked and wheeled vehicles.
- Conventional landing craft (LCU), lighter air cushion vehicles (LACVs), lighter amphibious resupply cargo vehicles (LARC-LXs), and causeways to transport cargo from anchorages to shore facilities.
- Warping tugs for maneuvering small craft alongside ships or piers.
- Steel piers modified with a series of caissons to create temporary shore reception platforms.
- Truck-mounted cranes, forklift trucks, and rough-terrain container handlers to unload cargo from LCUs and amphibians at shore reception sites.

Zaire maintains a small number of tugs to assist ships in navigating the Congo River. These can be used to support LOTS operations and eliminate the requirement for warping tugs. The port of Banana has a wharf suitable for unloading small craft and sufficient space to support a modest LOTS operation. A dual-lane road connects Banana with Kitona, an airbase located just south of the port, which can be used for in-theater airlift operations to deliver cargo to the interior of Zaire.

In addition, Zaire has a number of cranes and forklift trucks for loading and unloading cargo from ships. Consequently, for the LOTS operation in Zaire, we assume that only calm-water Ro-ro discharge facilities, vessels to transport equipment from anchorages to the wharf, and a small number of cranes and rough-terrain container handlers have to be brought in.

The LOTS equipment can be brought to Zaire by ships particularly configured to carry such cargo—barge ships, lighter aboard ships (LASHs)—or by the FSS and MPS(A) candidates. Existing barge ships and LASHs typically have speeds of 18 knots.

To support timely cargo deliveries from all FSS and MPS(A) forces in short warning scenarios, these ships have to be properly prepositioned. For example, if they happened to be in U.S. ports at the time of call-up, they would arrive after the FSS and MPS candidates.

MPS(A)s carry powered and unpowered causeways to unload cargo at sea. Consequently, they do not require LOTS equipment to make initial deliveries. However, since causeways are relatively slow and limited in range, MPS(A)s bring LACVs and LARC-LXs for subsequent cycles.

In this hypothetical scenario, FSS candidate forces bring calm-water Ro-ro discharge facilities, 20 LACVs, and 10 LARC-LXs to establish LOTS operations. An LACV carries a load of 23 stons at a speed of 22 knots. LARC-LXs carry 60 to 100 stons at speeds of about 6 knots.[5] From ship anchorages approximately 6 nmi from Banana, allowing about 27 minutes for loading and unloading, an LACV can complete a round trip in roughly one hour. Assuming that their loading and unloading time is one hour, LARC-LXs can complete a round trip in roughly three hours. With a vehicle availability of 0.8, we estimate a cargo delivery rate of roughly 15,000 stons of u/e per day. This assumes that LOTS operations are conducted in smooth seas and that LOTS operation set-up takes one day.

Under these conditions, the high-capacity MPS(A) commences delivering cargo two days before the SES and five days before the improved T-AKR (Fig. 11). As in previous scenarios, the improved T-AKRs continue to deliver more cargo over time than the other candidates. Over 90 days, they deliver roughly 1.2 million stons, compared to 1.1 million stons for the low-cost SES and 0.6 million stons for the high-capacity MPS(A). The difference in performance between the improved and baseline T-AKRs and low-cost SESs is very small.

PERFORMANCE OF FSS AND MPS(A) CANDIDATES IN DEPLOYMENTS TO THAILAND

In the postulated Thailand scenario, the United States agrees to assist local forces by providing combat support equipment and supplies. No U.S. force deployments are envisioned in this scenario. Under these conditions, MPS(A)s carrying u/e are not likely

[5]DoD Joint Test Director, *Joint Logistics Over-the-Shore II Analysis and Evaluation Report*, August 1985, pp. 2-42 and 2-43.

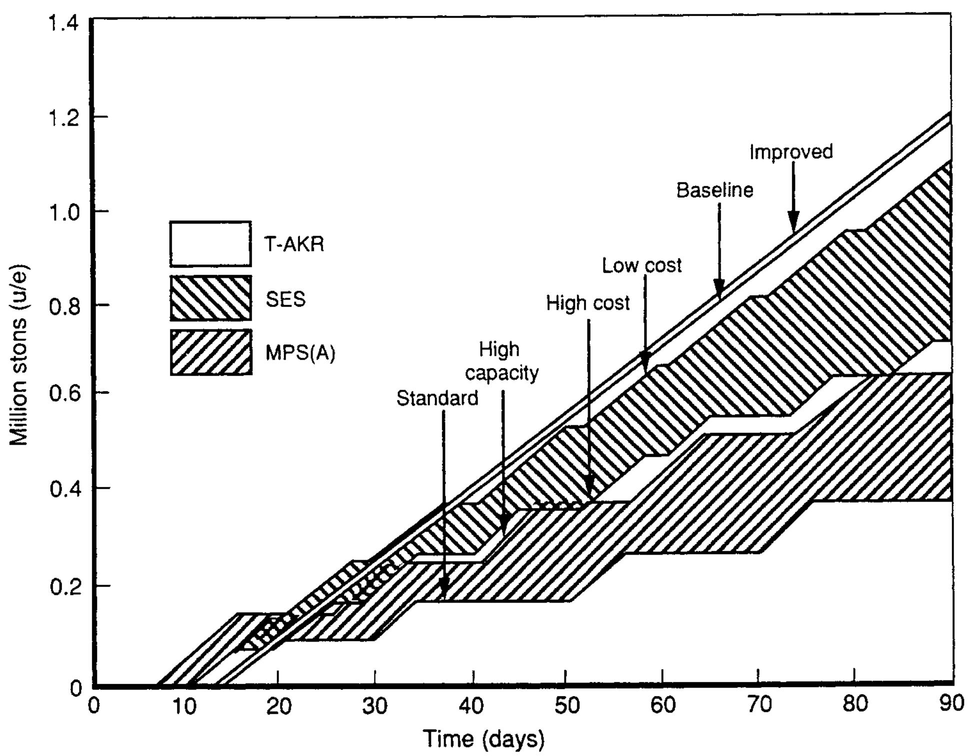

Fig. 11—Performance of FSS and MPS(A) candidates (Zaire, zero warning, no ship attrition)

to be employed. To participate in the scenario, MPS(A)s would have to proceed to U.S. ports, unload u/e and associated resupplies, load specific material required in Thailand, and then travel to SPODs. In these conditions, existing merchant ships would outperform MPS(A)s. One might consider the use of a concept similar to the APS force, but uncertainties about the type of cargo to be loaded argue against the design of maritime prepositioning concepts to support local forces of specific countries.

The distance from ports on the U.S. West Coast to Thailand is roughly 8000 nmi. Thailand has seven ports of various sizes that routinely support moderate-size ships with drafts of up to 30 ft. They do not have channels or piers with sufficient depth to accommodate T-AKRs. However, unlike Zaire, Thailand appears to have sufficient lighters to permit T-AKRs to unload cargo at anchorages without the use of LOTS equipment. Under these conditions, we estimate that T-AKRs can deliver roughly 25,000 stons of cargo per day.

Three ports in Thailand (Bangkok, Sattahip, and Sonkhla) have adequate channel and pier depths to permit SESs operating on air cushion to unload cargo in port. The available pier space can accommodate up to 13 SESs at any one time. In operations to these ports, we estimate that each SES requires roughly one day to enter port, unload, and clear the harbor. Thus, it takes two days to completely unload each candidate SES force.

The SESs commence delivering cargo to Thailand in 12 days, at a rate two times that of the T-AKRs (Fig. 12). The T-AKRs commence delivering cargo five days later than SESs. However, in 90 days, the improved T-AKR delivers approximately 0.16 million more stons than the low-cost SES.

FSS AND MPS(A) CANDIDATES IN RESUPPLY OPERATIONS

After delivering u/e, all ships would be called upon to support resupply operations. It is important to understand how the performance of the different types of ships might vary in such operations and establish whether specific features can be incorporated into their design to facilitate this role.

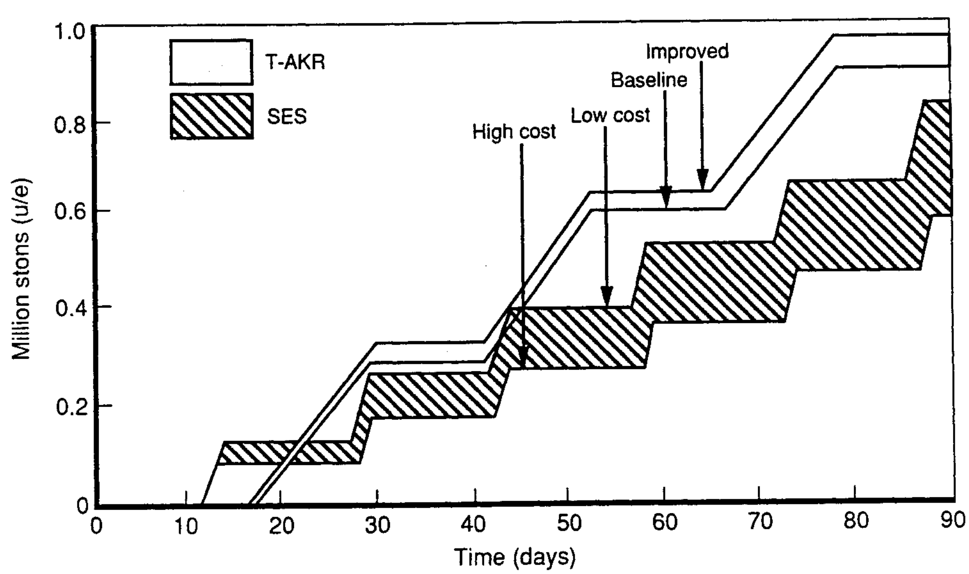

Fig. 12—Performance of FSS candidates (Thailand, zero warning, no ship attrition)

To carry large quantities of u/e, FSSs are designed as Ro-ro ships with large internal spaces and minimum vertical obstructions. Their tie-down systems consist primarily of deck chocks and adjustable chains. This configuration is not well suited for the transport of breakbulk and palletized cargo. However, the ships can be effective in resupply operations if the cargo is containerized.

Adequate access for loading and unloading containers can be included in the design of FSSs. Hinged flat deck hatches can be built to permit over-the-top handling of containers with pier-side or shipboard cranes. Another way is to provide adequate-size Ro-ro ramps and ship openings with sufficient vertical clearances to drive chassis with containers on board. The tie-down system could include provisions for erectable container-securing posts or guides.

MPS(A) candidates are configured to carry substantial quantities of resupplies. This capacity was not included in the assessment of candidate forces in u/e deliveries. In resupply operations, this capacity would be available. As a consequence, MPS(A)s would be more productive for resupplies than for u/e deliveries.

Conventional monohull ships (T-AKRs and MPSs) have limited space in which to carry u/e, and consume available volume before reaching maximum weight limits. In resupply operations, where the weight per unit volume of cargo is greater than for /ue, they can carry more tons of resupplies. The catamaran hull of an SES provides ample space for transporting u/e but is weight limited. Consequently, SESs in resupply operations carry the same weight of cargo as in force deployment.

However, because of their higher speed, SESs might be more important in responsive resupply operations. They may be used to transport time-sensitive supplies when airlift is not available or when the cargo is not suitable for airlift. Also, SESs provide increased flexibility for reassignments of SPOEs and SPODs within their unrefueled range. This approach might be used to reduce port congestion and smooth cargo flows.

PERFORMANCE SUMMARY

The performance analysis of the enhanced sealift candidates indicates that the preferred conventional monohull FSS candidate is the 33-knot improved T-AKR. It outperforms the baseline T-AKR across all tested scenarios, and outperforms the SES in all but the most time-critical scenarios. With zero warning, the improved T-AKRs in

ROS can deliver first cargo to Europe in 12 days, to SWA in 22 days, to Thailand in 17 days, and to Zaire in 14 days. In each of these scenarios, the improved T-AKR delivers more cargo than any other fast sealift or maritime prepositioning candidate over 45, 60, and 90 days.

The SES candidate offers moderate improvement in response time over the improved T-AKR, but at a cost of reduced capacity. With zero warning, the SESs in ROS deliver first cargo to Europe in 9 days, to SWA in 15 days, to Thailand in 12 days, and to Zaire in 10 days. This translates to initial cargo deliveries three to seven days earlier than the improved T-AKR. However, the SESs (low cost) deliver 24 percent less cargo to Europe, 33 percent less cargo to SWA, 9 percent less cargo to Zaire, and 17 percent less cargo to Thailand over 90 days than the improved T-AKRs.

Performance results also indicate that the preferred MPS(A) candidate is the high-capacity MPS(A). When moved to the contingency area on warning, it outperforms the standard and new-design variants across all tested scenarios. With zero warning, the high-capacity MPS(A) in active status delivers initial cargo to Europe in four days, to SWA in five days, and to Zaire in eight days. This translates to initial cargo deliveries two to ten days earlier than the SES. The penalty for this rapid response is the added cost of maintaining the ship in an active operating regime and the cost of procuring an extra set of u/e for storing on board. Because of these added costs, the high-capacity MPS(A) delivers substantially less cargo over 90 days than the improved T-AKR or the SES (low cost).

For most circumstances, the improved T-AKR appears attractive. As warning time increases, the advantages of the SES and high-capacity MPS(A) candidates decrease—these options provide earlier initial cargo deliveries than the improved T-AKR, but at the cost of total throughput over time. Assuming that early deliveries by sea are less valuable in the future and that the demand for total cargo deliveries remains constant, the improved T-AKR's advantages increase.

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