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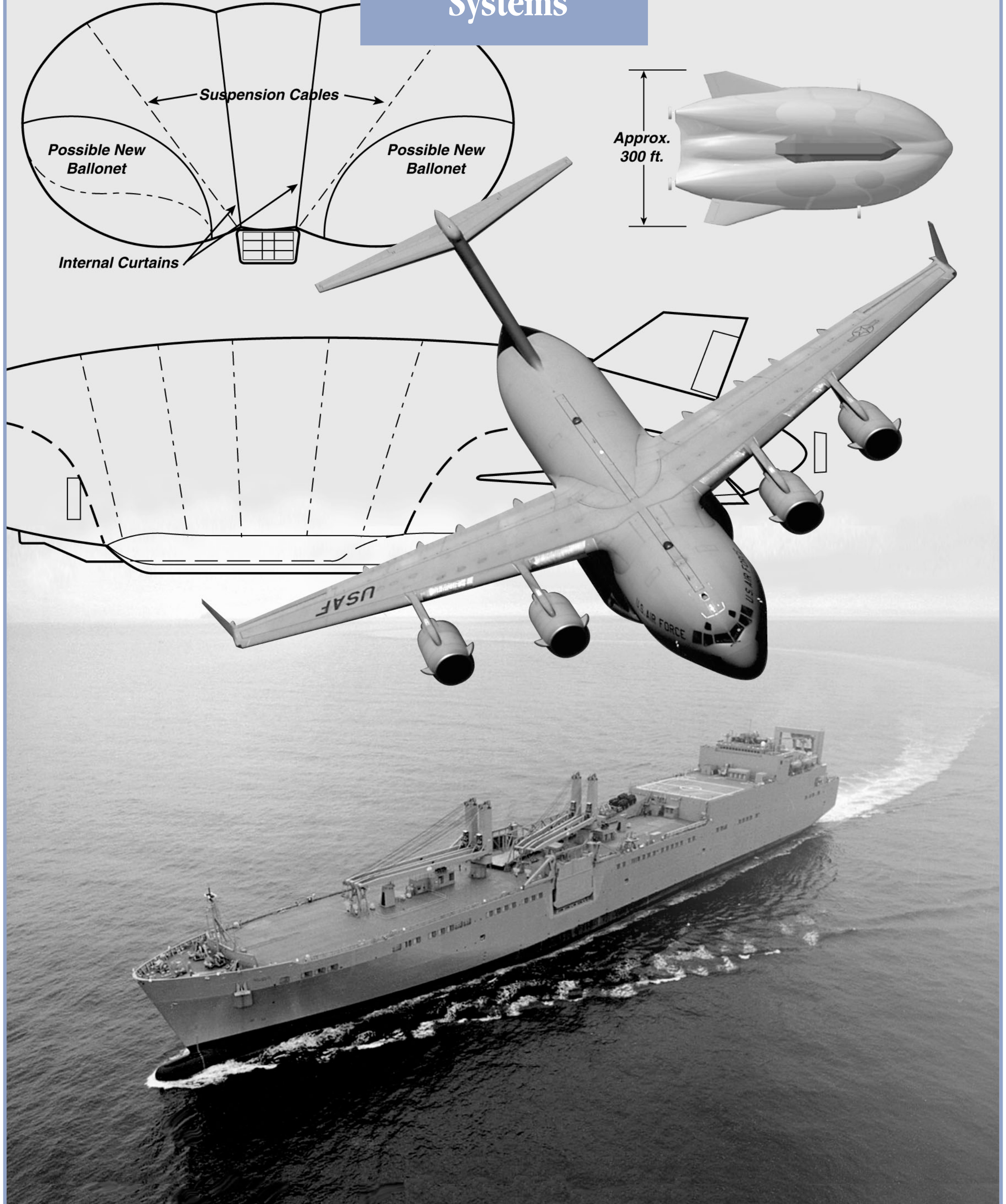
Options for Strategic Military Transportation Systems



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The Congress of the United States ■ Congressional Budget Office

Notes

Unless otherwise indicated, all cargo weights mentioned in this report are in short tons; the years referred to in the appendix are fiscal years,

Numbers in the text and tables may not add up to totals because of rounding.

On the cover, the drawings of the conceptual airship are from the Naval Air Systems Command; the photograph of the C-17 airplane was taken by Staff Sgt. Sean M. Worrell, U.S. Air Force; and the photograph of the large, medium-speed roll-on/roll-off ship is from the Military Sealift Command.

Preface

The Administration's strategy for national defense emphasizes the ability to respond rapidly to military crises wherever they might arise. To that end, the Department of Defense (DoD) is pursuing a variety of initiatives designed to reduce the time necessary to deploy combat forces around the world. Those initiatives include ongoing production of C-17 transport aircraft by the Air Force, development of concepts for the sea basing of military forces by the Navy and Marine Corps, and development of lighter, more easily transportable combat vehicles by the Army as part of its Future Combat Systems program.

This Congressional Budget Office study—prepared at the request of the Readiness Subcommittee of the House Committee on Armed Services—looks at the technical, operational, and cost issues associated with alternative transportation systems that DoD might develop and procure to reduce the time needed to deploy forces. The study compares the advantages, disadvantages, and costs of six transportation alternatives: four that would use existing technologies and two that would develop more-advanced systems. In keeping with CBO's mandate to provide objective, impartial analysis, this study makes no recommendations.

David Arthur of CBO's National Security Division wrote the study under the supervision of J. Michael Gilmore. Raymond Hall of CBO's Budget Analysis Division, with assistance from David Newman and Jason Wheelock, prepared the cost estimates and wrote the appendix under the supervision of Jo Ann Vines. Craig Cammarata, Robert Dennis, and Adebayo Adedeji of CBO provided thoughtful comments on earlier drafts, as did Robert Button of RAND Corporation. (The assistance of an external participant implies no responsibility for the final product, which rests solely with CBO.)

Christian Spoor edited the study, and John Skeen proofread it. Cynthia Cleveland produced drafts of the tables. Maureen Costantino, along with Andrew Hemstreet of Art Services, Inc., designed the cover. Lenny Skutnik printed the initial copies, and Simone Thomas and Annette Kalicki prepared the electronic version for CBO's Web site (www.cbo.gov).

Douglas Holtz-Eakin
Director

September 2005

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Summary

Since the end of World War II, the United States has maintained the ability to project combat power rapidly around the globe. That ability has been achieved through a dual approach: "forward basing" units overseas in regions of particular importance and fielding long-range (strategic) transportation systems that can move forces around the world quickly, either to reinforce the forward-based units or to respond to needs that arise elsewhere.

Following the Cold War, emphasis has shifted away from forward basing and toward increasing the mobility of forces based in the United States. In the past 15 years, the U.S. military has cut the number of forward-based troops by about half and has improved its strategic transportation capability by fielding such systems as C-17 airlift aircraft and large, medium-speed roll-on/roll-off ships (LMSRs) for sealift. In addition, the Army is largely focusing its current "transformation" efforts on changing equipment and organization to create units that can be deployed more quickly and easily. Nevertheless, officials in the Department of Defense (DoD) seek to increase the speed of military deployments to an even greater degree, because the ability to deliver forces to a distant theater in the first few days or weeks of a crisis is seen as critical to ensuring a favorable outcome.

Several general approaches exist for speeding up the U.S. military's response to crises, such as:

- Better matching the locations of forward bases to locations where conflicts are likely to arise,
- Redesigning ground combat and support units and their equipment to make them easier to transport, and
- Improving strategic transportation forces.

Previous studies by the Congressional Budget Office (CBO) have analyzed the first two approaches and concluded that they would reduce the deployment times of large forces to only a limited extent.[1] This study looks at the third approach; it analyzes how potential changes in strategic mobility forces could speed the deployment of ground troops and equipment to a distant theater early in an operation.

Today's strategic transportation forces have three main components: airlift aircraft, surge sealift ships, and afloat prepositioned equipment (see Summary Table 1). The latter consists of equipment for Marine Corps or Army units that is kept on ships stationed at forward locations—such as ports on the Mediterranean Sea, the island of Guam in the western Pacific Ocean, and the island of Diego Garcia in the Indian Ocean—which are closer than U.S.-based ships to many regions where military forces might be needed.

This study analyzes six options for improving today's strategic mobility forces. Four of the options would purchase greater quantities of existing systems: C-17 airlift aircraft, LMSRs, and equipment for afloat prepositioning forces. To examine the potential benefits of new technologies, the other two options would develop new systems: large, blimp-like airships capable of transporting heavy loads of cargo, and high-speed sealift ships. CBO selected the number of systems that would be purchased in each option so that all of the alternatives would have similar total costs over a 30-year service life (see Summary Table 2).[2] This analysis focuses on how the options would affect

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[1] See Congressional Budget Office, *Options for Changing the Army's Overseas Basing* (May 2004) and *Options for Restructuring the Army* (May 2005).

[2] CBO chose to create options with similar costs and compare their capabilities rather than define a target capability and compare the costs of achieving it because of uncertainty about what capabilities DoD will desire for its future mobility forces. Several DoD studies are currently examining that issue.

Summary Table 1.

The Size of Current Strategic Transportation Forces

	Quantity
Airlift Aircraft	
C-17s	180 [a]
C-5s	126
KC-10s	59
Civil Reserve Air Fleet	
Cargo aircraft	More than 100 [b]
Passenger aircraft	More than 100 [b]
Surge Sealift Ships	
Fast sealift ships	8
Large, medium-speed roll-on/roll-off ships	11
Other roll-on/roll-off ships	31
Other	27
Afloat Prepositioning Ships	
With Marine Corps equipment	16
With Army equipment	10 [c]
With other sustainment supplies	9

Source: Congressional Budget Office.

a. The 180th C-17 will not be delivered until around 2010.

b. Quantities vary as participation in the Civil Reserve Air Fleet varies.

c. Eight large, medium-speed roll-on/roll-off ships and two container ships.

the "promptness" of the transportation force (its ability to get cargo to a distant theater in the initial days of a deployment), its "throughput capacity" (the amount of cargo transported over time), and the extent to which its ability to deliver cargo could be hurt by limitations on infrastructure at air bases or seaports at the destination site.

Within the context of similar cost levels, CBO's analysis of the options points to several general conclusions:

- Prepositioning sets of unit equipment offers greater improvements in the promptness of cargo deliveries than the other options that CBO examined. Prepositioned ships have much larger payloads than aircraft do, and they arrive more quickly than ships sailing from the United States because they avoid lengthy loading times and travel shorter distances. The use of prepositioned equipment can be delayed, however, if adequate port facilities are not available for unloading the ships.

- Increasing the number of existing ships and aircraft (LMSRs and C-17s) would offer very limited improvements in the promptness of unit deliveries during large deployments. Although LMSRs are faster than many of the other ships in the current sealift force, they still need more than three weeks to reach destinations on the other side of the globe, such as the Persian Gulf. Aircraft offer rapid delivery of individual loads, but any attempt to significantly increase their total cargo deliveries to a distant theater would probably be hampered by constrained infrastructure at airfields, which is anticipated for many, if not most, future conflicts.[3]

- Heavy-lift airships and high-speed sealift ships would have a promptness and throughput capacity intermediate between those of existing airlift and sealift forces. Initial airship deliveries would occur earlier, but the later-arriving high-speed ships would deliver substantially greater amounts of cargo.

- Airships would be virtually independent of air bases and would be well suited to deliver combat-ready troops, along with their vehicles and other equipment, directly to their destination. (With current mobility forces, by contrast, troops and equipment usually travel separately.) Delivering fully equipped units straight to their destination would reduce the time that units typically spend between arriving in a theater and beginning operations. High-speed ships could be designed to be less dependent on seaports and to transport cargo and passengers together, but such capabilities would probably result in higher costs for a given amount of throughput capacity.

The Capabilities of Today's Strategic Transportation Force

To provide a basis with which to compare the options, CBO assessed the throughput capacity of the current mobility systems that are most critical to deploying ground forces early in a crisis: strategic airlift, roll-on/roll-off ships (RO/ROs), and Marine Corps and Army preposi-

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[3] The observation that more C-17s would offer little improvement in the context of a large deployment to a single theater does not imply that more C-17s would not be useful to support the military's broader worldwide demands for airlift aircraft.

Summary Table 2.

Options for Expanding Strategic Transportation Forces

	Key Characteristics	Production Considerations	Total Investment and Operating Costs (Billions of 2006 dollars)[a]
	Airlift		
Option 1A: Buy 21 Additional C-17 Aircraft	Average payload: 45 tons Average speed: 410 knots Range: 3,200 nm	Continued production of existing design	11.3
Option 1B: Develop and Buy 14 to 16 Heavy-Lift Airships	Payload: 500 tons Speed: 100 knots Range: 6,000 nm	Concept never demonstrated at that size; component technology exists, but large-scale integration of it is unproven	11.3
	Surge Sealift		
Option 2A: Buy 17 Additional LMSRs	Payload: 380,000 sq ft or 18,000 tons Speed: 24 knots Range: 10,000 nm Power: 64,000 horsepower	Additional production of existing design	11.3
Option 2B: Develop and Buy Six Advanced-Technology High-Speed Sealift Ships	Payload: 200,000 sq ft or 10,000 tons Speed: 45 knots Range: 5,000 nm Power: 335,000 horsepower	Design is beyond state of the art, requiring advanced materials, hull design, and water-jet technology	11.1
	Afloat Prepositioning		
Option 3A: Buy Four Sets of Stryker Brigade Equipment and Four LMSRs	Speed: 24 knots Based close to anticipated conflicts	Continued production of existing ships and Army equipment	11.4
Option 3B: Buy Five Sets of Stryker Brigade Equipment and Store Them on Existing LMSRs	Speed: 24 knots Based close to anticipated conflicts	Use or continued production of existing ships and Army equipment	11.1

Source: Congressional Budget Office.

Note: nm = nautical miles; LMSR = large, medium-speed roll-on/roll-off ship; sq ft = square feet.

a. Includes costs for research and development (if necessary), procurement, and 30 years of operations and support (after delivery of the option's first aircraft or ship), over and above the costs needed to maintain current strategic mobility capabilities.

tioned forces.[4] CBO did not use a specific planning scenario for its assessment, but it chose deployment distances similar to those expected for a scenario set in the Persian Gulf or Indian Ocean—7,000 nautical miles (nm) by air and about 10,000 nm by sea from the United States—for its base-case calculation of cargo deliveries. Such distances represent about the longest possible on the globe, thus allowing alternative mobility forces to be compared under stressing circumstances. (As part of its analysis, CBO explored how sensitive the results of its calculations were to the assumptions of the base case.)

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[4] The assessment did not explicitly consider other transportation systems, such as container ships, which are used primarily to bring sustainment supplies to units already operating in a theater. Such systems are more easily obtained from the commercial sector (for example, through emergency charters) than are the specialized vehicle carriers that are preferable for transporting unit equipment.

If adequate support infrastructure was available at the destination, the current transportation systems described above would be able to deliver an average of about 30,000 tons of cargo each day to the notional theater over the first 60 days of a large deployment, although deliveries during the first week to 10 days would be substantially below that average (see Summary Figure 1). Airlift aircraft would start arriving after one or two days and would deliver cargo at a relatively steady rate (the smoothly increasing wedge for airlift in Summary Figure 1 reflects many individual aircraft with small loads rapidly cycling through the delivery system). Sealift arrivals would come in surges. Ships carrying prepositioned equipment would arrive soonest, beginning on day 6, because they are kept in a higher state of readiness and have much shorter distances to travel than sealift ships based in the United States. The fastest sealift vessels (fast sealift ships and LMSRs) would arrive next, on about day 21. Finally, the slower RO/ROs in the Ready Reserve Force would begin making deliveries around day 35. That throughput would be reduced if the transportation systems were slowed by infrastructure constraints such as inadequate airfields or port facilities.

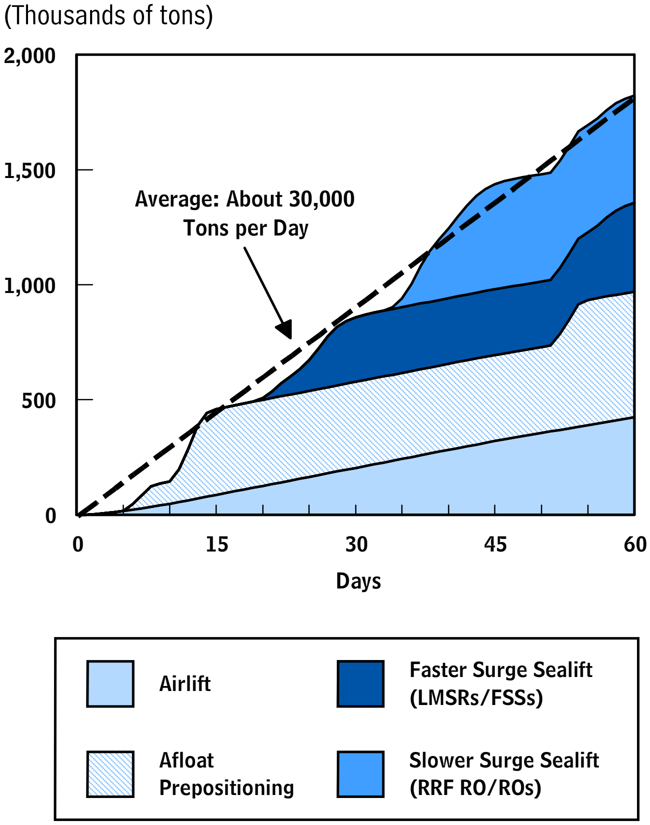
Whether those delivery rates meet DoD's requirements depends on the outcomes of ongoing DoD studies of requirements for mobility capability. Previous requirement studies have generally concluded that a shortfall exists in the ability to deliver cargo in the early days of a deployment but that after several weeks, the throughput capacity of the strategic transportation system catches up with the stated delivery requirements.

Options for Improving Strategic Transportation

The alternatives for improving strategic transportation in this analysis focus on approaches that would increase deliveries in the initial days of a deployment. CBO examined six options, two each for airlift, sealift, and afloat prepositioned forces. The options, which would add to the existing strategic transportation forces, were sized to cost a total of about $11 billion in 2006 dollars for research and development (if any), procurement, and 30 years of operations once the first new system had been delivered.[5] (By comparison, DoD has spent an average of about $12 billion *per year* on all strategic transportation programs and activities over the past two decades, according to data in the 2006 Future Years Defense Program.)

Summary Figure 1.

Cargo Delivery Capability of Current Mobility Forces



Source: Congressional Budget Office.

Notes: This notional delivery scenario assumes a theater of operations in the Persian Gulf or Indian Ocean region with no constraints on infrastructure in the theater. Surge sealift in this figure includes only roll-on/roll-off ships.

LMSR = large, medium-speed roll-on/roll-off ship; FSS = fast sealift ship; RRF = Ready Reserve Force; RO/RO = roll-on/roll-off ship.

The estimated costs for those options represent incremental spending in addition to the spending necessary to maintain and operate the current strategic mobility forces.[6]

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[5] The figure of $11 billion results from the need to have a whole rather than a fractional number of prepositioned units (four in Option 3A and five in Option 3B). Those units are the most expensive system, per increment of capability provided, in CBO's analysis.

[6] The improvements offered by the options might enable DoD to retire some of today's older, slower systems, but CBO did not assume such savings in its estimates of the costs of the options.

The first airlift option (1A) would purchase 21 additional C-17 aircraft like those already in DoD's inventory. The second airlift option (1B) would be more innovative: it would develop and buy 14 to 16 heavy-lift airships similar to concepts being explored by the Defense Advanced Research Projects Agency under the Walrus program and by the Naval Air Systems Command. The notional airship in Option 1B would carry more than 10 times the average payload of a C-17 but would travel at only one-fourth the speed (see Summary Table 2). Lift would be generated both by the buoyant force of the helium inside the airship and by the airfoil shape of the airship's hull, which would act like a wing when the craft was moving forward. That hybrid design would eliminate the need for large transfers of ballast during loading and unloading and would make the airship easier to handle on the ground. High winds could still present problems, however.

The sealift alternatives also offer a choice between existing and conceptual systems. Option 2A would buy 17 additional LMSRs; Option 2B would develop and procure six high-speed sealift (HSS) ships that would have only half the range and cargo capacity of an LMSR but almost twice the speed. Proposals have been advanced for sealift ships with speeds as high as 75 knots (nautical miles per hour), but the technology needed to realize such performance is well beyond today's state of the art. The speed of the notional HSS ship in Option 2B—45 knots—would also be very technically challenging for so large a vessel. However, that HSS ship would offer substantial improvements over current sealift ships without the greater technical and cost risks inherent in an even more advanced design.

Compared with the approaches that would use existing systems, the options to develop a heavy-lift airship or a high-speed sealift ship would take advantage of modern and emerging technologies but would be subject to greater uncertainty about technical feasibility, operational performance, and cost.

The last two options would preposition additional equipment for the Army's new medium-weight Stryker brigade combat teams (BCTs). Option 3A would buy four sets of Stryker BCT equipment and four LMSRs to store them on. Option 3B would purchase five such unit sets but keep them on existing LMSRs, which would be taken from the surge sealift fleet.

Comparison of the Options' Capabilities

Although all of the options analyzed in this study could improve the strategic mobility force, each alternative offers a distinct combination of operational capabilities relative to those of today's force. The primary capabilities—promptness, throughput capacity, and dependence on support infrastructure—are discussed below. (Other factors, such as the potential impact that an option might have on efforts to modernize the current force, are described in Chapter 4.)

Promptness and Throughput Capacity

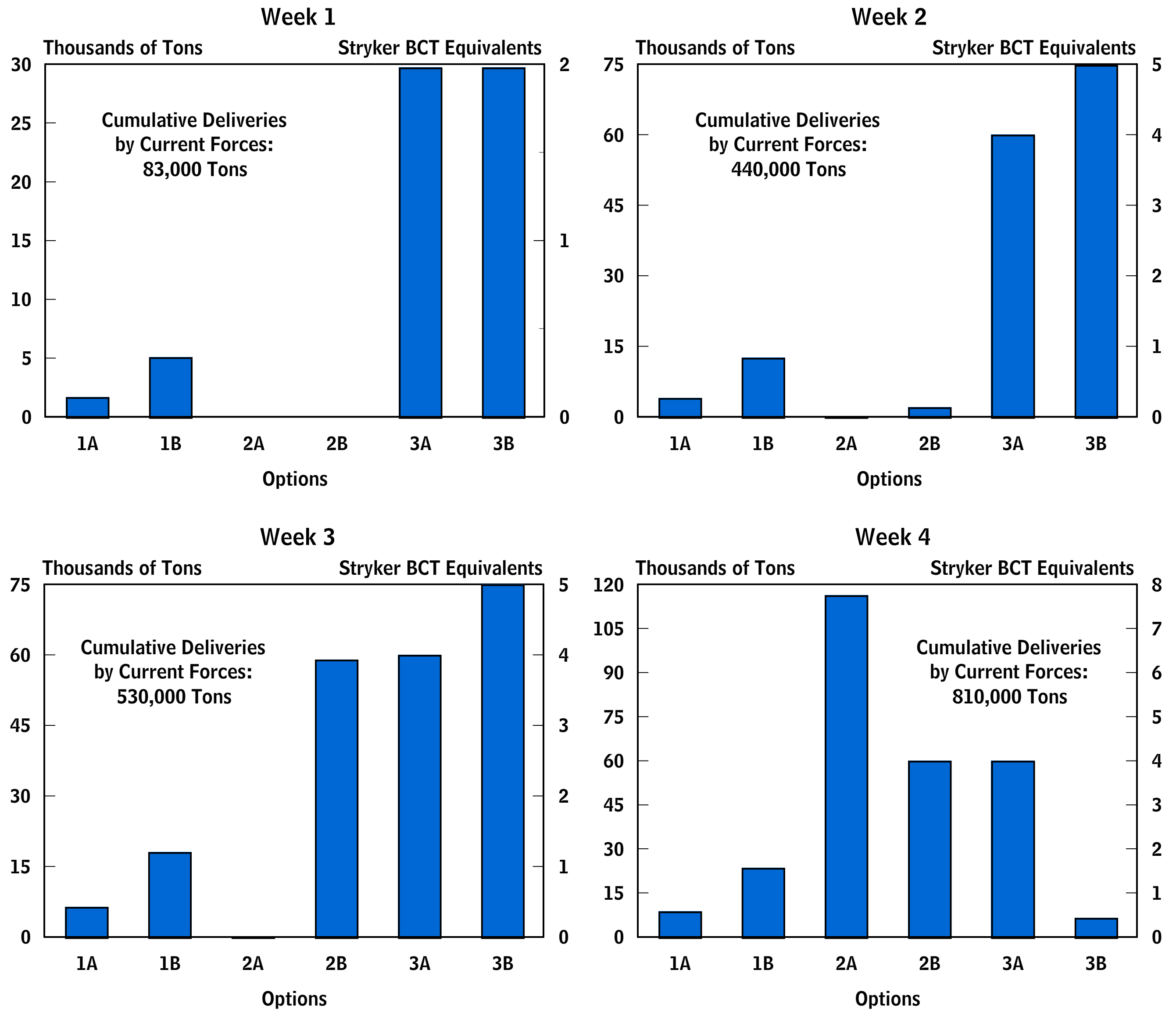
Constraining each option to have roughly equal costs results in very different improvements in promptness and throughput capacity (see Summary Figure 2).

The alternatives for afloat prepositioning would offer both an improvement in promptness and a relatively large improvement in capacity over the base case. By the end of the first week of operations, Options 3A and 3B would have delivered two of their sets of Stryker BCT equipment, with the remainder arriving before the end of the second week. That promptness would come at the expense of some flexibility, however, because the equipment to be delivered would have been determined before the specifics of a conflict could be known. Option 3A would increase the overall throughput capacity of the transportation force because it would purchase both ships and equipment for prepositioning. Option 3B would not increase overall capacity because its ships would be drawn from the surge sealift force. Instead, that option shifts deliveries to earlier in the representative scenario. The advance in deliveries early in the scenario under Option 3B begins to shrink relative to the base case during the fourth week because the extra arrivals of prepositioned equipment early in the scenario would be offset by the corresponding reduction in arrivals by the now-smaller surge sealift force.

The airlift options (1A and 1B) would also increase cargo deliveries in the first week, but that cargo could be tailored to the specific situation. The airship option (1B) would deliver cargo at rate nearly three times greater than that of the C-17 option. Both options' deliveries, however, would be much smaller overall than those of the prepositioning alternatives. For example, by the end of the fourth week, airship deliveries would approach the

Summary Figure 2.

Increases in Cargo Deliveries, by Week, Under Various Options



Source: Congressional Budget Office.

Notes: This notional delivery scenario assumes a theater of operations in the Persian Gulf or Indian Ocean region with no constraints on infrastructure in the theater. The numbers shown here are increases beyond the capability of current mobility forces. Note that the scale of the y axes changes with each week as more cargo accumulates in the theater. Only about half of the LMSRs under Option 2A have arrived at the end of the fourth week.

Option key:
1A---Buy 21 additional C-17 aircraft
1B---Develop and buy 15 heavy-lift hybrid airships
2A---Buy 17 additional LMSRs
2B---Develop and buy six advanced-technology high-speed sealift ships
3A---Buy four sets of Stryker brigade equipment and four LMSRs on which to preposition it
3B---Buy five sets of Stryker brigade equipment and preposition it on five LMSRs from the existing surge sealift force.

BCT = brigade combat team; LMSR = large, medium-speed roll-on/roll-off ship.

amount delivered by the prepositioning options (3A and 3B) in the first week.

Of the sealift options, the high-speed ships in Option 2B arrive by the end of the third week with slightly less cargo than prepositioning option 3A provided. The LMSRs in Option 2A would arrive last (during the fourth week), but with far more cargo than transported under the other options.

The promptness of those options depends on the performance characteristics of each system. Throughput capacity, in turn, depends both on promptness and on the number of systems purchased. If there are no constraints on support infrastructure, purchasing greater quantities of a system can increase throughput capacity. But promptness limits that approach for boosting throughput capacity, because having an unlimited number of aircraft or ships will not increase the speed with which the first ones arrive in a theater. The relative value of promptness versus throughput capacity—and hence the types and quantities of strategic transportation systems that the military might choose to buy—will depend on DoD's determination of its plans and requirements for responding to future crises.

The relative performance of the six options would be essentially the same under a wide range of deployment distances from the United States. At the distances assumed in the base-case scenario (7,000 nm for airlift aircraft and 9,900 for sealift ships), a Stryker BCT prepositioned afloat no farther than 6,000 nm from its destination—a distance that would represent a poorly selected location for a prepositioned force—would arrive in about 14 days: less time than under any of the options that would leave from the United States. The airship and high-speed-ship options would deliver the same amount of cargo a few days later. Those two options would compete favorably with a prepositioned force located at 6,000 nm for shorter deployment distances from the United States, but better prepositioning locations (say, 4,000 nm or 2,000 nm away) would negate that advantage (see Summary Figure 3). The extra aircraft or ships transporting forces from the United States in Options 1A and 2A would not compete favorably with even the poorly located prepositioned force unless the transit distances from the United States were about one-third of those to the Persian Gulf or Indian Ocean region.

Reliance on Support Infrastructure

The delivery results discussed above are based on the assumption of an unconstrained support infrastructure at the destination site. The strategic transportation system would not be able to realize that full potential if it was limited by air-base or seaport constraints. The availability of such facilities can vary widely. For example, the large seaports and spacious airfields in Saudi Arabia are favorable for deployments. At the other extreme, Afghanistan has a limited number of air bases and no seaports; cargo sent there by ship would have to travel an additional distance by air or land through another country. Rather than select some arbitrary level of infrastructure for its scenario, CBO assessed each option's dependence on infrastructure in terms of how the option would alter the need for support relative to that of the base-case force.

Option 1A, which would buy additional C-17s, would require about 3 percent more airfield infrastructure than needed by the airlift force in the base case. However, the need for airfield infrastructure in the base case is already quite high. For example, CBO estimates that the base-case airlift force would require about 40 percent more infrastructure capacity than was available during Operation Desert Shield in the Arabian Peninsula. If the base-case airlift force was constrained with regard to the infrastructure available, its throughput capacity would be lower than estimated here, and the additional aircraft under Option 1A would produce little or no improvement.

The heavy-lift airship option (1B) would have the least impact on the demand for infrastructure. Under proposed designs, the airship would be able to operate from open areas only about two to three times its size. It would not require a runway upon arrival in the theater, and the roll-on/roll-off design of its cargo bay would minimize the need for cargo-handling equipment.[7] Besides not competing with other aircraft for airfield support, that independence would give commanders greater flexibility to choose where forces would be delivered. Such flexibility would typically offer the advantage of decreasing the time between when a unit was delivered to a theater and when it finally reached its assigned area of operations. Depend-

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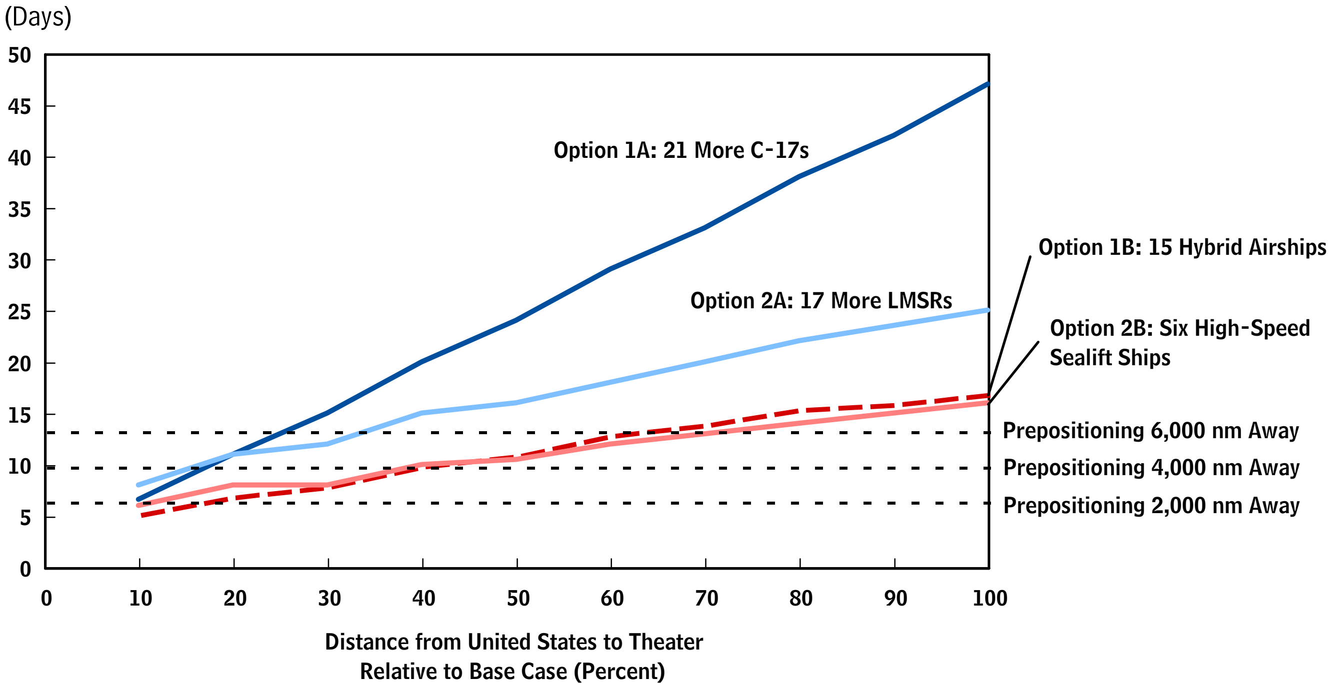
[7] An airship would require a much larger open area at its loading site, because a fully loaded and fueled airship would need the aerodynamic lift from a takeoff run to get airborne. Less lift (and hence less speed) would be needed for landing because fuel would have been burned during transit. Once unloaded, the airship could take off almost vertically.

Summary Figure 3.

Time Needed to Deliver First Additional Stryker Brigade Combat Team at Various Deployment Distances



Source: Congressional Budget Office.

Notes: The transit distances assumed in the base-case deployment scenario are 7,000 nm for C-17s; 8,500 nm for airships; and 9,900 nm for LMSRs and high-speed sealift ships.

LMSR = large, medium-speed roll-on/roll-off ship; nm = nautical miles.

ing on the scenario, a unit might need several days to assemble and then move (or be moved) to its final destination. An airship's ability to deliver cargo regardless of airbase or port locations could help reduce that time. In such a situation, the airship option would be, in effect, more prompt relative to the other options than is shown here. However, factors such as the airship's vulnerability to enemy fire would remain a consideration.

Like Option 1A, the sealift and afloat prepositioning options would increase the demand for support infrastructure (in this case, seaports). The average need for port support, as measured by the number of ships in port over time, would rise by about 25 percent during the first 60 days of an operation under Option 2A and by about 10 percent to 20 percent under the other sealift and prepositioning options. Unlike with air-base support, however, the demand for port infrastructure is uneven over time because ships arrive less frequently. Consequently, although those options would result in a higher *average* demand, only Options 2A and 3B would have a *peak* demand for port infrastructure that exceeded that in the base case (by one ship on one day and two ships on two days, respectively).

Of course, some situations could arise in which the available infrastructure would not accommodate either the base-case transportation force or the additions to it envisioned under these options. A new sealift ship designed to fit into smaller ports or to operate independently of ports could mitigate some constraints, but such a ship would have a smaller payload and higher cost than current ships. Alternatively, the Navy and Marine Corps are developing sea-basing concepts that would involve transferring cargo and personnel at sea from large strategic transports to smaller intratheater systems capable of operating without support infrastructure. Those plans are still in the early stages of concept definition.

CHAPTER

1

Today's Strategic Transportation Capabilities

The United States maintains considerable capabilities to transport its military forces to distant locations. Even so, the Department of Defense (DoD) seeks to improve those strategic transportation capabilities, particularly the promptness with which units can be moved to their destinations.[1] The experience of Operations Desert Shield and Desert Storm in 1990 and 1991 led many planners to conclude that the ability to deploy units more rapidly would be needed because a future adversary would be unlikely to permit a lengthy buildup of U.S. forces, as Iraq did then. Today's focus on military "transformation" has further emphasized the desire for rapid deployments, because the proposed shift to smaller, lighter networked units places a premium on getting them to their destinations as early as possible so their firepower or other capabilities can be applied quickly and decisively.

This Congressional Budget Office (CBO) study looks at the potential operational effectiveness and costs of various options for expanding strategic mobility forces to speed up the deployment of military units. The study considers improvements that might result from purchasing additional transportation systems—either existing types or newly designed, better-performing types—as well as improvements that could stem from changing the ways in which existing forces are used.

The Evolution of U.S. Strategic Transportation Forces

After World War II, the United States' desire to help reestablish and maintain international stability resulted in greater global military commitments than ever before. The most notable was the commitment to defend Western Europe against a possible Soviet invasion, but smaller events, such as the blockade of West Berlin and North Korea's invasion of South Korea, illustrated how the need for military forces could occur with little warning almost anywhere in the world. The U.S. military's previous practice—deliberately mobilizing units based in the United States and then transporting them to a conflict by ship—was seen as no longer adequate to address needs for military forces that planners thought might arise.

The United States oriented its military posture, and fielded transportation forces, accordingly. First, substantial combat forces were forward deployed to counter what were thought to be the most likely or most serious threats. The largest contingents were placed in Europe, where more than 300,000 U.S. personnel were based through the 1980s, and in East Asia and the Pacific, where about 100,000 personnel were stationed in South Korea, Japan, and the Philippines during that period. Those troops were augmented by additional sets of unit equipment that were stored (or prepositioned) in strategic locations to be ready for use by soldiers or marines flown from the United States.[2]

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[1] Strategic transportation (or mobility) systems are those designed primarily to deliver military units and supplies to theaters far from the United States, by contrast with tactical systems, which are designed to move units and supplies over shorter distances within a theater. (Although Navy amphibious ships carry Marine Corps units over long distances, they are typically thought of as combat assets rather than transportation assets.)

[2] During the Cold War, the Army had a stated requirement for 13 brigade-equivalent unit sets of prepositioned equipment under the Prepositioning of Overseas Materiel Configured to Unit Sets program, and the Marine Corps kept prepositioned equipment for a Marine expeditionary brigade in Norway.

Second, the U.S. military invested in strategic transportation forces that could move units to distant theaters, either to conflicts in unanticipated locations or in support of forward-deployed forces. To better provide traditional transport by ship, the Military Sealift Transportation Service was established in 1949 as a single agency to oversee movement by sea. That agency—which was renamed the Military Sealift Command in 1970—provides strategic lift for large forces, particularly heavy units, with their many armored and support vehicles. Its assets include both afloat prepositioning ships and surge sealift ships. The former are loaded with unit sets of equipment and kept at forward locations; the latter are used to transport shore-based units when necessary.

In addition to sealift, advances in aircraft technology during World War II enabled militarily significant cargoes to be transported over long distances by air. Although aircraft payloads are orders of magnitude smaller than payloads of large cargo ships, the much higher speed of aircraft makes them ideal for rapidly transporting time-critical cargo and passengers. The Military Air Transport Service was established in 1948 as part of the newly formed Air Force. It became the Military Airlift Command in 1966 and the Air Mobility Command in 1992. To better coordinate mobility operations, the President in 1987 ordered the establishment of what would become the U.S. Transportation Command (USTRANSCOM), with the Military Sealift Command, the Military Airlift Command, and the Army's Military Traffic Management Command (now known as the Military Surface Deployment and Distribution Command) as its three major components.

With the end of the Cold War, having the flexibility to move forces to regional conflicts as the need arose became more important than having large forward-deployed forces arrayed against specific threats, such as the Soviet Union. Consequently, the importance of the transportation services provided by USTRANSCOM increased as well. As forward-deployed forces have been reduced by nearly half since the Berlin Wall came down (and additional reductions have been proposed), strategic transportation capabilities have been steadily enhanced.

USTRANSCOM's first experience with trying to rapidly deploy large forces to a major theater war came in Operations Desert Shield and Desert Storm in 1990 and 1991. Although the military was able to move 3.7 million tons of dry cargo, 6.1 million tons of petroleum products, and more than 500,000 personnel to the Persian Gulf in about seven months, lessons learned from that operation indicated a need for improved transportation systems as well as better planning, coordination, and execution of such missions.

In response to that experience and to the results of mobility studies conducted in the early 1990s, DoD has upgraded its strategic transportation forces. Improvements have included buying 180 C-17 airlift aircraft (the last of which is scheduled for delivery around 2010) and 19 large, medium-speed roll-on/roll-off ships (LMSRs). Although the C-17s are nominally being purchased to replace earlier C-141 transport planes, they offer a considerable improvement in capability. In particular, C-17s can carry larger pieces of cargo than C-141s can, making them more effective at transporting the equipment of Army units, and they can operate from smaller runways, potentially increasing the number of locations to which cargo can be delivered. The LMSRs have added to already-significant improvements in sealift that the Navy made during the 1980s.[3] Eight of the 19 LMSRs are loaded with Army equipment and prepositioned at forward locations. Additionally, improvements in planning and execution processes have helped eliminate many of the problems experienced during Desert Shield and Desert Storm.

The Structure of Current Strategic Mobility Forces

Today's strategic transportation forces fall into three general categories: airlift, sealift, and prepositioning. Each has particular advantages and disadvantages in terms of the capabilities it offers to the regional combatant commanders that USTRANSCOM may be directed to support. Airlift aircraft travel the fastest but carry relatively small loads. Sealift ships take longer to arrive but can transport large of amounts of cargo, especially vehicles. Depending on where it is based, prepositioned equipment can arrive in a theater before sealift ships do, but because it is preloaded, it cannot easily be reconfigured in response to the needs of a particular operation.

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[3] At the beginning of that decade, the Navy formally recognized sealift as a major naval function and began upgrading its sealift forces with the goal of being able to move a mechanized division to Europe in five days or to the Persian Gulf in two weeks.

Airlift

Strategic airlift is provided by a mix of large jet transport aircraft owned by the Air Force and (in the case of major operations) commercial aircraft from the Civil Reserve Air Fleet (CRAF). The CRAF is a voluntary partnership between DoD and commercial air carriers that is used to augment Air Force airlift. As an incentive for carriers to enter into contractual commitments with the CRAF, DoD makes peacetime charter business available to participants. When Air Force aircraft and commercial charters cannot meet deployment needs in times of crisis, DoD can activate the CRAF to help close the gap. If fully activated, the CRAF would provide about one-third of the theoretical throughput capacity (total cargo delivered) of the combined military/civilian airlift force.[4]

Air Force Aircraft. The Air Force's current strategic airlift force consists mainly of 126 C-5A/B Galaxy and 138 C-17A Globemaster III jet transports.[5] The C-5A was developed in the 1960s and is one of the world's largest operational aircraft, with a length of 248 feet and a wingspan stretching 223 feet (see Table 1-1). The last C-5A was delivered in 1973, and 50 C-5B models, which incorporated some improvements in reliability, were purchased during the 1980s. To help address problems with the aging and reliability of the C-5 fleet, the Air Force plans to upgrade 109 of its C-5s with modern engines, digital avionics, and other improvements. That effort is scheduled to be completed around 2018 and is expected to cost about $10 billion. C-17A aircraft were produced starting in the mid-1990s, and a total of 180 are planned for delivery through 2010. Although the commander of the Air Mobility Command has expressed a need for at least 42 more C-17As, no current plans exist to continue production beyond 180 aircraft.

Table 1-1.

Characteristics of Strategic Transport Aircraft

	Air Force		Civilian
	C-5	C-17	B-747
Length (Feet)	248	174	232
Wingspan (Feet)	223	169	196
Maximum Takeoff Gross Weight (Pounds)	840,000	585,000	836,000
Maximum Payload (Tons)[a]	89	65	113
Ability to Carry Outsize Cargo	Yes	Yes	No
Roll-On/Roll-Off Capability	Yes	Yes	No
Mininimum Runway for Landing (Feet)			
Length	6,000	3,500	6,600
Width	147	90	90
Cruise Speed (Mach)	0.77	0.76	0.84

Source: Congressional Budget Office based on Department of the Air Force, *Air Mobility Planning Factors*, Pamphlet 10-1403 (December 18, 2003).

a. Based on a flight of 3,200 nautical miles for the C-5 and C-17 or 3,500 nautical miles for the B-747.

Both the C-5 and C-17 are designed to carry large, heavy pieces of military equipment. They have wide fuselages and doors as well as low cargo floors with ramps that allow vehicles to be driven on and off the aircraft, greatly easing the task of loading and unloading a ground unit's equipment. Although the two are generally similar in layout and can both carry outsize cargo, the C-5 is considerably larger than the C-17 (see Table 1-1).[6] The C-17's smaller size and special flaps and engine thrust reversers enable it to operate from substantially smaller airfields than the C-5, giving it access to many more air bases around the world. The greater flexibility of the C-17 is offset by its smaller payload relative to that of the C-5.

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[4] Theoretical throughput capacity is the amount that the entire fleet could carry in the absence of external constraints or inefficiencies. Usually measured in terms of millions of ton-miles per day, it overstates actual delivery rates because of inevitable constraints or inefficiencies during conflict. The CRAF's percentage contribution to theoretical throughput capacity varies slightly from year to year with changes in the Air Force's force structure and the number of aircraft participating in the CRAF.

[5] Tanker aircraft, especially the larger KC-10A, can also contribute to the amount of Air Force airlift available. They can be especially useful for moving Air Force squadrons, refueling a squadron's aircraft en route while simultaneously carrying some of its ground equipment. The primary mission of KC-10s is refueling, however, and their contribution to airlift is small compared with that of the C-5s and C-17s.

[6] "Outsize" is the Air Force's largest cargo category. It is loosely defined as cargo that will fit only on C-5s or C-17s. An item's weight or external dimensions determine whether it is outsize, "oversize" (cargo that can fit on some smaller military and some commercial airplanes), or "bulk" (small items that can be loaded onto standard shipping pallets and transported on all types of cargo aircraft).

Civilian Aircraft. The Civil Reserve Air Fleet contains many different types of commercial aircraft, which can be broadly separated into two categories: those configured to carry cargo (air freighters) and those configured to carry passengers. The largest CRAF air freighter is the Boeing 747. Although air freighters in the CRAF lack the low floors and integral ramps of their C-5 and C-17 counterparts, their doors are large enough for loading items of moderate size. Because they have large payloads and are designed for economical operation (to maximize the return on their owners' investment), air freighters are ideal for carrying cargo on pallets, freeing up military aircraft to carry more of the larger, hard-to-load pieces of equipment, such as military vehicles. (The practical implications of the differences between military transports and commercial air freighters are discussed in Chapter 2.)

Passenger aircraft are a critical component of the CRAF. Because they are designed to carry people, they have a much higher capacity than a similarly sized military cargo plane. For example, the Boeing 767 is similar in length and wingspan to the C-17, but it can carry more than twice as many passengers (190 versus 90). Passenger aircraft are also much more comfortable for the troops being deployed. For those reasons, DoD tends to prefer CRAF aircraft for moving large numbers of people. During Desert Shield and Desert Storm, for example, CRAF planes carried only about one-quarter of the cargo transported by air but nearly two-thirds of the personnel.

Surge Sealift

The strategic sealift forces available to DoD consist of ships belonging to the Military Sealift Command; ships in the Ready Reserve Force (RRF), which are owned and maintained by the Department of Transportation's Maritime Administration; and commercial ships that have been committed to the Voluntary Intermodal Sealift Agreement, an arrangement that is conceptually similar to the CRAF. Ships with prepositioned cargo are also part of strategic sealift forces, but they are treated separately in this study from the surge sealift forces that are used for transport. Surge sealift forces include various types of ships:

- Roll-on/roll-off ships (RO/ROs), such as LMSRs;
- Other dry-cargo ships, including container, heavy-lift, auxiliary crane, break-bulk, and specialty support ships;
- Tankers; and
- Hospital ships.

Most of those vessels are maintained in a reduced operating status (ROS) and require four to 20 days for activation. The use of such status decreases peacetime operating expenses while matching the time when a ship can be available to the availability of its cargo. For example, in most cases, even if a transport ship was ready at a moment's notice, its cargo (say, an Army unit) would need at least several days before being ready for transport.

The most important type of sealift ship for CBO's study of rapid unit deployment is roll-on/roll-off ships. Those vessels are designed to facilitate the loading, transport, and unloading of vehicular cargo. Vehicles can be driven aboard using built-in ramps lowered from the ship to the pier and then driven to their stowage location on internal ramps (much like those in a parking garage) between decks.[7] RO/ROs are preferred for vehicle-dominated cargo and hence for deploying most ground units, because vehicles can be loaded and unloaded much faster than on other ships and with less need for port infrastructure, such as large cranes. DoD's RO/RO fleet is particularly important for deploying units because the U.S. commercial fleet does not include many ships of that type.

Today's strategic surge sealift RO/ROs include eight fast sealift ships (FSSs) and 11 LMSRs under the Military Sealift Command plus 31 RO/ROs of varying size and speed in the Ready Reserve Force. During peacetime, the FSS and LMSR fleets are held in four-day reduced operating status, denoted as ROS-4, whereas most of the RRF's roll-on/roll-off ships are held in ROS-5.[8] The one-

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[7] Although the layout of a RO/RO ship can be likened to that of a parking garage, the size and awkward handling of many military vehicles, and the need to pack them densely aboard ship, make the loader's job difficult.

[8] As a result of ongoing operations in the war on terrorism, some ships normally kept in ROS are now active, and some prepositioned ships are currently unloaded or in some stage of reconstitution if their embarked unit equipment was needed in Iraq or Afghanistan. Unless otherwise noted, this text refers to nominal conditions in peacetime.

Table 1-2.

Characteristics of Roll-On/Roll-Off Sealift Ships

	Fast Sealift Ships	LMSRs	Ready Reserve Force
Length (Feet)	946	907–954	499–750
Beam (Feet)	106	106	75-105
Maximum Draft (Feet)	37	34–36	28–36
Speed (Knots)	33	24	14–19
Cargo Capacity			
Usable square feet	150,000–155,000	226,000–290,000	66,000–222,000
Cargo deadweight (Tons)	16,000–17,000	17,000–21,000	10,000–32,000

Source: Congressional Budget Office based on Military Traffic Management Command, Transportation Engineering Agency, *Logistics Handbook for Strategic Mobility Planning*, Pamphlet 700-2 (September 2002).

Note: LMSR = large, medium-speed roll-on/roll-off ship.

day shorter ROS and higher sustained speeds of the FSSs and LMSRs mean that they are usually the first ships from the United States to arrive in a theater. (Prepositioned ships typically arrive earlier because of their forward location.)

Fast sealift ships are conversions of the eight SL-7 container ships built for the Sealand Corporation in the early 1970s. At 946 feet in length, they are nearly as long as Nimitz class aircraft carriers. Sealand hoped the 33 knot speed of the ships (about double that of typical freighters at that time) would be attractive to customers with time-sensitive cargoes. However, the rising cost of fuel in the 1970s made the SL-7s not cost-effective as merchant ships. The Navy purchased all eight of them in the early 1980s and converted them to their present roll-on/roll-off configuration. Although initially rated at 33 knots, fast sealift ships are usually expected to achieve a sustained speed of between 27 and 30 knots.

Mobility studies after Operation Desert Storm indicated a need to augment the FSS fleet with more relatively speedy RO/ROs. Consequently, between 1997 and 2003, the Navy bought 19 LMSRs capable of sustained speeds of about 24 knots. Although slower than an FSS, each LMSR can carry a substantially greater load despite having a similar length, beam, and draft (see Table 1-2). DoD did not try to match the speed of the fast sealift ships, deciding instead that 24 knots was adequate to support deployment plans and thus avoiding the added cost associated with ships designed for higher speeds (see Chapter 3). Of the 19 LMSRs, 15 were newly constructed and four were conversions of existing ships to a roll-on/roll-off configuration. Today, 11 of those LMSRs are based in the United States and assigned to deploy domestically based forces. The other eight are part of the afloat prepositioned forces discussed below.

Prepositioning

Prepositioned sets of unit equipment are stored either on land or on ships (afloat). Much of that equipment has been put into service in Operation Iraqi Freedom and is either still in use or in some stage of reconstitution. It is unclear whether, after that operation, DoD will try to reconstitute those prepositioned assets as they existed before or whether changes in the United States' global military posture or new initiatives (such as the Navy's sea-basing concepts and the Army's proposed reorganization into "modular" units) will result in very different prepositioned forces.[9]

During peacetime, the land prepositioning force comprises six brigade sets of Army equipment—three in Europe, two in the Persian Gulf (Kuwait and Qatar), and one in South Korea—and one set of Marine Corps equipment in Norway. The Army sets in Kuwait and Qatar,

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[9] For information about sea basing, see Congressional Budget Office, *The Future of the Navy's Amphibious and Maritime Prepositioning Forces* (November 2004); for information about the Army's modularity initiative, see Congressional Budget Office, *Options for Restructuring the Army* (May 2005).

plus some of the equipment from the sets in Europe, were issued for use in Iraq. The Marine Corps set in Norway is only partially filled; because the Soviet Union no longer poses a threat to the northern flank of NATO, the Marine Corps is exploring other uses for that equipment.

The afloat prepositioning force consists of 36 ships:

- Sixteen ships in the Marine Corps' Maritime Prepositioning Force (MPF),
- Ten ships in the Army Prepositioning Stock (APS) program,
- Seven ships with sustainment supplies (four Air Force and one Navy ammunition ship and two tankers for the Defense Logistics Agency),
- Two aviation logistics support ships, and
- One high-speed catamaran, the *Westpac Express* (although listed as part of the prepositioning force, that chartered ship is not kept loaded with equipment but rather is used by the Marine Corps for intratheater lift).

All of those ships are maintained in full operating status, ready for movement at any time, except the two aviation logistics support ships, which are kept in ROS-5. The 16 MPF and 10 APS ships are most relevant to analyses of the deployment of unit equipment.

The Maritime Prepositioning Force is organized into three squadrons, each of which contains equipment and supplies to support a Marine expeditionary brigade for up to 30 days. Ordinarily, those squadrons are based in the Mediterranean Sea, at Diego Garcia in the Indian Ocean, and at Guam in the western Pacific. When needed, an MPF squadron sails to the appropriate port, where its equipment is unloaded and picked up by Marine Corps personnel flown in from their home base.[10] The MPF squadrons in Mediterranean and Diego Garcia have been off-loaded, and their equipment is being used in Operation Iraqi Freedom.

Of the 16 ships in the MPF, three are government-owned and 13 are on long-term charter. As part of its 2006 budget request, the Military Sealift Command is seeking about $750 million to purchase the 13 chartered ships. Eventually, the Marine Corps would like to replace today's MPF with more-capable MPF (Future), or MPF(F), ships. Although the characteristics of the MPF(F) are not yet well defined, emerging ideas about it and the broader concept of sea basing suggest a focus on greater independence from infrastructure and flexibility of employment rather than a desire for faster arrival times (although quicker arrivals would result from those other improvements if infrastructure was constrained). In assessing the effectiveness of options for strategic mobility forces, CBO looked at the improvements they would offer over the capability of today's force, noting (where appropriate) the potential impact if some form of MPF(F) is eventually fielded.

The Army's afloat prepositioned equipment is stored on the eight LMSRs mentioned above plus two chartered container ships. In all, those stocks include more than enough equipment for a heavy brigade plus a variety of other combat-support equipment that the Army would need to set up large-scale operations in a theater. Most of the unit equipment and much of the combat-support equipment is being used in Iraq.

The Delivery Rate of Today's Strategic Mobility Forces

The transportation capability offered by a strategic mobility system is a function of three main factors:

- The system's throughput capacity—the total rate at which it can move military units;
- The system's promptness—the amount of time it takes to move cargo a given distance after the decision to do so has been made; and
- The system's independence from external constraints, such as limited airfield or seaport facilities, that can increase the time needed to make deliveries.

Those three factors combine to determine how rapidly military forces can be transported where needed. Although the first two factors are similar, a distinction exists between the average rate at which a transportation system can move military units (throughput capacity) and the

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[10] Those Marine expeditionary brigades are distinct from amphibious forces, which travel on Navy ships specially designed to support forcible-entry operations. See *Congressional Budget Office, The Future of the Navy's Amphibious and Maritime Prepositioning Forces.*

time needed to deliver a particular unit or load (promptness). For example, a system capable of delivering one brigade on the fifth day of an operation and a second brigade on the tenth day has the same throughput capacity as a system that can deliver two brigades on the tenth day. But the former is more prompt because it can deliver the first brigade five days earlier.

To assess the effects of options to expand strategic transportation forces, CBO first calculated the rate at which current forces can deliver cargo to a distant theater (the base case in this analysis). That delivery rate depends mainly on the distance that the combat units being deployed must travel, the size and characteristics of the mobility force executing the deployment, and the capacity of transportation infrastructure (such as ports and airfields) necessary to support the deployment.

Parameters of the Base-Case Assessment

CBO did not use a specific planning scenario for its base-case calculations, but it choose deployment distances similar to ones expected for an operation set in the Persian Gulf or Indian Ocean region: about 7,000 nautical miles (nm) by air and 10,000 nm by sea from the United States. Deployment to those regions represents about the longest distance possible from the United States, allowing CBO to compare alternative mobility forces under stressing circumstances. Additionally, because the current positioning of afloat prepositioned equipment is oriented toward the Persian Gulf region, CBO could use actual prepositioning locations as part of the base case. (Land-based prepositioned units were not included in the base case, but the possible effects of such units are considered in the discussion of options in Chapters 3 and 4. That discussion also looks at how CBO's estimates would differ using different deployment distances, both for prepositioned units and for U.S.-based units.)

Besides deployment distance, another factor that influences the delivery rate that a given mobility force can achieve is the availability of transportation infrastructure. A theater with large airfields and modern port facilities will generally be able to receive military forces at a higher rate than a less developed theater will. CBO did not make any assumptions about the level of infrastructure that might be available in a future conflict. Instead, it calculated the capability of the current force and of various alternatives in the absence of constraints on infrastructure and then analyzed the relative sensitivity of each force to decreases in available infrastructure. (That analysis is also part of the comparison of options in Chapter 4.)

Because this study focuses on options to speed the deployment of military forces in the early phases of a conflict, CBO limited its assessment of current capabilities to mobility systems that are most critical to that mission—strategic airlift (both Air Force and CRAF), afloat prepositioned forces with Army equipment and two of the MPF squadrons with Marine Corps equipment (the other squadron was held in reserve in case another conflict arose), and RO/ROs for transporting units based in the United States (see Table 1-3). Of the characteristics of those systems, speed and ground or port time determine the total time needed to complete a delivery mission; payload determines how much is delivered in each mission; and, in the case of aircraft, the utilization rate constrains the operational tempo that the fleet can maintain.

Limiting the assessment to that subset of today's strategic mobility forces allows for a more useful comparison of current capabilities with those of various alternatives. (For example, the improvement offered by new roll-on/roll-off ships is best compared with the throughput capacity of current RO/ROs, not with total throughput capacity.) Transportation systems such as container ships to carry sustainment supplies are also very important for supporting large military operations, but they were excluded from the assessment because they are more numerous than the systems listed above and can be more easily obtained from the commercial sector. Likewise, CBO did not explicitly track the movement of passengers to its notional theater because commercial airlines have sufficient throughput capacity to support very large deployments. Passenger flights to a theater can, however, contribute to congestion at airfields. For that reason, CBO included the estimated impact of passenger flights on airlift delivery rates as part of its assessment of the effects of constrained infrastructure in Chapter 4.

Results of the Base-Case Assessment

Each element of the mobility forces described above—airlift, afloat prepositioned units, fast RO/ROs (fast sealift ships and LMSRs), and slower RO/ROs in the Ready Reserve Force—can deliver at least one load of equipment to the theater within 45 days under the conditions of CBO's assessment. By that time, the forces will have delivered a total of about 1.4 million tons of cargo, CBO estimates (see Figure 1-1). By day 45, each ship will have

Table 1-3.

Airlift, Sealift, and Afloat Prepositioning Forces Used to Estimate Current Capability

	Number	Average Payload[a] (Tons)	Average Speed (Knots)	Utilization Rate[b] (Hours per day) Surge	Sustained	Time on the Ground or in Port (Hours) Loading	En Route Stop[c]	Unloading
Airlift Aircraft								
C-17	155	45	409	14.5	12.5	3.25	2.25	3.25
C-5	95	61	420	11.5	8.1	4.25	3.25	4.25
KC-10	37	33	440	9.8	8.6	4.25	3.25	4.25
Civil Reserve Air Fleet[d]	85	98	460	10.0	10.0	5.00	1.50	5.00
Surge Sealift Ships								
Fast Sealift Ships	8	13,000	27	n.a.	n.a.	72	n.a.	48
LMSRs	11	16,500	24	n.a.	n.a.	96	n.a.	72
Ready Reserve Force RO/ROs	31	15,000	16	n.a.	n.a.	72	n.a.	48
Afloat Prepositioning Ships								
Maritime Prepositioning Force[e]	11	18,000	16	n.a.	n.a.	0	n.a.	72
Army Prepositioning Stock	8	21,600	24	n.a.	n.a.	0	n.a.	72

Source: Congressional Budget Office based on Department of the Air Force, *Air Mobility Planning Factors*, Pamphlet 10-1403 (December 18, 2003), and Military Traffic Management Command, Transportation Engineering Agency, *Logistics Handbook for Strategic Mobility Planning*, Pamphlet 700-2 (September 2002).

Note: n.a. = not applicable; LMSR = large, medium-speed roll-on/roll-off ship; RO/RO = roll-on/roll-off ship.

a. Payloads of RO/RO ships are usually measured in square feet. CBO used weight to allow more-direct comparisons between ships and aircraft. The weight of cargo varies widely depending on its density (for example, a tank is much heavier per square foot of deck space than a helicopter is). Weights for prepositioning ships are for expected loads. Weights for surge sealift ships are derived from Army data on logistics planning factors and reflect a weighted average of light-unit and heavy-unit loads.

b. Utilization rate is the fleetwide average number of hours per day that a type of aircraft can fly. It applies only to long-term, large-scale operations. The surge utilization rate is a flying-hour goal set by a command for the first 45 days of an operation. It assumes that normal maintenance is deferred, spare parts are fully funded and stocked, and active and reserve forces are fully mobilized. The subsequent sustained utilization rate is based on normal-duty days and assumes that maintenance deferred during the surge period is performed.

c. The number of stops that an aircraft must make en route for refueling depends on the distance to be traveled.

d. B-747 equivalent aircraft.

e. Two of three Maritime Prepositioning Force brigades activated.

delivered one load, and each aircraft will have delivered between 10 and 20 loads.

Although that total equates to a forcewide average delivery rate of 31,600 tons per day, actual deliveries vary widely from day to day (the stair-step profile in Figure 1-1) as different parts of the mobility force complete their missions. Airlift arrives first because of its high speed and then quickly settles into a smooth delivery profile (characteristic of smaller payloads, relative to those of ships, being delivered by many individual aircraft cycling rapidly through the system). Sealift arrivals come in surges, with each subcategory arriving at a different time based on its distance traveled, its ROS (which determines how soon it can begin its mission), and its speed. Ships carrying prepositioned equipment arrive earliest, on day 6 in the base-case deployment, because they are assumed to have a much shorter distance to travel than sealift ships from the United States (2,000 nm to 6,000 nm versus 10,000 nm) and because they are not kept in reduced operating status. Fast sealift ships arrive next, around day 21, and finally the slower RRF ships arrive on about day 35.

Assuming that no land-based prepositioned equipment is already in the theater, airlift provides all of the cargo delivered during the first week of CBO's notional deployment (see Figure 1-2). As other assets arrive, airlift's contribution drops to around 20 percent of deliveries. That percentage is high relative to experience (a figure of about 5 percent is often quoted for Operations Desert Shield and Desert Storm) for three main reasons. First, the assessment includes only the roll-on/roll-off portion of the sealift fleet. Airlift's percentage would drop if other sealift, such as container ships with sustainment cargo, was included in total deliveries. Second, the base case assumes no constraints on infrastructure, a condition that is seldom realized in practice. (The implications of such constraints are discussed in Chapter 4.) Third, the calculations do not reflect inefficiencies that often plague airlift because of its great speed and flexibility. Inevitably over the course of a deployment, airlift is diverted to move unexpected cargoes as the specifics of the conflict require. As a result, aircraft can be forced to wait for late-arriving emergency cargo or fly missions with inefficient loads or on inefficient routes. CBO's calculations do not attempt to predict such occurrences but rather estimate the capability of each element of the mobility force. The extent to which that capability is actually realized will differ from operation to operation.

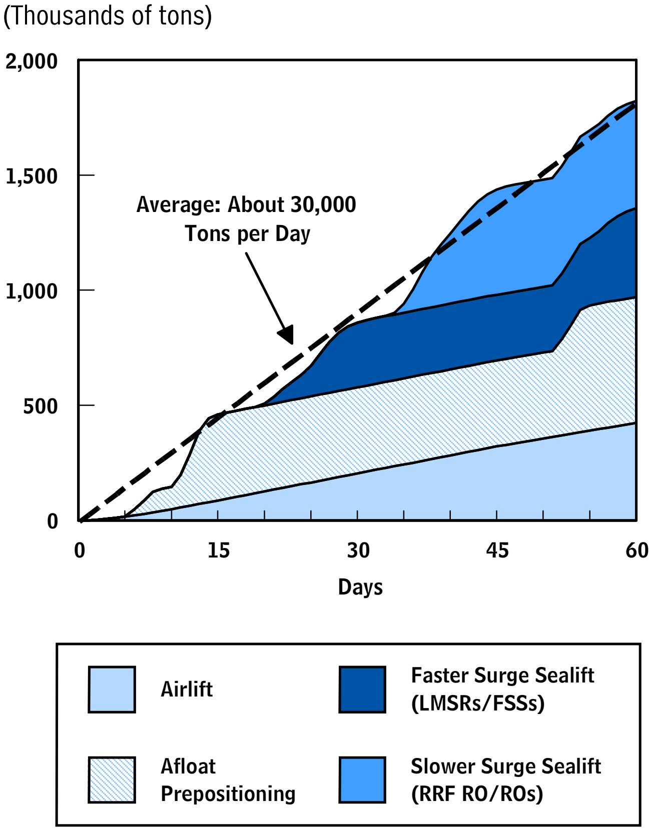
Nonetheless, CBO's calculations are consistent with DoD's more-detailed analytical methodologies for calculating strategic mobility. CBO tested its methodology by trying to replicate results from earlier DoD studies. When the same forces and assumptions were used, delivery estimates from CBO's methodology were within a few percent of DoD's results.

Perceived Shortfalls of Current Forces

Two often-cited shortcomings of today's strategic mobility forces are inadequate cargo delivery early in deployment and overreliance on support infrastructure in the theater of operations. Those concerns are reflected in two common proposals by DoD officials for improving mobility: purchasing additional C-17s, thus increasing deliveries (possibly to small airfields) early in a deployment, and developing shallow-draft high-speed sealift ships, with the greater speed improving promptness and the shallow draft reducing the need for deepwater ports.

Figure 1-1.

Cargo Delivery Capability of Current Mobility Forces



Source: Congressional Budget Office.

Notes: This notional delivery scenario assumes a theater of operations in the Persian Gulf or Indian Ocean region with no constraints on infrastructure in the theater. Surge sealift in this figure includes only roll-on/roll-off ships.

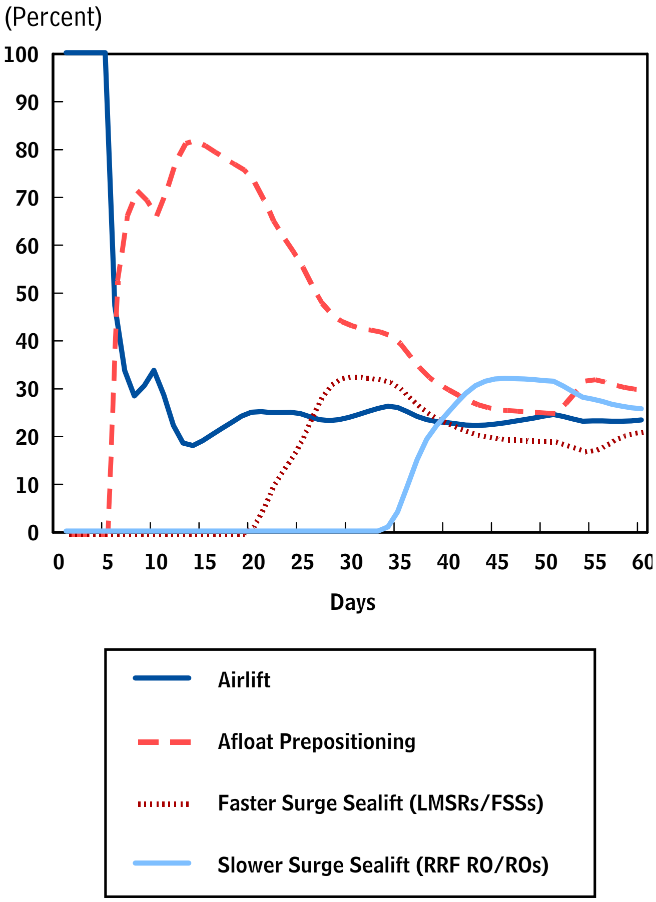
The prepositioned cargo shown arriving around day 50 is not actually part of a prepositioned unit but rather a second load of cargo carried by the prepositioning force ships, which CBO assumes return to the United States for additional loads after delivering their preloaded cargo.

LMSR = large, medium-speed roll-on/roll-off ship; FSS = fast sealift ship; RRF = Ready Reserve Force; RO/RO = roll-on/roll-off ship.

Mobility studies by DoD over the past decade have emphasized shortfalls in the ability to deliver forces in the early days of a conflict. Ideally, a commander wants all forces in place immediately, because the time needed to amass forces represents a period of vulnerability that an adversary might be able to exploit. In addition, the Army's transformation efforts have focused largely on getting more forces to a conflict in less time, placing an even greater premium on promptness than in the past. Except in cases in which forces are forward deployed at the right

Figure 1-2.

Relative Contributions of Different Mobility Systems to a Notional Deployment



Source: Congressional Budget Office.

Notes: This notional delivery scenario assumes a theater of operations in the Persian Gulf or Indian Ocean region with no constraints on infrastructure in the theater. Surge sealift in this figure includes only roll-on/roll-off ships.

FSS = fast sealift ship; LMSR = large, medium-speed roll-on/roll-off ship; RRF = Ready Reserve Force; RO/RO = roll-on/roll-off ship.

place and time, however, requirements for mobility must be tempered by the feasibility of transportation. A mobility system with adequate throughput capacity over a longer time scale can fall short at earlier times if initial units cannot be moved promptly.

In keeping with that focus on promptness, CBO's analysis emphasized factors that affect unit delivery times and examined options that would shorten those times. (Expanding mobility systems to improve promptness would also increase total throughput capacity, unless slower systems were retired as faster systems were introduced.) CBO did not choose options to meet a specific requirement for mobility, because new requirements are currently being defined. When this report was being prepared, DoD was completing a new Mobility Capabilities Study to update its requirements, and results of that effort were not available.

Analysis of the other perceived shortcoming—excessive reliance on local support infrastructure—is complicated by the degree to which such reliance depends on the conditions of particular scenarios. Studying scenarios with constrained infrastructure typically leads to the conclusion that infrastructure independence is essential. However, regions with little or no infrastructure are unlikely to have large enough economies to support strong opposition forces, nor are they likely to have sufficient importance for national security to require the deployment of large, heavy U.S. forces. Some observers have noted that the U.S. military was able to prevail easily in Afghanistan with light forces and air power because a country with so little infrastructure could not field a formidable military. Others have argued, however, that such a light force was adequate only because a friendly local force (the Northern Alliance) was in place, an advantage that cannot be expected in future conflicts.

In scenarios that include large ports and airfields in good locations relative to units' destinations, an infrastructure-independent system may actually perform worse than other alternatives by some measures. For example, C-17s can operate from shorter, softer runways than similarly sized aircraft because of their special thrust reversers, flaps, and high flotation landing gear; but that equipment adds weight and complexity to the C-17, increasing its cost and reducing its range and payload from what they might be otherwise. In scenarios in which the operational flexibility of the C-17 was unnecessary, that flexibility adds cost while it degrades performance.

As noted above, CBO's analysis made no judgments about the support infrastructure that might exist in future scenarios. However, CBO assessed the infrastructure dependence of the options in this study and, where appropriate, estimated the effects on cost and throughput capacity of less dependent variations.

CHAPTER

2

Factors That Affect Delivery Times of Strategic Transportation Forces

Various factors determine the promptness of a strategic mobility system, and external constraints can act to slow otherwise prompt systems. The time required for each stage of a strategic mobility mission—from origin to destination—contributes to total delivery time. The time per stage can differ between airlift, surge sealift, and prepositioning, and each stage is subject to different constraints on infrastructure. The interaction of those factors underlies the framework that the Congressional Budget Office used to select the strategic mobility options described in Chapter 3.

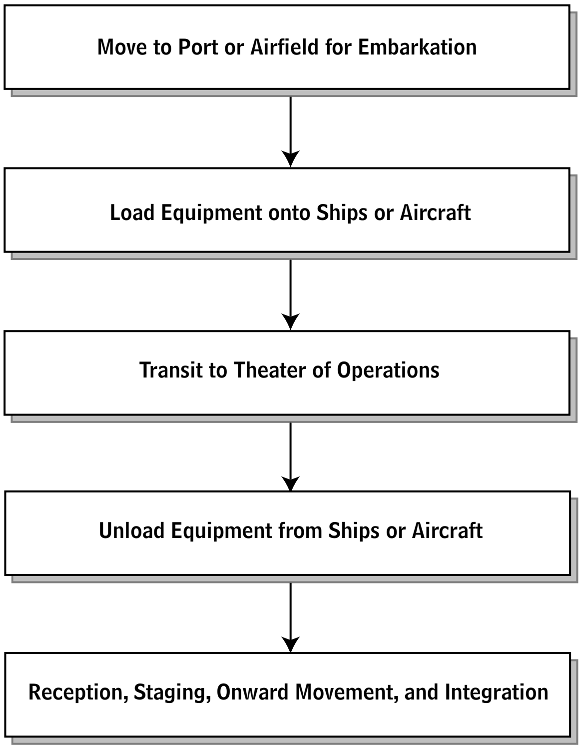
The Time Needed to Move a Unit to Its Destination

The amount of time necessary to transport a unit from its point of origin to its destination is not simply the distance to be traveled divided by the speed of the transportation platform. Transit time, although significant, is only one of the components of total delivery time. The act of moving a unit from its point of origin to its destination is composed of several stages, each of which contributes to the overall movement time (see Figure 2-1). The lengths of those stages depend on the characteristics of the unit being transported, the characteristics of the mobility system, and the details of the specific scenario. Two especially important scenario-dependent factors are the transit distance and the availability of transportation infrastructure, such as airfields or ports.

The sequence of five stages shown in Figure 2-1 is representative of a unit deploying from the United States to another continent. In other circumstances, some of those stages would not occur. (For example, in the case of a force prepositioned on ships, there would essentially be no initial movement or loading stages. The force would simply begin its transit when ordered to deploy.) Nevertheless, the five-stage sequence provides a useful general framework for discussing unit movement times.

Figure 2-1.

Mobility Stages of a Strategic Deployment



Source: Congressional Budget Office.

Stage 1: Move to Embarkation

In general, the first stage of unit movement lasts from when the order to deploy is received until the first elements of a unit reach the embarkation point (usually an airfield or seaport) and begin being loaded on the mobility platform that will carry them to the theater of operations. Two main factors contribute to the length of this stage: the time needed to prepare the unit being deployed and get it to the loading site, and the time needed to activate the platforms that will carry the unit and get them to the loading location. Because those activities typically take place at the same time, the longer of the two usually determines the time needed for this stage.[1] (The description that follows of the move-to-embarkation time for a ship or aircraft applies only to its first load. For subsequent loads, the length of this stage consists of the return transit time from the destination plus any maintenance time that may be necessary.)

Moving Units. The time needed to prepare a unit for deployment and move it to its point of embarkation varies widely. For example, light units held on alert status and located near suitable airfields can be ready for deployment by air in a matter of hours. In contrast, a heavy unit based far from its port of embarkation can take several days to more than a week to reach its assigned ships. For instance, moving a heavy brigade from Fort Riley, Kansas, to a potential embarkation port more than 800 miles away in Beaumont, Texas, might take as long as 10 days. Basing units closer to their embarkation points could shorten that time, but the port facilities needed to accommodate large sealift ships are typically in urban industrial areas that do not offer the open space that heavy units need for day-to-day training. (CBO did not examine alternative domestic or overseas basing locations that are closer to embarkation ports, because the time savings offered by such alternatives are limited compared with other alternatives for improving delivery times and because relocating the home bases of units would have implications far beyond strategic mobility.)[2]

Besides the distance between the base and the embarkation point, the throughput capacity of the transportation infrastructure between those two (usually railways or roads) and the unit's proficiency at packing up and moving on that infrastructure will affect its move-to-embarkation times. Inadequate transportation networks could have bottlenecks that would slow movement. However, by design, transportation infrastructure in the United States is usually adequate to handle planned rates of unit movement. Units prepositioned on land in other countries would have a similar reliance on infrastructure in their host nation and would thus need to be located near adequate airport or seaport facilities to minimize the time required to reach their embarkation point.

Whether based in the United States or prepositioned elsewhere, units slated for early deployment in a crisis also need to be well versed in efficiently using the infrastructure if overall deployment times are to be kept as short as possible. For example, personnel might need to be trained to load their vehicles on rail cars rapidly. (As noted above, units prepositioned afloat do not require any time to reach an embarkation point because they have already embarked.)

Moving Ships and Aircraft. If the time needed to move transport ships or aircraft to their initial loading locations is greater than a unit's time to reach them, the ship or aircraft movement will determine the elapsed time before the loading stage can begin. Some Air Force aircraft are generally available for loading in a matter of hours, if not immediately. For example, McChord Air Force Base in Washington State, the main western U.S. base for C-17s, is located adjacent to Fort Lewis, home of the Army's first Stryker brigade combat teams.[3] But some aircraft might require several days to reach embarkation points, because at any given time, strategic airlift aircraft are in use around the world. Depending on their status, units and aircraft in the Air Force Reserve and Air National Guard might require extra time for activation. The rate at which aircraft in the Civil Reserve Air Fleet are activated by the Secretary of Defense or the President will depend on the severity of the need for additional airlift.

Those considerations are reflected in the aircraft-generation schedule (the schedule by which aircraft are

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[1] That statement assumes that once the initial elements of a unit have arrived at the loading location, the arrival of subsequent elements will occur more quickly than the mobility platform(s) carrying them can be loaded. If the rate of loading is faster than the unit's rate of arrival, the loading time (stage 2) will be subsumed by the move-to-embarkation time (stage 1), and the end of the loading stage will be determined by when the unit's final elements arrive at the embarkation point, not by the inherent loading time of the mobility system.

[2] See Congressional Budget Office, *Options for Changing the Army's Overseas Basing* (May 2004).

[3] Stryker brigade combat teams are relatively new medium-weight armored units that are designed to be easier to transport than traditional heavy units.

Table 2-1.

Reduced Operating Status of Surge Sealift Ships

	Reduced Operating Status (Days)			
	4	5	10	20
Fast Sealift Ships	8	0	0	0
LMSRs	11	0	0	0
Ready Reserve Force				
RO/ROs	0	27	4	0
Auxiliary crane ships	4	4	1	1
Other	0	8	8	1

Source: Congressional Budget Office based on information from the Military Sealift Command.

Notes: LMSR = large, medium-speed roll-on/roll-off ship; RO/RO = roll-on/roll-off ship.

Ships in reduced operating status are manned by skeleton crews that maintain systems to allow the ships to be activated in the number of days allotted.

introduced into the strategic flow) that CBO used for this analysis. It assumes that the small fleet of KC-10 tankers (which can be used for carrying equipment as well as refueling) is fully introduced, or generated, the soonest because all of those aircraft are in the active component of the Air Force. C-17s and C-5s are fully generated slightly later, although still quite quickly, because some of them have been allocated to the Guard and Reserve. The CRAF fleet is fully generated last, reflecting the sequential call-up of commercial aircraft as the need for them grows. CBO's generation rates are representative of schedules used in past DoD analyses of mobility.

Move-to-embarkation times are typically longer for surge sealift ships than for aircraft, primarily because those ships are kept in a state of reduced readiness during peacetime. As noted in Chapter 1, most surge sealift ships are maintained in four-, five-, 10-, or 20-day reduced operating status until they are activated for a mission (see Table 2-1). Ships in reduced operating status have small crews on board to ensure that the ship's primary systems are maintained and that the vessel can be ready to sail in the time allotted. Reduced operating status results in lower peacetime operating costs and serves to match ships' arrivals at their embarkation ports with the arrivals of units they will carry (having the ship ready to load on day 1 is of little use if the cargo will not arrive until day 4). That matching is designed to minimize any adverse impact on overall deployment times.

Stage 2: Loading

The loading stage can begin after the deploying unit (or its lead elements) and its assigned ship or aircraft have reached the embarkation point. The time required for loading depends on the availability of support infrastructure, the type of unit being loaded, and the characteristics of the mobility platforms.

As with transportation infrastructure for the move-to-embarkation stage, it is usually assumed that loading infrastructure—piers at which to dock ships, cranes for loading cargo on ships, and airfield materiel-handling equipment—will be in adequate supply at the embarkation point, because loading requirements can be estimated in advance, allowing planners to match their demand for infrastructure with its local availability. The type of unit can be an important factor in that planning. Units with particularly heavy or bulky equipment generally need more time for loading because such items are more difficult to fit on mobility platforms, must be more carefully positioned on board to maintain a proper weight distribution, and may require additional tie-down points to secure them for transit. As an extreme example, equipment such as helicopters must be partly disassembled to fit on some types of transport aircraft.

Loading times for ships vary widely, from as little as two days for a fast sealift ship to more than five days for some large container ships (see Table 2-2). Those times are influenced by a ship's ease of loading and by the total cargo to be loaded. For example, a roll-on/roll-off ship with two vehicle ramps to the pier can theoretically be loaded twice as fast as a RO/RO with only one ramp. The number of items to be loaded can be a more important factor than their cumulative size or weight because each item (such as a truck or a container of supplies) must be individually moved into the ship's hold and secured in place.[4] Part of the Army's move toward shipping supplies in commercial containers has been motivated by the benefits of having fewer items to handle: a single container

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[4] Of course, the size or weight of an individual item has some effect on loading time. A tank might take longer to load than a truck because it is more difficult to maneuver on the ship's ramps and might require a greater number of tie-down lines in the ship's hold.

Table 2-2.

Planned Loading and Unloading Times for Ships and Aircraft

	Hours for Loading	Hours for Unloading
Ships		
Fast sealift ship	48–72	24–36
LMSR	72	48
Auxiliary crane ship (Break bulk)	70–95	70–95
Barge carrier		
Seabee	79–92	79–92
Lighter aboard ship	232–264	232–264
Container ship[a]	88–136	88–136
Aircraft[b]		
C-17	3.25	1.75–3.25
C-5	4.25	2.00–4.25
KC-10	4.25	3.25–4.25
B-747	5.00	5.00
B-767	3.00	3.00

Source: Congressional Budget Office based on Military Traffic Management Command, Transportation Engineering Agency, *Logistics Handbook for Strategic Mobility Planning*, Pamphlet 700-2 (September 2002), and Department of the Air Force, *Air Mobility Planning Factors*, Pamphlet 10-1403 (December 18, 2003).

Note: LMSR = large, medium-speed roll-on/roll-off ship.

a. Times depend on the size of the ship (the number of containers) and the speed of the cranes servicing it.

b. Figures are for total ground time at the loading or unloading location, including time spent in fueling or maintenance.

can consolidate many items that would need to be handled individually on a break-bulk type of cargo ship. (Containers also have the advantage of rapid tie down because they are designed to be easily secured to the ship.)

Loading times for aircraft are subject to similar considerations, although they are measured in hours rather than days (see Table 2-2). Those times depend on the amount of cargo, the type of cargo, and the type of aircraft. C-17 and C-5 military airlifters are designed specifically for vehicular cargo and for operations with less support infrastructure than is typically needed with commercial aircraft (or derivatives of commercial aircraft, such as the KC-10A). Both the C-17 and C-5 have cargo floors that are low to the ground (only about 64 inches high for the C-17) and integral ramps that allow vehicles to be driven directly aboard. As a result, special materiel-handling equipment, such as the Air Force's 60K loaders, are not always necessary to lift cargo up to the aircraft's cargo-deck level. Moreover, the C-17's and C-5's cargo doors and ramps are coaxial with the aircraft fuselage, so vehicles do not have to be maneuvered through an often tricky and time-consuming 90-degree turn, as can be the case when loading them through a side cargo door. For nonvehicular equipment and bulk supplies, rollers built into the cargo floor of the C-17 and C-5 allow items to be slid aboard directly from trucks or other cargo carriers.

Commercial aircraft designs such as the KC-10 and Boeing 747 usually have floor rollers too, but their cargo decks are typically many feet above the ground (about 15 feet for the KC-10), and materiel-handling equipment is required for all items of cargo. As a result, the loading times for commercial aircraft tend to be longer than for their military counterparts. Additionally, commercial aircraft are more limited in the size of individual items that will fit on board because they have smaller cargo doors and weaker cargo floors. (Many commercial air freighters have only a side cargo door, and on a 747, the height of the nose door opening is limited by the presence of the flight deck above it.) Because of the greater difficulty of loading commercial aircraft, planners try to allocate bulk supplies to them and vehicles to military aircraft.

The loading times needed for aircraft are not entirely determined by the mechanics of getting cargo aboard. The aircraft loading times shown in Table 2-2 are more accurately described as the planned ground time for the aircraft's loading stage. Fueling and other aircraft maintenance can contribute to that time—although, insofar as possible, those activities are conducted while the plane is being loaded.

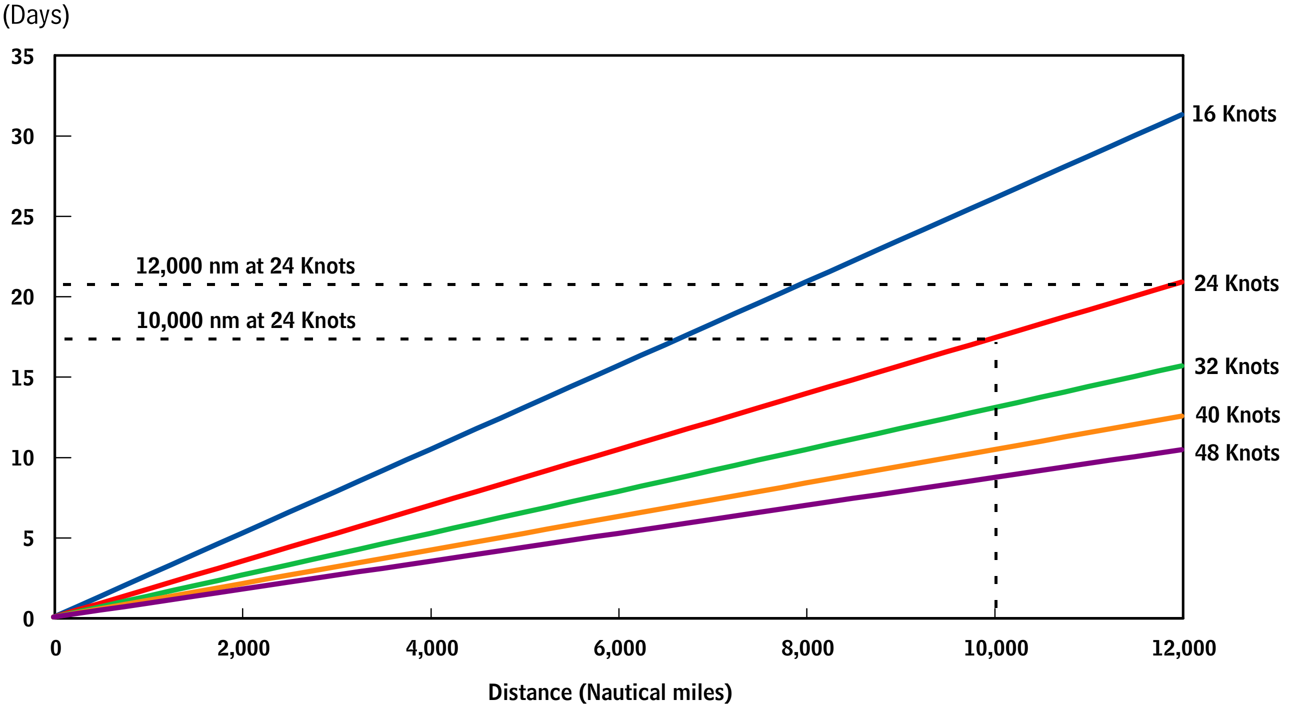
Stage 3: Transit

Transit time is the elapsed span between when the transport ship or aircraft departs from its embarkation point and when it arrives at its debarkation point. This stage includes time spent moving as well as any time spent at stops on the way. The primary factors that influence transit time are the distance to be traveled (including routing through canals or around denied airspace), the speed of the transport platform, and the number and duration of any stops en route.

For today's cargo ships, transit time is made up almost exclusively of time spent under way. Those ships can gen-

Figure 2-2.

Transit Times for Sealift at Different Distances and Ship Speeds



Source: Congressional Budget Office.

Note: The transit times shown here do not include stops for fuel or passage through canals.

erally travel around 10,000 nautical miles or more without refueling, so stops for fuel are seldom necessary. Speeds range from about 16 knots for a typical commercial ship up to about 30 knots for the Military Sealift Command's fleet of fast sealift ships, meaning that transit times over the same distance can vary by about a factor of two (see Figure 2-2).

Transit times can be significantly longer if—as is almost always the case—a ship cannot steam directly from its origin to its destination. For example, as the crow flies, the shortest distance from the port of Charleston, South Carolina, to Kuwait is about 6,000 nm. A ship, however, must pass through the Mediterranean Sea, transit the Suez Canal, and sail around the Arabian Peninsula, for a total of nearly 10,000 nm. That distance would increase to about 12,000 nm if the Suez Canal was closed and the ship had to travel around the Cape of Good Hope. That longer route would add several days to the transit time of a 24-knot ship (see Figure 2-2). Even if it could use the Suez Canal, the ship might have to wait for access to the canal and would be restricted to a lower speed once in the canal. (Army planners have recommended adding 16 hours to assumed schedules to reflect passage through the Suez or Panama Canal.) Delays resulting from canals and other restricted sea lanes mean that transit times will not necessarily decline in proportion to the increases in speed offered by faster ships.

Despite the greater flexibility of aircraft, they, too, can seldom take a direct route to their destination. Countries along the shortest path may deny overflight rights, and the need to make en route stops for fuel will usually result in a longer one-way flight distance and transit time. For instance, a C-17 flying from Charleston to Kuwait would travel about 7,000 nm with a typical set of en route stops (two or three stops, each with a planned ground time of 2.25 hours). The need for such stops could be reduced with aerial refueling, if it was available and deemed necessary. Of course, even when they must stop along the way, aircraft have much shorter transit times than ships do—hours rather than weeks—because of their much higher speeds. A typical airlift mission from the United States to Kuwait, for instance, could have a transit time of less than

24 hours, compared with about three weeks for a 20-knot ship.

Stage 4: Unloading

The factors that influence unloading times are generally similar to those that affect loading. However, unloading times are subject to much greater uncertainty in planning, because the location will not be known until a particular crisis arises, and the characteristics of potential unloading locations around the world vary greatly. Deployment to an area with spacious deepwater ports and large airfields will generally involve shorter unloading times. If, by contrast, the local infrastructure limits the number of aircraft or ships that can be unloaded simultaneously, this stage will lengthen as transportation platforms wait before support infrastructure is available. In some cases, infrastructure constraints could also slow the act of unloading itself. For example, some sealift ships carry barges that can be used to shuttle cargo ashore if adequate port facilities are not available, but that process is much slower than unloading at a pier. Ship and aircraft designs that offer greater independence from support infrastructure—such as shallow-draft ships that can unload at ports too small to accommodate deeper-draft ships—have the potential to substantially improve unloading times in austere theaters.

The Navy and Marine Corps are exploring the feasibility of bypassing ports altogether by employing and supporting ground units directly from specially configured ships—a concept known as sea basing. However, sea basing would still require a potentially time-consuming cycle of transporting units between ship and shore.[5]

The unloading situation is similar for airlift aircraft. The availability of runways long enough and strong enough to support large transport aircraft can limit the flow of cargo at its unloading point. The availability of other airfield services, such as materiel-handling equipment, can also force aircraft to wait before unloading their cargo. C-17 aircraft have been designed to operate from smaller airfields to help ease such constraints. But that capability may be of limited use, because a unit delivered to a small airfield would arrive slowly (perhaps only one C-17 load at a time), which could unacceptably slow the buildup of combat power. Moreover, such a unit might have to move significant distances on the ground to link up with units delivered to other locations.

Stage 5: Reception, Staging, Onward Movement, and Integration

The final mobility stage of a strategic deployment extends from when the unit is unloaded from its transportation platform until it is in place and ready for operations—a stage known as reception, staging, onward movement, and integration (RSOI). As its name suggests, RSOI comprises several activities, most of which are functions of the type of unit and its level of training. Typically, personnel fly into an airfield, move to the place (port or airfield) where their equipment is being unloaded, prepare the equipment, assemble into units, and proceed to the final destination to begin operations. Thus, RSOI technically occurs after the unit has exited the strategic mobility system.

Although RSOI is generally thought of as a series of intratheater functions, it is relevant to the discussion of strategic mobility because a strategic system can strongly influence the time required for that stage in several ways. First, a strategic system that can deliver its cargo closer to the final destination offers shorter onward-movement times. Aircraft can usually deliver cargo as close or closer to the final destination as ships can (although the extent depends on the characteristics of a particular scenario), because airfield locations are not limited to coastlines. Similarly, aircraft or ships that are able to make deliveries to smaller airfields or ports can potentially get cargo closer to its final destination, because there are a greater number of smaller facilities spread around the world. Second, a mobility system that allows personnel to travel with their equipment has the potential to shorten the RSOI stage by shortening the reception time.

Because RSOI is a function of the attributes of a given scenario, CBO did not estimate specific times for that stage for the base case or the options. Rather, the discussion of options in Chapter 4 includes only qualitative comparisons of their advantages or disadvantages for RSOI.

The Importance of Payload

The total time needed to transport a load of cargo from origin to destination is the sum of the first four stages described above. For existing aircraft, that time can be as

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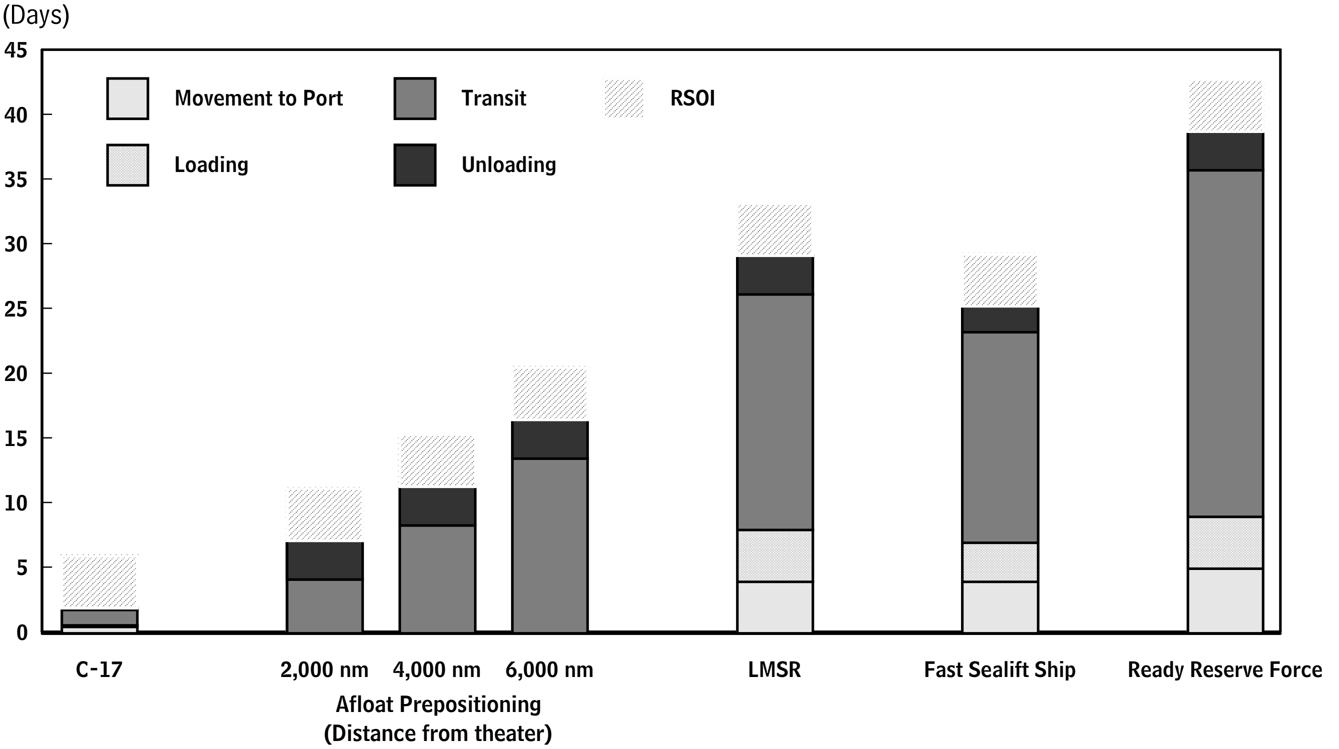
[5] For more details, see Congressional Budget Office, *The Future of the Navy's Amphibious and Maritime Prepositioning Forces* (November 2004).

Figure 2-3.

Total Delivery Times for Different Strategic Mobility Platforms



Source: Congressional Budget Office.

Notes: The times shown here are for a notional deployment from the United States (or the location of afloat prepositioning forces) to the Persian Gulf. They assume that prepositioning ships travel at a speed of 20 knots and that LMSRs and fast sealift ships in the United States are kept in four-day reduced operating status (ROS-4), whereas ships of the Ready Reserve Force are kept in ROS-5.

The RSOI portion of the bars is included as a reminder that additional time may be needed after delivery before a unit can begin operations. The times shown here do not represent estimates of actual RSOI times.

RSOI = reception, staging, onward movement, and integration; nm = nautical mile; LMSR = large, medium-speed roll-on/roll-off ship.

short as two days for an initial load delivered from the United States to the Persian Gulf (see Figure 2-3). Surge sealift ships from the United States need about a month. Prepositioned ships have shorter delivery times than U.S.-based ships because they do not need to move to the initial port or load equipment and because, if positioned wisely, they will have shorter transit distances as well.

The times shown in Figure 2-3 are single-mission delivery times. From the perspective of combat power delivered, the time when the last elements of a unit arrive—the unit closure time—is more important. Only then is the unit ready to fully join the operation. The payloads of mobility platforms play a role in closure times because payloads determine how many trips each mobility platform must make to deliver an entire unit. Ground units of any significant size are larger than any single transportation platform can carry in one load (see Table 2-3). Ships can transport even very large units, such as an armored (heavy) division, in relatively few loads, whereas aircraft need to fly hundreds more missions because of their smaller payloads. For example, although C-17s are very prompt—they can carry a single load from the United States to the Persian Gulf in about one-tenth the time of LMSRs—about 30 of the aircraft, flying a total of almost 300 missions, would be required to deliver an entire Stryker brigade in the same total amount of time as an LMSR (about 27 days).

The interactions between payload and delivery times suggest two initial conclusions. First, in the case of airlift, unit closure times could most easily be improved by

Table 2-3.

Number of Loads Needed to Deploy Army Units

	C-17	LMSR	FSS
Stryker Brigade Combat Team	330	1.0	2.0
Heavy Brigade Combat Team	543	1.6	3.0
Light Infantry Division	425	2.0	3.7
Heavy Division	1,722	5.4	9.8

Sources: Congressional Budget Office; Military Traffic Management Command, Transportation Engineering Agency, *Logistics Handbook for Strategic Mobility Planning*, Pamphlet 700-2 (September 2002); and Alan Vick and others, *The Stryker Brigade Combat Team: Rethinking Strategic Responsiveness and Assessing Deployment Options*, MR-1606-AF (Santa Monica, Calif.: RAND Corporation, 2002).

Note: LMSR = large, medium-speed roll-on/roll-off ship; FSS = fast sealift ship.

increasing throughput capacity with either more aircraft or larger aircraft rather than increasing promptness with faster aircraft or shorter ground times. The reason is that aircraft already have very short delivery times even for long transit distances, such as from the United States to Asia, so there is little room for substantial improvement on an absolute scale—a 50 percent improvement, for example, would save less than one day. Although such savings might be important in small, specialized missions (such as inserting a force to protect an embassy), they would be less beneficial in the context of larger deployments that involve many missions for each aircraft. Increasing airspeed and shortening ground times would yield improvements on the order of a few extra loads per aircraft over a several-week deployment.[6]

Second, in the case of sealift, existing ships are already of a size and payload to require good port facilities for timely loading and unloading. Increasing the capacity of sealift ships would come at the cost of reducing operational flexibility, because fewer ports could handle larger vessels. Increasing ships' speed, by contrast, could cut many days off the time needed to deliver large loads.

CBO developed six illustrative options for improving strategic mobility on the basis of the ways in which promptness and throughput capacity combine to determine the overall capability to deliver military cargo in a timely manner. Those options are described in Chapter 3, and their effects on the capability of current mobility forces are compared in Chapter 4.

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[6] In any event, substantially reducing round-trip times for airlifters would be very challenging technically. Military air transports are already designed for rapid loading and unloading, and they fly at about 450 knots (or about 0.77 Mach). Higher speeds would require some combination of smaller payloads (and thus more missions to move a given force), shorter ranges (and thus more delays for refueling stops), or larger aircraft (and thus higher costs and possibly greater demand for infrastructure at airfields).

CHAPTER

3

Options for Improving Strategic Transportation Forces

Many different ways exist to improve the military's strategic mobility capabilities. Potential approaches can be broadly grouped into five categories:

- Buying greater numbers of the existing systems that have the shortest delivery times (such as airlift aircraft);
- Developing new versions of those systems with greater payloads (such as larger airlifters);
- Developing prompter versions of current systems (such as higher-speed surge sealift ships);
- Deploying existing systems differently (such as moving surge sealift ships into the prepositioning force and loading them with new or existing equipment); or
- Lightening military equipment so that greater quantities can be carried by fewer lift assets.

For this analysis, the Congressional Budget Office developed six illustrative options to explore a variety of ways to enhance strategic mobility (see Table 3-1). Those options are based on all but the last approach listed above. (A previous CBO study concluded that fielding lighter equipment for ground combat units would offer only limited improvement in deployment times, because ships would still be needed to deliver most unit equipment during a large deployment.)[1]

This chapter describes the changes to strategic mobility forces that would be made under each option. The next chapter compares the extent to which the options would improve cargo deliveries in a long-range deployment—such as one from the United States to the Persian Gulf or Indian Ocean region—and other characteristics of the options, including dependence on infrastructure and survivability.

Approach for Developing the Alternatives

In developing the options for this analysis, CBO focused on alternative ways to spend the same amount of money: roughly $11 billion (in 2006 dollars) beyond the amount needed to maintain current strategic mobility capabilities. That additional expenditure includes costs for research and development (if necessary), procurement, and operations and support for 30 years after the first new system is delivered. By comparison, the Department of Defense has spent an average of about $12 billion *per year* on strategic transportation, including investment and operations, over the past 20 years, CBO estimates.

CBO chose the target value of approximately $11 billion as sufficient to develop and purchase enough systems under each option to allow for a meaningful comparison of their resulting capabilities. The actual costs of the six options range from $11.1 billion to $11.4 billion (see Table 3-1) because the alternatives were sized so that they would use whole numbers of force elements, such as prepositioned units, and so that their costs would be as close to one another as possible. Although a lower target cost could make some of the options impractical, a higher target would not significantly alter the relative improvements in capability offered by the options. The reason is that capability increases in proportion with force size, and

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[1] See Congressional Budget Office, *Options for Restructuring the Army* (May 2005).

Table 3-1.

The Options for Expanding Strategic Transportation Forces Examined in the Analysis

	Major Effect	Total Investment and Operating Costs[a] (Billions of 2006 dollars)
	Airlift	
Option 1A: Buy 21 Additional C-17 Aircraft	Increases the number of the most prompt type of system	11.3
Option 1B: Develop and Buy 14 to 16 Heavy-Lift Airships	Provides large improvement in payload relative to other airlifters	11.3
	Surge Sealift	
Option 2A: Buy 17 Additional LMSRs	Shifts cargo from slow Ready Reserve Force ships to faster LMSRs	11.3
Option 2B: Develop and Buy Six Advanced-Technology High-Speed Sealift Ships	Provides ship-sized payloads much earlier in a deployment	11.1
	Afloat Prepositioning	
Option 3A: Buy Four Sets of Stryker Brigade Equipment and Four LMSRs	Puts more unit equipment close to likely areas of conflict	11.4
Option 3B: Buy Five Sets of Stryker Brigade Equipment and Store Them on Existing LMSRs	Puts even more unit equipment close to likely areas of conflict but shrinks the surge sealift fleet	11.1

Source: Congressional Budget Office.

Note: LMSR = large, medium-speed roll-on/roll-off ship.

a. Includes costs for research and development (if necessary), procurement, and 30 years of operations and support (after delivery of the option's first aircraft or ship), over and above the costs needed to maintain current strategic mobility capabilities.

the bulk of funds for the options would be spent on procuring and maintaining force structure.[2]

Designing alternatives around a constant cost rather than a specific requirement for mobility was done for two reasons. First, as noted in Chapter 1, information about DoD's current definition of mobility requirements, and hence about what mobility shortfalls DoD might try to correct, was not available to CBO. Second, the national security environment and thus DoD's perceived mobility requirements are likely to change by the time many of the systems considered in these options could be fielded. Given that uncertainty, the constant-cost approach provides broader information about the relative cost-effectiveness of different options over a range of total strategic lift capabilities.

CBO included operation and support (O&S) costs for the systems purchased under each option in the total costs for the option because O&S costs could differ significantly among the alternatives. For example, afloat prepositioned forces require maintenance of the unit equipment on board the ships, not just of the ships themselves. Similarly, a surge sealift ship can be maintained in

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[2] An option with a large fraction of spending devoted to research and development could show a greater relative improvement in capability if additional funds were made available. The potential impact of that fact is noted in the discussion of the options that would develop new systems if the development costs would significantly affect the number of systems that could be purchased.

a less-expensive reduced operating status, whereas a prepositioned ship needs to be maintained in full operating status to provide the most responsiveness to a deployment order. A 30-year window for O&S costs, although longer than the time lines used in many past studies, is consistent with the long operational lives expected for today's ships and transport aircraft. The 30-year window begins with the delivery of an option's first ship or aircraft.

In developing the options, CBO assumed that the bulk of the strategic mobility forces would remain as planned: a mix of airlift, surge sealift, and prepositioned equipment similar to that described in Chapter 1. Current plans call for the Navy to purchase the existing Maritime Prepositioning Force ships when their leases expire and to continue operating them until they can be replaced with proposed MPF (Future) squadrons. Some of the roll-on/roll-off ships in the Ready Reserve Force and some fast sealift ships may also need to be replaced in coming decades. This study considers such changes or replacements to be part of the cost of maintaining the current base-case capabilities. However, the analysis notes ways in which particular options might affect that background cost.

Options to Improve Airlift

Given the interactions between payload and delivery time described at the end of Chapter 2, CBO's options for improving airlift capabilities focus on increasing the amount of cargo that the strategic airlift force can carry instead of the speed of individual aircraft. Option 1A would expand throughput capacity by purchasing more conventional aircraft: 21 additional C-17s. Option 1B explores the potential improvement offered by a new airlifter—in this case, a helium-filled hybrid airship—with a payload many times larger than those of current aircraft.

Option 1A: Purchase More C-17s

The first approach in CBO's analysis would speed up strategic deployments by increasing the throughput capacity of the conventional airlift force, the most prompt form of transportation in today's strategic mobility forces. This option would expand the currently planned fleet of C-17s by 21 aircraft, or 12 percent. That approach has the advantage of relying on a proven airlifter rather than on more-advanced and not yet proven concepts that might be developed. However, it has the disadvantage of adding to the already substantial demand for support infrastructure of the current airlift force. In an infrastructure-constrained theater, more aircraft might offer little or no improvement in capability (see Chapter 4).[3]

CBO selected the C-17 for its conventional-airlift option for several reasons. First, that aircraft is the only military strategic airlifter now in domestic production. The Administration's current plans call for purchasing 15 C-17s in 2006 and a final 12 in 2007, bringing the total throughout the program to 180 aircraft. Second, other existing options for increasing the throughput capacity of airlift lack the C-17's performance. For example, the C-130J (which is also in production) is a tactical transport plane with a much shorter range, a much smaller payload, and an inability to carry outsize cargo. Another possible alternative might be to get more private-sector aircraft into the Civil Reserve Air Fleet, but CRAF aircraft have limited ability to carry the vehicle cargos that dominate unit deployments. Third, the C-17 is the most efficient airlifter in terms of cargo delivered per amount of support infrastructure needed—a potentially important advantage in locations with constrained infrastructure.

Buying 21 additional C-17s would cost $4.4 billion, CBO estimates, assuming a purchase price of about $210 million per aircraft. Operating the new aircraft would cost another $6.9 billion over 30 years. That figure is based on the Air Force's estimate of annual operating costs for the C-17 of about $12 million per aircraft. The estimate may be optimistic for a 30-year period, however, because it is based on the current operations of a relatively young C-17 fleet (the first production C-17s were delivered in the mid-1990s). Maintenance costs tend to rise as aircraft get older and are especially sensitive to the number of hours flown, the number of takeoffs and landings, and even the characteristics of individual missions.[4] (For more details of how CBO estimated the costs of the various options in this study, see the appendix.)

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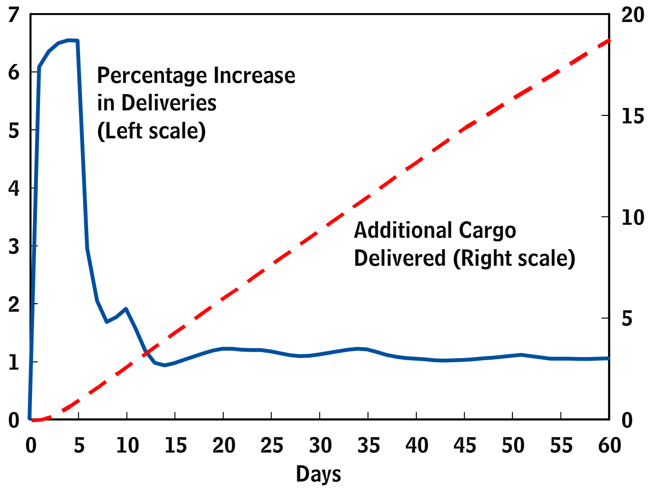
[3] The implication of trying to avoid infrastructure constraints by developing a strategic airlifter that can operate from even smaller airfields is also discussed in Chapter 4.

[4] For example, missions involving very heavy loads, landings on unimproved runways, or aerial refueling (when an aircraft must fly in the turbulent wake of the tanker) put greater wear and tear on an airlifter than do missions with light loads, long and smooth runways, and no aerial refueling.

Figure 3-1.

Improvement in Deliveries from Buying Another 21 C-17s (Option 1A)

(Percent) (Thousands of tons)



Source: Congressional Budget Office.

Because some fraction of the airlift fleet is usually assumed to be unavailable for reasons such as depot maintenance, CBO assumed that 19 of the 21 additional C-17s would be available to contribute to this analysis's representative deployment. In the absence of infrastructure constraints, those aircraft would provide increased deliveries to the theater in just one to two days. By day 6 (when the first prepositioned ship would arrive), this option could deliver about 1,400 more tons of cargo than the current force—a 7 percent increase in total deliveries to that point (see Figure). After day 6, the percentage improvement offered by Option 1A would drop because prepositioned ships would have begun unloading large amounts of cargo. Nevertheless, Option 1A would continue to increase deliveries to the theater by about 350 tons per day during surge operations.

Option 1B: Develop Heavy-Lift Airships

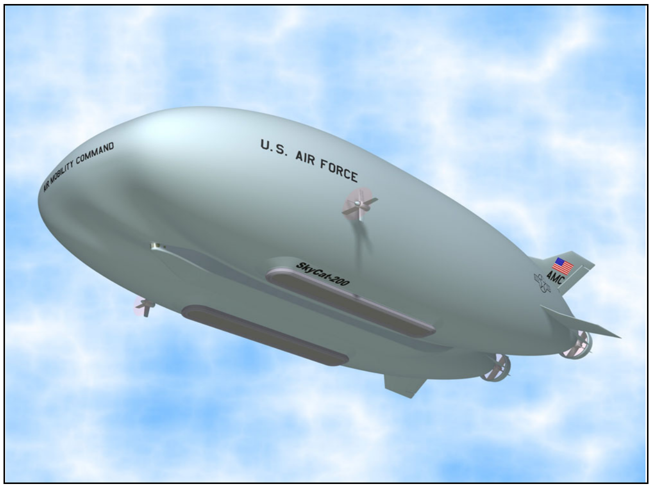
Instead of buying more aircraft with the payload size of current airlifters, this option would develop and field an aircraft with a significantly larger payload. Two very different approaches have been proposed for such a heavy-lift aircraft: one would develop new fixed-wing aircraft with larger payloads and longer ranges than current airlifters, and the other would develop heavy-lift airships (which would have propulsion and steering systems and be lighter than air or nearly so).

An example of the first approach is a blended-wing body concept, an airframe that would combine efficient high-lift wings and a wide airfoil-shaped body to generate lift and minimize drag, thus increasing fuel economy. Such a design has been proposed for a wide variety of missions, including strategic transportation, aerial refueling, and aerial launch of long-range air-to-surface missiles. In addition to its larger payload, the longer range of such an aircraft could improve cycle times (the total time from loading one cargo to returning for the next) by reducing the number of en route stops needed to reach a distant theater. The disadvantage of a larger fixed-wing aircraft is that it would probably be more constrained to operate from large airfields than current aircraft are. Consequently, that approach would add to the current force's already substantial capability to deliver cargo to large air bases but would run counter to the trend of seeking greater flexibility to operate airlifters from the more numerous smaller airfields available around the world.

Because of those drawbacks, CBO chose the second approach for Option 1B—a conceptual heavy-lift hybrid airship (see Figure 3-2 for an artist's conception of such an aircraft). A hybrid airship differs from a conventional airship, such as a blimp, in that it derives its lift from more than just the buoyancy of the helium inside the hull. The airfoil shape of the hull provides additional lift,

Figure 3-2.

Artist's Rendition of a Potential Heavy-Lift Hybrid Airship



Used by permission.

essentially acting as a wing when the airship is moving forward. Specific design concepts for such an airship vary, but roughly speaking, the static lift provided by the helium-filled gas bags in the hull supports the weight of the airship and its fuel, and the dynamic lift provided by the hull's shape offers the extra lift to allow the ship and its payload to make the transition to flight. Some concepts also include actual wings to provide dynamic lift. Forward speed comes from propellers, much as with current airships.

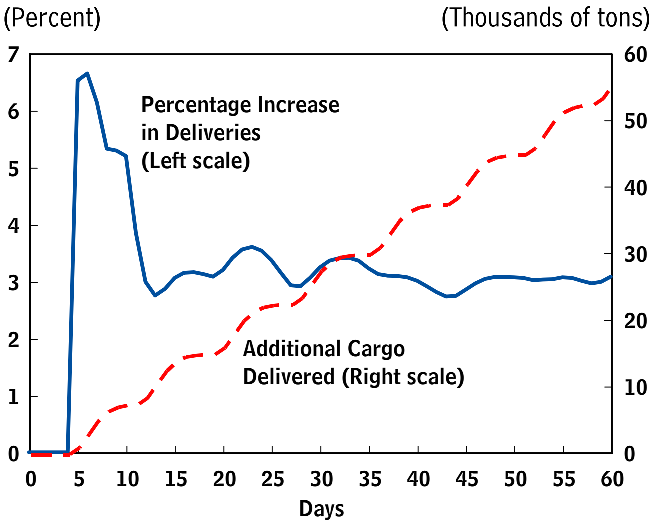
The balancing of static and dynamic lift means that total lift is much easier to control—both on the ground and in the air—than with conventional airships. (Old newsreel footage of a crowd of ground handlers being lifted into the air when a gust of wind hit a Zeppelin during docking graphically illustrates the problem of controlling a large conventional airship.) In principle, a hybrid airship would not need to be held down with strong tethers upon landing or to have ballast added during unloading because the ship, minus its payload, would be about neutrally buoyant. High winds could still be a problem, however, because the size of the hull would present a large sail area for winds to act on.

Option 1B would develop and field a hybrid airship similar in performance to the goals of the Defense Advanced Research Projects Agency's (DARPA's) Walrus program: an aircraft with a payload of at least 500 tons that could operate from unimproved locations and transport its load anywhere in the world in a few days.[5] Specific designs could vary significantly, but concept designs envision an airship roughly 1,000 feet long and 300 feet wide. Its structure would probably consist of a nonrigid hull to hold the helium and an underslung gondola to carry cargo and troops. Estimates of achievable speeds for hybrid airships range from about 80 knots to 120 knots. For this analysis, CBO assumed an average speed of 100 knots.

This option would have a total cost of $11.3 billion, CBO estimates—about $3.0 billion to $4.0 billion to develop the airship and the rest to purchase 14 to 16 airships and operate them for 30 years.[6] Those estimates are based on a DoD study of advanced mobility concepts and on contractor data for proposed heavy-lift airships (see the appendix for more details). CBO assumed that all of the airships would be available for operations in the event of a crisis. (The calculations of the additional capability provided by this option assume a fleet of 15 airships.)

Figure 3-3.

Improvement in Deliveries from Buying 15 Heavy-Lift Hybrid Airships (Option 1B)



Source: Congressional Budget Office.

Although not as prompt as conventional aircraft, hybrid airships could still begin arriving in the Persian Gulf region from the United States in about five days (see Figure 3-3), assuming that the units they transported were ready for loading immediately. The 15 airships would deliver about 1,000 tons of cargo per day—about three times as much as the 21 C-17s in Option 1A. Despite delivering more cargo than Option 1A, this option shows a similar percentage increase in cargo delivered early in the scenario, a peak of about 7 percent, because the first prepositioning ships would be arriving at about the same time as the airships under the assumptions of CBO's deployment scenario. If the prepositioned ships were located farther from the theater and hence arrived later, the initial percentage increase in deliveries attributable to this option would be higher.

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[5] In addition to DARPA, the Naval Air Systems Command and DoD's Office of Force Transformation are exploring the potential utility of ultralarge airlifters.

[6] There is significant uncertainty about development costs for the hybrid airship because of the lack of historical experience with similar systems (see the appendix).

The throughput capacity of Option 1B would decline if the cost of the airships grew relative to CBO's estimates and reduced the number of airships that could be bought within the spending target for these options. Among other possibilities, unforeseen technical hurdles during development could increase development costs. Alternatively, lower development costs could allow the purchase of a slightly larger airship fleet, with a corresponding increase in throughput capacity. (For example, a development cost half that of CBO's low estimate would allow the purchase of three additional airships within the total cost target.)

Aside from very large payloads, the biggest advantage of hybrid airships would be their potential ability to operate essentially independently of large air bases in a theater. Such airships could also offer shorter time lines for reception, staging, onward movement, and integration than would the other alternatives, both because cargo could be delivered closer to its final destination and because airships have the potential to efficiently carry troops with their equipment, eliminating the need for personnel to marry up with equipment that has been transported on a different platform. (Those factors are discussed in more detail in Chapter 4.)

Set against those positive features, there are potential disadvantages to pursuing large hybrid airships. Proponents argue that the technical risk inherent in developing such aircraft is lower than might be expected because the necessary component technologies have, for the most part, already been developed for other applications. However, a hybrid airship with a payload on the order of 500 tons and an approximate gas volume of 25 million to 35 million cubic feet would be much larger than any previous airship—four to five times larger than the biggest airships of the 1930s. Although the expertise to build individual components may already exist, integrating them into such a large structure could prove more difficult than expected.

Other possible disadvantages of an airship relative to conventional aircraft are its potential vulnerability both to military action, such as antiaircraft fire, and to political action, such as countries along its route refusing to let it fly through their airspace. Both of those vulnerabilities are increased because the hybrid airship would fly at a lower speed and altitude than aircraft such as the C-17: at 80 to 100 knots (versus more than 400 knots for the C-17) and at less than 10,000 feet (compared with more than 30,000 feet). Overflight rights might be more difficult to obtain for airships because their passage would be much more apparent than that of a conventional aircraft. Consequently, nations willing to quietly allow high-altitude overflights might be more reluctant to permit low, slow overflights by airships. (To capture the effect of possible restrictions on overflight rights, CBO's deployment scenario assumes a transit distance of 8,500 nautical miles for airships, halfway between the values for conventional airlifters and surge sealift ships.)

Options to Improve Surge Sealift

CBO's alternatives for expanding surge sealift capabilities are based on increasing the speed of the strategic sealift force instead of the payload of individual ships. (As noted in Chapter 2, sealift ships larger than those in the current force would be seriously limited in terms of the number of ports around the world that could accommodate them.) As with airlift, one of the sealift alternatives would increase the number of current ships, and the other would design a new vessel. Specifically, Option 2A would buy more of today's faster roll-on/roll-off ships, and Option 2B would develop a new sealift ship capable of achieving much higher speeds than current ships of similar size.

Option 2A: Purchase More LMSRs

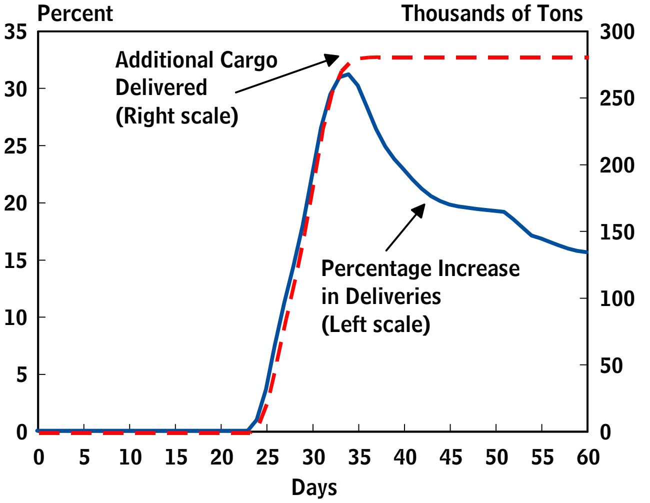
This option would speed strategic deployments by adding to the number of large, medium-speed roll-on/roll-off ships in the strategic sealift force. Although the Military Sealift Command's fast sealift ships are faster, CBO chose LMSRs for this option because they were in production much more recently (the last one was delivered in 2003, whereas the FSSs were produced in the early 1970s) and because they were built domestically. Thus, LMSRs offer the advantage of a proven ship design with which U.S. shipyards have recent production experience. Trying to build a ship with FSS-like performance would entail greater technical and cost risks and would require extra expenditure on new design work.

This option would buy 17 additional LMSRs at a total cost of $8.4 billion, CBO estimates, with production split between the two shipyards that built the current fleet of LMSRs (National Steel and Shipbuilding in California and Avondale in Mississippi). No funds would be needed for development. Operating the new LMSRs would cost about $7 million per ship per year, or about $2.9 billion over the 30 years after the first ship was delivered. Those

Figure 3-4.

Improvement in Deliveries from Buying Another 17 LMSRs (Option 2A)

(Percent) (Thousands of tons)



Source: Congressional Budget Office.

Note: LMSR = large, medium-speed roll-on/roll-off ship.

operating costs assume that the LMSRs would be maintained in four-day reduced operating status, as current surge sealift ships are.

The 17 ships purchased under Option 2A could deliver their first cargo to a Persian Gulf conflict in about 24 days, making this option the least prompt alternative in CBO's analysis. However, the average throughput capacity of this option would be very high. Assuming no constraints on infrastructure, by day 35 the additional LMSRs could deliver about 280,000 tons of cargo (more than enough equipment for two heavy divisions) from the United States—approximately a 30 percent increase over the base case (see Figure 3-4).[7] The throughput capacity offered by this option is so large that it would probably allow the Department of Defense to retire older RO/RO ships in the Ready Reserve Force in exchange for the new LMSRs, which could arrive 10 days earlier. (That potential implication for the modernization of the base-case sealift force is discussed in Chapter 4.)

If this option bought FSS-like ships instead of LMSRs, initial deliveries would occur five days earlier, assuming that the new ships could maintain an average speed of 33 knots. The amount of cargo delivered in the first wave of arrivals would be much smaller, however, for two reasons. First, each FSS-like ship would have a smaller payload than an LMSR. Second, a new FSS-like design could possibly be more expensive than an LMSR, allowing fewer to be purchased under the spending target for these options.

Option 2B: Develop High-Speed Sealift Ships

Faster ships could improve the promptness of strategic sealift by substantially shortening the transit stage. For example, approximately doubling the speed of an LMSR from 24 knots to more than 45 knots would cut delivery time for a 10,000 nm transit by about nine days (see Figure 3-5). As noted in Chapter 2, transit time is the largest component of total delivery time (excluding scenario-specific RSOI) for a notional deployment by ship—whether to the Persian Gulf, which is at the upper end of transit distances from the United States, or over much shorter distances.

As with aircraft, increasing the speed of ships requires making design compromises that affect the hull form, range, payload, overall size, and cost. Such compromises can reduce the advantage offered by greater speed. For example, a very high speed ship might have a short range, requiring many time-consuming stops for refueling. A good choice of speed for a future sealift ship should balance those factors against the benefit of shorter transit times and the technical risk inherent in pursuing a design significantly more advanced than those of contemporary ships. That balancing act is especially important given the declining marginal benefit of adding each knot of speed as overall speed increases (an effect illustrated by the fact that the lines in Figure 3-5 are closer together at higher speeds).

Various designs have been proposed for high-speed sealift ships (see Table 3-2). They show how greater speed comes at the cost of much larger power requirements and

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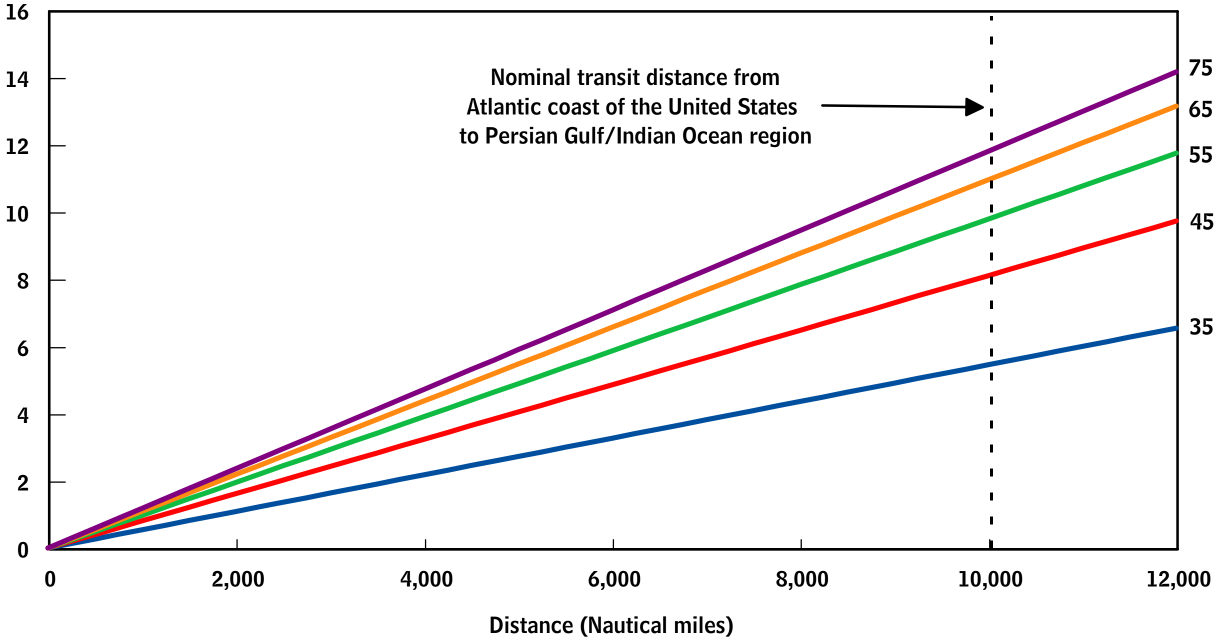
[7] Payloads of RO/ROs are typically measured in square feet of vehicle-parking space instead of in weight. The weight of cargo varies greatly depending on its density (for example, a tank is much heavier per square foot of deck space than is a helicopter). However, CBO used weight in this analysis to allow more-direct comparisons with airlift. Payload figures for prepositioned ships (the Maritime Prepositioning Force and Army Prepositioning Stock) are for expected loads. Payload figures for surge sealift ships are derived from Army data on logistics planning factors and reflect a weighted average of light-unit and heavy-unit loads.

Figure 3-5.

Decrease in Transit Time Relative to That of a 24-Knot Ship

(Number of days less)



Source: Congressional Budget Office.

smaller payloads (over a given range) for ships with external dimensions similar to those of current sealift ships.[8]

Improvements in technology over time have the potential to reduce the impact of those performance compromises; for example, advanced lightweight structural materials and propulsion plants might enable the 55-knot trimaran proposed by Naval Sea Systems Command (NAVSEA) to achieve similar ranges and payloads as a 37-knot ship with today's technology. But such advanced technologies can be difficult to realize and are likely to be more expensive than current technologies.

For its illustrative high-speed sealift (HSS) option, CBO selected a monohull design with a speed midway between those of the NAVSEA Rapid Strategic Lift Ship concept and the advanced-technology NAVSEA trimaran (see Table 3-2). Despite being slower than the conceptual trimaran, CBO's notional high-speed ship still represents a very advanced design that would push the current state of the art in hull-form design, materials technology (for lightweight hulls that can withstand the pounding of high-speed movement through water), and propulsion technology.

The characteristics of that notional HSS ship are an amalgamation of several specific designs that CBO reviewed. The ship's size would allow it to transit the Panama and Suez Canals, if necessary, and give it at least the same port accessibility as today's LMSRs. With a cruising speed of 45 knots, the HSS ship could travel 10,000 nm in eight fewer days than a current LMSR and just one to two more days than the 55-knot trimaran. That slightly longer delivery time would be balanced against having a design that was less reliant on undeveloped technology than the trimaran's. A drawback of CBO's notional ship is that, barring great technological leaps, it would not have a long enough range to travel anywhere in the world (carrying its full payload of 10,000 tons) without refueling. Consequently, it would require a ship for refueling that

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[8] Larger ships might offer both higher speed and payloads similar to those of current FSSs and LMSRs, but such ships would require even more power (to propel the increased hull and fuel weight), would be more costly, and would be very limited in the ports they could use. The world's supposed largest-capacity container ship, scheduled for delivery in 2007, is expected to be about 1,200 feet long and have a 150-foot beam, approaching the limits of even the biggest container terminals.

Table 3-2.

Characteristics of Proposed High-Speed Ships

	Sustained Speed (Knots)	Installed Power (Mwatts)	Time to Transit 10,000 nm (Days)	Nominal Payload (Tons)[a]	Range (nm)
LMSR-Type Ship	24	48	17.0	20,000	More than 10,000
FSS-Type Ship	30	90	14.0	16,000	More than 10,000
NAVSEA Rapid Strategic Lift Ship Concept (Near-term technology)[b]	36	144	11.6	5,100	8,000
CBO's Notional High-Speed Ship	45	250	9.0	10,000	5,000
NAVSEA Trimaran Concept (Long-term technology)	55	360	8.0	5,000	8,700

Sources: Congressional Budget Office; and Naval Sea Systems Command briefings.

Note: nm = nautical miles; LMSR = large, medium-speed roll-on/roll-off ship; FSS = fast sealift ship; NAVSEA = Naval Sea Systems Command.

a. Payload figures for LMSRs and FSSs come from MTMCTEA PAM 700-2; operational payloads are usually smaller. Payloads for the NAVSEA ships could be larger with midocean refueling.

b. This design is not a roll-on/roll-off ship but a ship intended to carry troops and high-value cargo, such as Marine Corps aircraft.

could be dispatched ahead or prepositioned in likely locations for that task. Alternatively, the HSS ship could carry extra fuel to extend its range, but at the expense of cargo space. This option would purchase two oilers to provide underway refueling for the HSS ships; one for trans-Atlantic missions and one for trans-Pacific missions.[9]

Less reliance on advanced technologies, coupled with the greater experience that shipyards have with monohull designs, should also make the notional HSS ship less expensive than a faster design. CBO estimates that developing the ship would cost about $2.0 billion (building on research already in progress), and buying six of them would cost $6.4 billion. The six ships would cost a total of $1.6 billion to operate for 30 years, or about $10 million annually per ship, if they were kept in four-day ROS. Despite having the same operating status, an HSS ship would cost more to operate than an LMSR, primarily because it would consume more fuel when in use. The additional procurement and operation costs of the two oilers would bring the total for this option to about $11.1 billion.

The six high-speed ships purchased under this option could make their first deliveries to a Persian Gulf deployment in about 14 days (see Figure 3-6), including an at-sea refueling so the ships could maintain a speed of 45 knots with a 10,000-ton load. That arrival time would be seven days earlier than for current fast sealift ships and 10 days earlier than for today's LMSRs, though HSS ships would deliver less cargo than those vessels because of their smaller payloads. The high-speed ships would complete delivery of a payload equivalent in weight to one Stryker brigade combat team around day 16. The base-case FSS and LMSR fleets would complete equivalent deliveries by about day 21 and day 24, respectively, under the assumptions of CBO's notional scenario. The HSS ships could deliver a second load from the United States around day 40, shortly after the first ships from the Ready Reserve Force would be expected to arrive. The deliveries from the first wave of HSS ships would increase the amount of cargo that could be delivered by almost 11 percent around day 20 (see Figure 3-6). That figure is not higher because by the time the first HSS ships arrived, a large amount of cargo would already have been delivered by prepositioned ships.

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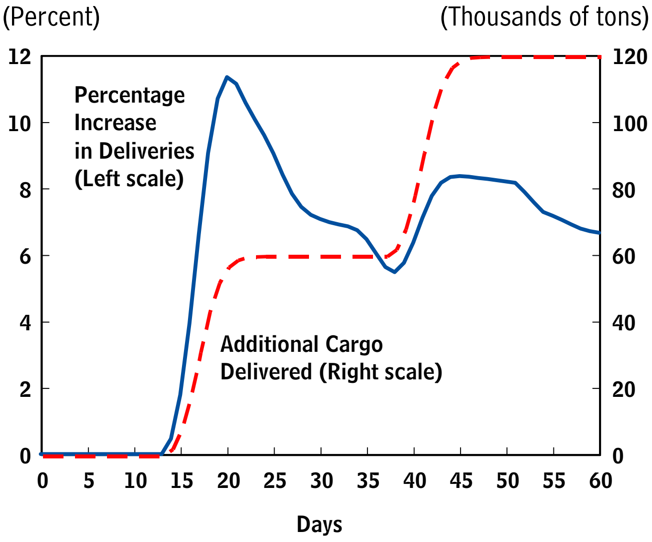
[9] HSS ships might also be able to refuel from Navy support ships already located in forward locations, if the naval task groups supported by those refueling ships could spare the fuel.

Figure 3-6.

Improvement in Deliveries from Buying Six High-Speed Sealift Ships (Option 2B)



Source: Congressional Budget Office.

Options to Expand Prepositioned Forces

Another approach for improving strategic mobility is to change how units are based or deployed in peacetime. A previous CBO analysis looked at how altering the locations of Army bases might affect deployment times. It concluded that such changes would yield only small improvements in response times to conflicts worldwide because deployment times to many potential trouble spots from the likely locations of new bases would not be significantly shorter than deployment times from current bases.[10] This study examines how greater use of prepositioned equipment might improve response times to distant conflicts.

CBO considered two approaches to expand prepositioning. For almost the same total cost, the first approach (Option 3A) would purchase both additional Army equipment and new LMSRs to carry it. The second approach (Option 3B) would buy a greater amount of Army equipment but would preposition it on LMSRs taken from the current surge sealift fleet. The additional equipment would be purchased in sets configured for Stryker brigade combat teams (BCTs). The Army is fielding medium-weight Stryker BCTs as an interim way to provide armored forces that can be transported more easily than traditional heavy units can. The Army's ultimate goal is to field even lighter, more transportable Future Combat Systems (FCS) "units of action" sometime in the next decade. CBO based these options on the interim Stryker forces because considerable uncertainty remains about the structure and cost of the proposed FCS forces.

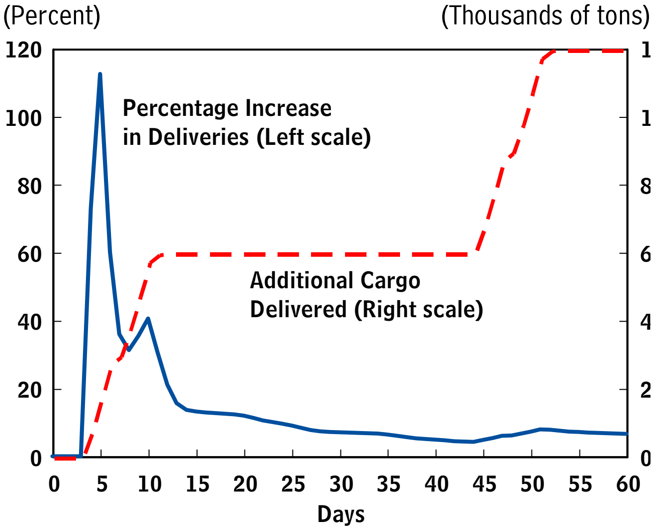
Option 3A: Purchase New Prepositioning Ships and Army Unit Sets

This option would buy four sets of Stryker BCT equipment and four LMSRs on which the equipment would be prepositioned afloat. In addition, a chartered container ship would be included for each brigade set in order to provide additional sustainment supplies to the brigade in case it was deployed for a long independent operation.

Procurement costs would comprise $2.0 billion for the four LMSRs and $6.0 billion for the four Army unit sets.

Figure 3-7.

Improvement in Deliveries from Buying Four Stryker BCT Equipment Sets and Prepositioning Them on Four New LMSRs (Option 3A)



Source: Congressional Budget Office.

Note: BCT = brigade combat team; LMSR = large, medium-speed roll-on/roll-off ship.

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[10] See Congressional Budget Office, *Options for Changing the Army's Overseas Basing* (May 2004).

Operations over 30 years would cost $3.5 billion. Of course, if more-expensive Army units were chosen for prepositioning (estimates for a similar-size unit equipped with the proposed FCS range as high as $7 billion), fewer sets of equipment could be purchased.

If two of the new brigade sets were prepositioned 2,000 nm from the site of CBO's representative deployment scenario and the other two were located 4,000 nm from that site (distances representative of past locations of prepositioned equipment), initial deliveries would begin around day 4 and would be completed around day 12.

The new prepositioned brigades would arrive earlier than the existing Maritime Prepositioning Force because these LMSRs are faster than the MPF ships. After day 45, the LMSRs could begin arriving with second loads transported from the United States.

This option would produce a large percentage increase in the amount of cargo delivered early in a conflict—more than doubling cargo deliveries on day 6, for example (see Figure 3-7). The reason is that the four LMSRs would be the first ships to arrive in the theater (only aircraft would have been making deliveries before then). The percentage improvement in cargo deliveries would drop quickly thereafter as the current MPF ships began to arrive. The peak improvement would be substantially lower if this option's four prepositioned ships were located farther from their destination. (The sensitivity of the results to assumptions about the locations of afloat prepositioned forces is discussed in Chapter 4.)

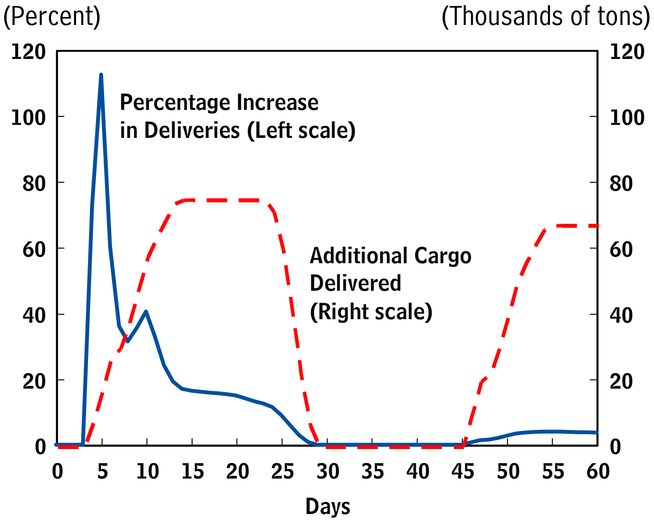
Option 3B: Purchase Army Unit Sets and Preposition Them on Existing LMSRs

The other prepositioning option in this analysis would buy five sets of Stryker BCT equipment rather than four. To make up for the greater spending on equipment, it would preposition those sets on existing LMSRs taken from the surge sealift force. As in Option 3A, a chartered container ship would be included with each brigade set to provide additional sustainment supplies if necessary. The costs of this option would total $11.1 billion: $7.5 billion for procurement of the Army unit sets and about $3.6 billion for operations and support over 30 years.

Initially, this option would produce the same improvement in deliveries as Option 3A, as the first four brigade sets arrived from their propositioning locations 2,000 and 4,000 nm away. Around day 16, however, this option would deliver more than the previous alternative because the additional brigade set would arrive (see Figure 3-8).[11]

Figure 3-8.

Improvement in Deliveries from Buying Five Stryker BCT Equipment Sets and Prepositioning Them on LMSRs Taken from the Surge Sealift Fleet (Option 3B)



Source: Congressional Budget Office.

Note: BCT = brigade combat team; LMSR = large, medium-speed roll-on/roll-off ship.

At about day 30, the amount of additional cargo delivered relative to the base case would drop to zero because the extra arrivals of prepositioned equipment early in the scenario would be cancelled by the corresponding reduction in arrivals by the now-smaller surge sealift force. The net effect would be positive, however, because even though the total amount of cargo delivered over time would not increase, each load carried by the five LMSRs transferred from the surge force to the prepositioned force would arrive several weeks earlier.

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[11] CBO assumed that the fifth brigade set would be prepositioned farther away (6,000 nm) to cover another part of the world but that it would be pressed into service in the notional scenario.

CHAPTER

4

Comparison of Strategic Transportation Options

Although the options for improving strategic mobility described in Chapter 3 would have roughly the same total costs, according to the Congressional Budget Office's estimates, they differ greatly in the military capabilities they offer. For example, the airlift options would improve the promptness of strategic deployments to a greater extent than the sealift options would; however, their addition to throughput capacity would be lower, on average. Some options would surpass others in terms of ability to operate with limited support infrastructure, to get units on their way quickly once cargo had been unloaded, and to survive enemy attack. Of course, a given capability may be more or less valuable depending on how the future unfolds. This chapter compares the six options according to various measures and describes the sensitivity of each option's performance to changes in the conditions of CBO's representative deployment scenario.

Promptness and Throughput Capacity

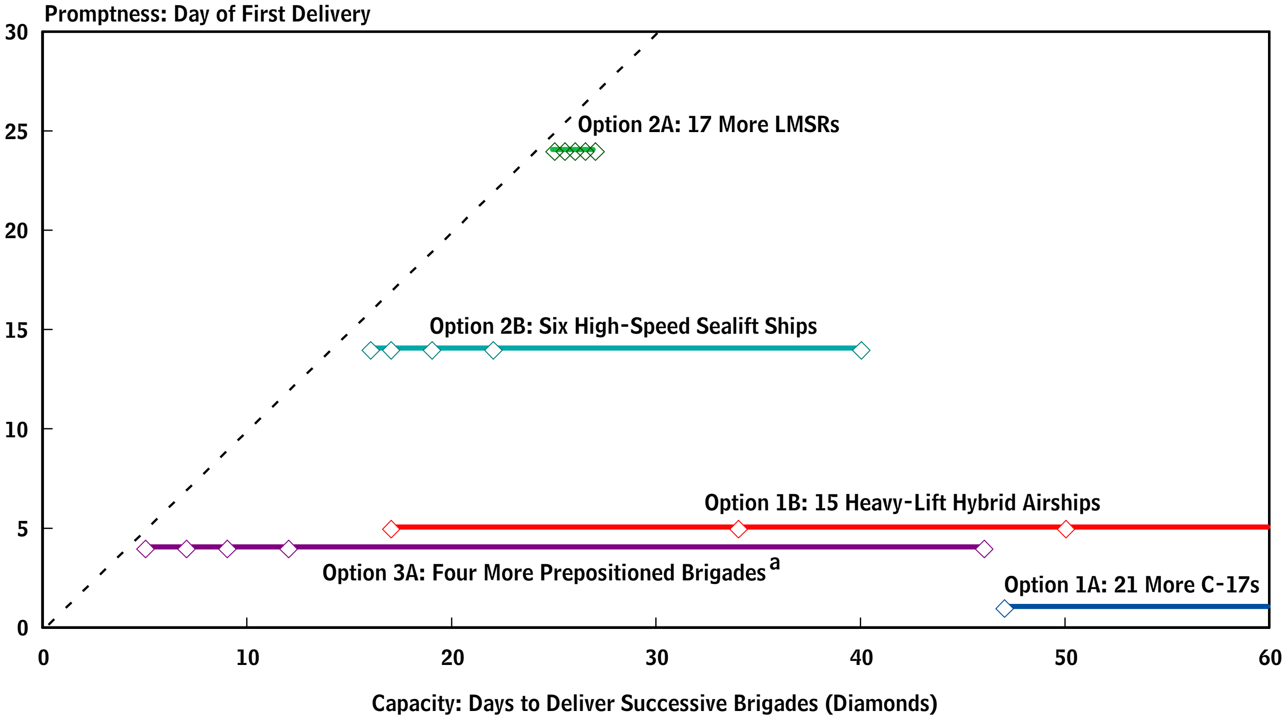
The amount of time needed to move military units a given distance after a deployment order and the amount of cargo that a transportation system can move are the primary measures that CBO used to assess the effectiveness of the options to expand mobility forces. As illustrated in Chapter 3, each option would have its own characteristic delivery profile, and differences between those profiles result in different improvements in cargo deliveries (relative to those of the base-case force) at any particular point in the scenario. Only the airlift and prepositioning options would improve deliveries in the first week of a notional deployment to the Persian Gulf or Indian Ocean region, and the prepositioning options would deliver significantly more cargo than the airlift options during that time. By the end of the second week, the more distant prepositioned brigades would have arrived, and the high-speed sealift ships in Option 2B would begin to arrive as well. By the end of week 3, the HSS force would have completed its first deliveries, and the contributions of airlift would continue to grow. The new large, medium-speed roll-on/roll-off ships in Option 2A would not arrive until the fourth week, but when they did, their enormous capacity would dwarf the deliveries of the other options.

In terms of delivering enough cargo for a Stryker brigade combat team, the prepositioning options (3A and 3B) would offer the best combination of promptness and throughput capacity (see Figure 4-1). In the figure, promptness is plotted on the vertical axis and measured by the time needed for the additional systems to make their first delivery to the theater of operations. Throughput capacity is plotted on the horizontal axis and is measured by the time required to complete delivery of amounts of cargo equivalent to those needed for successive Stryker BCTs (marked as diamonds on the line for each option).

The promptness of the options depends on the performance characteristics of each system. Throughput capacity, in turn, depends both on promptness and on the number of systems purchased. If there are no constraints on support infrastructure, purchasing greater quantities of a system can increase throughput capacity. But promptness limits this approach for boosting throughput capacity, because having an unlimited number of aircraft or ships will not increase the speed with which the first ones arrive in a theater. (Purchasing greater quantities of a system would shift deliveries to the left only as far as the dashed line in the figure, which denotes the earliest arrival of a type of ship or aircraft.) The relative value of promptness versus throughput capacity—and hence the types and quantities of strategic transportation systems that the military might choose to buy—will depend on

Figure 4-1.

Promptness and Capacity to Deliver Five Brigades Under Various Options for Expanding Strategic Mobility Forces



Source: Congressional Budget Office.

Note: The diamonds represent successive Stryker brigade combat teams arriving in the notional theater of operations. These deliveries are in addition to those made by current strategic mobility forces. The dashed line indicates the earliest possible delivery time for a brigade using a given transportation system. (The distance between that line and the first diamond represents the potential room for improvement from adding to the number of platforms in that system.)

a. Option 3B, which would preposition equipment for five additional brigades on large, medium-speed roll-on/roll-off ships (LMSRs) transferred from the surge sealift fleet, is not shown. It would deliver four Stryker brigade combat teams at the same times as Option 3A and a fifth about two days later. During the fourth week, however, those additional arrivals would be negated by the fact that the LMSR fleet arriving at that time would have five fewer ships.

DoD's determination of its plans and requirements for responding to future crises.

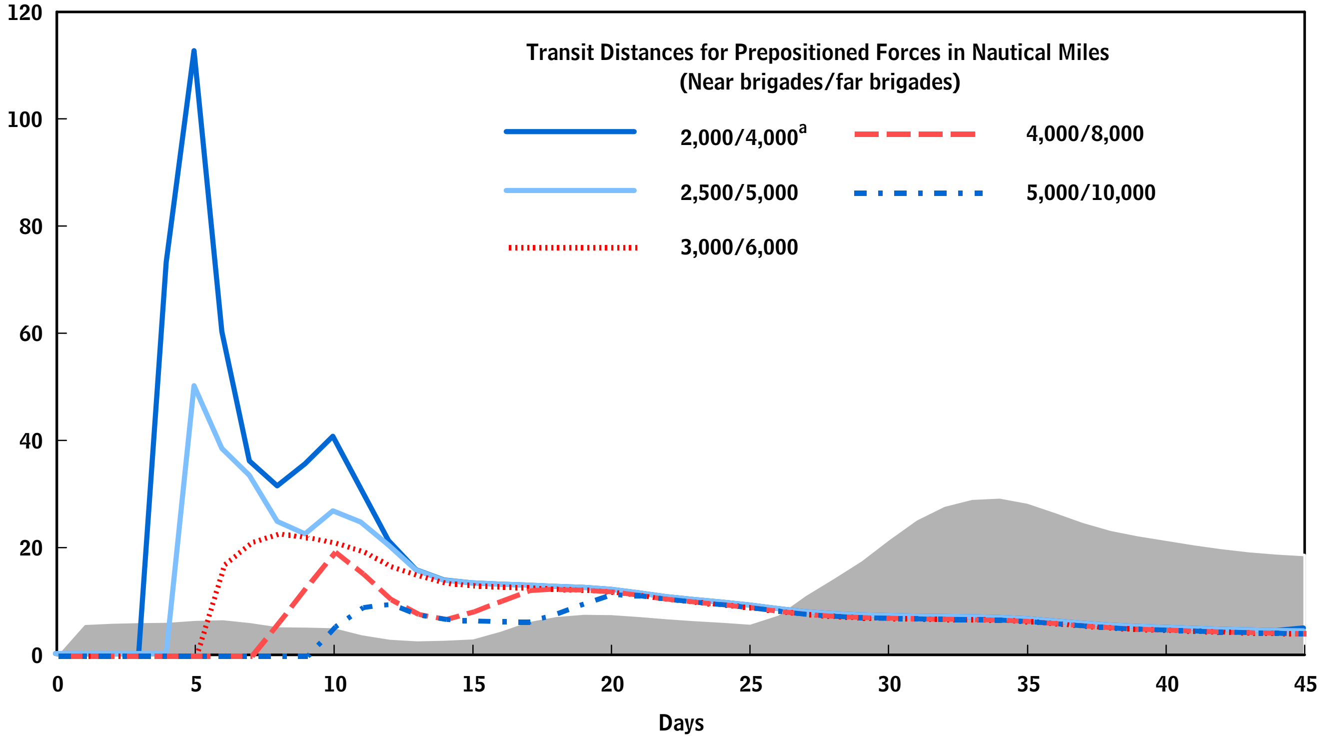
The relative results between options are sensitive to the geographic assumptions that underlie the base-case scenario—most important, how far the destination point is assumed to be from the location of prepositioning ships and from the United States. In the prepositioning options, only those brigade sets located 2,000 nautical miles from the theater would arrive in the first week of the notional scenario. Sets based 4,000 nm away would not arrive until the second week. Greater transit distances not only delay arrival times but also lower the percentage increase in cargo delivered at a given time (see Figure 4-2). Nevertheless, for a deployment from the United States to the Persian Gulf, the peak improvements offered by the prepositioning options (even under very pessimistic assumptions about the locations of prepositioned equipment) would be better than those of the other options.

Just as distance affects deliveries of prepositioned equipment, cargo deliveries from the United States by airlift or surge sealift could increase early in a conflict for scenarios closer to North America. As long as support infrastructure is not a constraining factor, shorter transit distances will allow more-rapid cargo delivery. Under the base-case

Figure 4-2.

Percentage Increase in Cargo Deliveries Under Option 3A at Various Transit Distances

(Percent)



Source: Congressional Budget Office.

Note: The shaded area shows, for comparison, the largest increase in deliveries offered on a given day by the airlift or sealift options (1A, 1B, 2A, or 2B). This figure assumes that the locations of current prepositioned forces remain the same.

a. The distances used in Option 3A.

scenario's assumptions about transit distances from the United States, airlift and sealift would take more time to deliver a Stryker brigade combat team than would an afloat prepositioning ship located 6,000 nm from its destination—a poor location for prepositioned forces. Of the airlift and sealift options, the high-speed ships in Option 2B could deliver a complete BCT from the United States in the least time (although still about two more days than an afloat prepositioned force located 6,000 nm from the conflict), and the heavy-lift airships in Option 1B would take about a day longer.

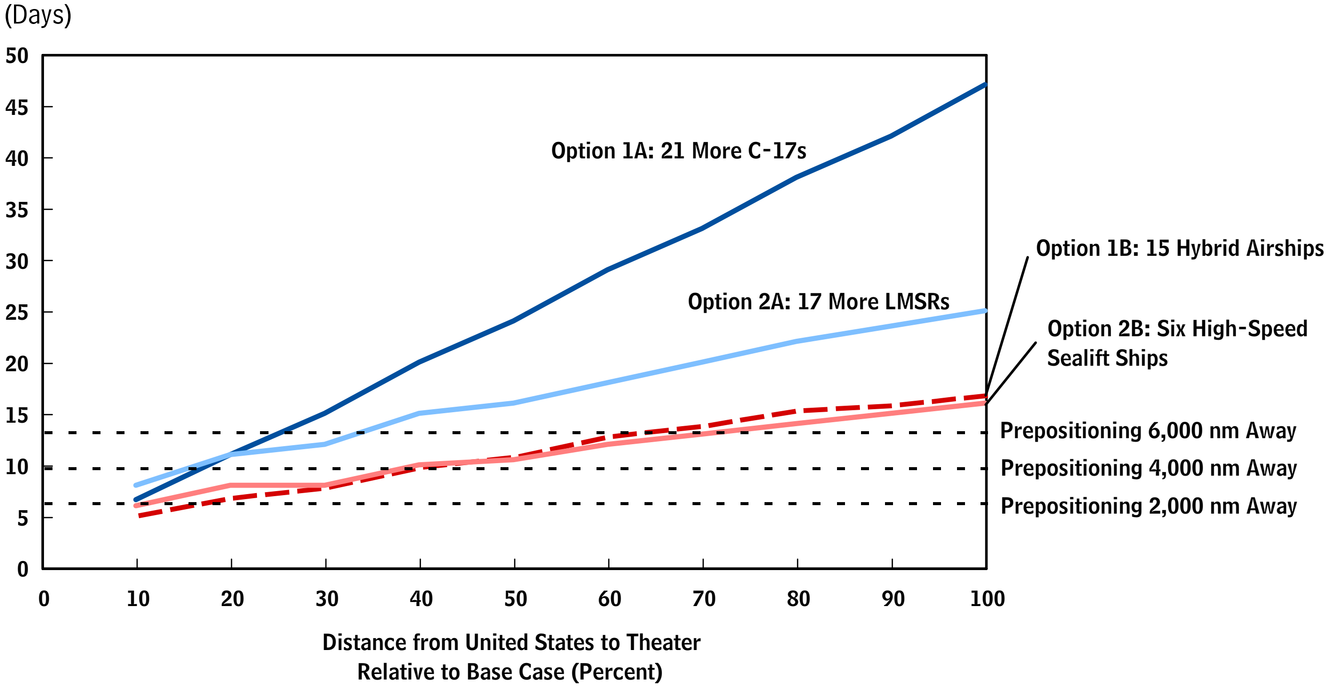
Deliveries for the high-speed ship and airship options match or beat those of the prepositioned forces located 6,000 nm from a conflict as the deployment distance from the United States decreases to less than about 75 percent of that of the base case (see Figure 4-3). The extra C-17s, LMSRs, or HSS ships deploying forces from the United States do not compete favorably with such prepositioning unless their transit distances are less than about one-third of those from the United States to the Persian Gulf or Indian Ocean region. Those aircraft or ships do not compete favorably with better-located prepositioned forces unless the distance to the conflict is actually shorter from the United States than from the site of the prepositioned equipment.

The Impact of Infrastructure Constraints

With few exceptions, today's strategic transportation systems rely on support infrastructure in a theater of operations to complete their deliveries. Aircraft require air bases and most sealift ships require deepwater ports for

Figure 4-3.

Time Needed to Deliver First Additional Stryker Brigade Combat Team at Various Deployment Distances



Source: Congressional Budget Office.

Notes: The transit distances assumed in the base-case deployment scenario are 7,000 nm for C-17s; 8,500 nm for airships; and 9,900 nm for LMSRs and high-speed sealift ships.

LMSR = large, medium-speed roll-on/roll-off ship; nm = nautical miles.

unloading.[1] In many cases, the availability of such facilities—not the availability of the transportation systems themselves—determines the rate at which cargo can be delivered to a theater. When infrastructure is a bottleneck, adding mobility systems that rely on the same infrastructure typically does little to improve the rate of cargo delivery.

Infrastructure for Airlift

The airfield infrastructure in a theater is measured by a quantity called maximum on ground, or MOG. The term MOG evokes an image of the number of aircraft that can physically be parked on an air base's tarmac. That number, however, is only a subset of MOG called "parking MOG." Of greater interest to mobility calculations is "working MOG," a measure of an air base's ability to process airlift missions, not just provide places to park. Working MOG is defined as the number of aircraft that a base can process simultaneously *within each aircraft's planned ground time*. Many factors can constrain working MOG, including limits on parking space, cargo-handling equipment, ability to refuel aircraft, and local air traffic control. Many of those factors change over time (for example, extra cargo loaders can be flown to a base), so MOG is a dynamic quantity. Each type of aircraft "consumes" some amount of MOG depending on such characteristics as its ground time, need for fuel, need for special loading equipment, and physical size. A theater's MOG is a situation-dependent aggregation of the MOGs of the constituent air bases.[2]

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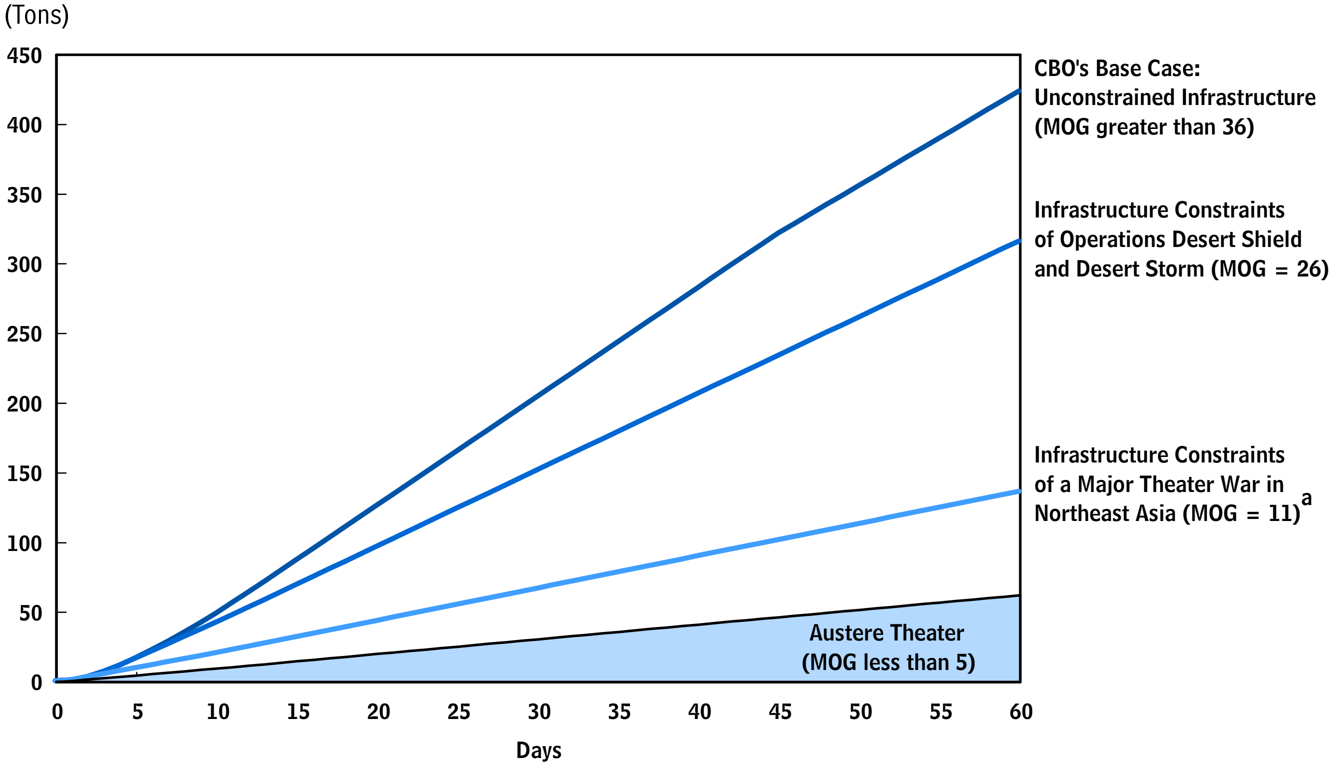
1. Exceptions might be airdrops of airborne units and the use of "over the shore" lighterage (barges) to unload transport ships. However, those and other alternative means of delivery are very limited in the types of cargo they can handle and the rate at which they can deliver it.

2. Theater MOG is not necessarily a simple sum of the MOGs of individual air bases. For example, planners usually assume that a C-5 transport plane consumes two C-17 MOG equivalents. A large air base with a MOG of 2 might have the capacity for two C-17s or one C-5. That capacity is not the same as a MOG of 2 that represents two smaller bases, each of which could handle one C-17 but might be too small for a C-5 to land.

Figure 4-4.

Airlift Deliveries Under Varying Degrees of Constraints on Airfield Infrastructure



Source: Congressional Budget Office.

Note: Maximum on ground (MOG) is a measure of the number of aircraft that a base can process simultaneously within the aircraft's planned ground times. It is affected by limits on parking space, cargo-handling equipment, ability to refuel aircraft, and local air traffic control, among other factors. MOG is usually defined in C-17 equivalents.

a. As estimated in Institute for Defense Analyses, *Cost and Operational Effectiveness of the C-17 Program* (Alexandria, Va.: IDA, 1993).

The base-case airlift fleet and deployment distances used in this analysis would require a working MOG of about 36 C-17 equivalents for unconstrained surge operations, CBO estimates.[3] That figure assumes there are no queuing inefficiencies at the offload base and includes the MOG needed for enough passenger aircraft from the Civil Reserve Air Fleet to deliver personnel at a rate commensurate with the rate at which unit equipment arrives. If the MOG available in the theater was less than 36, airlift deliveries would be constrained to a lower level (see Figure 4-4). Deliveries would be reduced by about 25 percent, for example, in a theater whose working MOG was roughly equivalent to that available in Operation Desert Shield. Many experts expect that limited infrastructure will be the norm in future conflicts.

In the case of infrastructure constraints, the 21 additional C-17s in Option 1A would not provide the improvement in deliveries estimated above. Those aircraft would add about 1.1 C-17 MOG equivalents to the total demand for airlift MOG, a demand that would already be higher than very extensive infrastructure could support. Some improvement might be realized if the additional C-17s displaced other aircraft in the scenario, because C-17s are more efficient in terms of payload delivered per unit of MOG consumed than those aircraft. That improvement would only be the difference between the two aircraft, however. Additional C-17s could also increase the effective MOG available in a theater by taking greater advantage of small airfields that other airlifters cannot use, although the 155 C-17s already in the base-case force would be likely to saturate those airfields as well.

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[3] Deployment distance influences the demand for MOG because aircraft can arrive at a destination more frequently when the round-trip time is shorter, driving up the demand for MOG. Defining MOG in terms of an aircraft type-equivalent allows the aggregation of the MOG demands of the particular aircraft types that might be supporting an operation.

The possibility that additional C-17s might offer little or no improvement in a large deployment to a single theater does not necessarily mean that more C-17s would not be useful in other circumstances. The Air Mobility Command supports military activities around the world. On any given day, those activities could include Presidential support flights, humanitarian relief missions, and missions to support the military's regional combatant commanders. Because this analysis did not assess those day-to-day demands for strategic airlift, its conclusions are only one piece of the information needed to make judgments about the appropriate force structure for the Air Mobility Command.

The hybrid airships in Option 1B would have the advantage of being virtually independent of airfield constraints. When departing its loading site with a full load, a hybrid airship would need a long runway or other open space to gain enough speed, and hence dynamic lift, for takeoff. That would probably not be a serious operational constraint, however, because loading locations would usually be in the United States, where they could be planned for in advance. Upon arriving in a theater, a hybrid airship should be able to land in a much shorter distance than on takeoff because it would have burned much of its fuel and thus would need less speed-generated dynamic lift for a gentle landing. After unloading, the now neutrally (or perhaps slightly positively) buoyant airship should be able to take off almost vertically.

Infrastructure for Sealift

The sealift alternatives analyzed in this study—both the surge options (2A and 2B) and the afloat prepositioning options (3A and 3B)—would require large deepwater ports so that ships could be unloaded at pier-side via their ramps. Because similar facilities would be needed for all of the sealift options, a comparison of their infrastructure requirements necessarily focuses on the extent to which each option would change the need for port infrastructure in the theater of operations.

The demand for port infrastructure varies over time as sealift ships arrive in the theater, are unloaded, and depart. That demand is uneven because similar types of ships require a similar amount of time to reach their destination and thus tend to arrive in clusters. Consequently, although the number of ships in port at any one time in the base-case scenario averages only about 3.4, that simultaneous demand peaks at 13 ships on days 12 and 13, when the second MPF squadron begins to arrive and Army prepositioned ships are being unloaded. If necessary, the peaks and valleys of demand for port infrastructure could be smoothed by deliberately scheduling ship arrivals. However, such scheduling would require delaying some arrivals, which would slow delivery rates.

Of the four ship-based options, only Option 2A, with its 17 additional LMSRs, and Option 3B, with its five additional prepositioned brigades, would result in a greater peak demand for port infrastructure than the base case. That peak would be exceeded on only one day (day 27) and by a total of just one ship for Option 2A, and on two days (day 12 and day 13) by two ships for Option 3B (see Figure 4-5). Otherwise, CBO's analysis indicates that a port infrastructure able to accommodate the base-case mobility force could accommodate the additions to that force under the surge sealift and afloat prepositioning options. Average demand for port facilities would increase by slightly more than one ship.

If adequate port facilities are not available, current mobility forces have some capability to move cargo ashore. Some MPF and Ready Reserve Force ships carry their own barges or other lighterage for that purpose, and the Joint Logistics Over the Shore system of portable causeways and lighterage can also move cargo from sealift ships. Those systems are slow, however, resulting in much longer unloading times than when a ship is at a pier. In addition, current over-the-shore systems cannot operate in poor weather or rough seas.

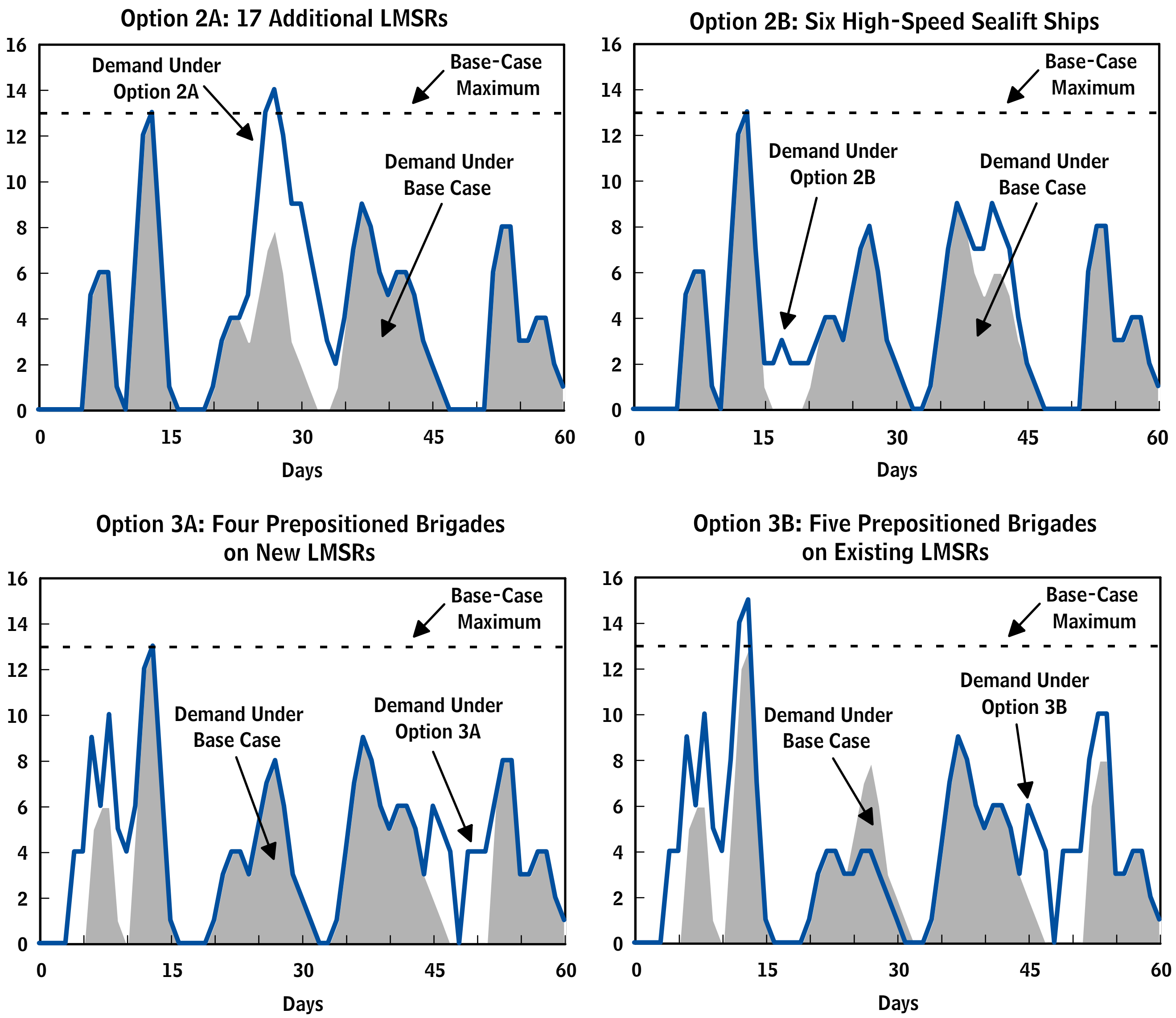
In the future, the Department of Defense would like to develop shallow-draft sealift ships (preferably with high speed as well) that could deliver cargo to smaller ports. Although such ships could increase a theater's total port capacity, (much as the C-17's ability to use small airfields can increase a theater's MOG), it is unlikely that even the best over-the-shore systems operating from smaller ports could match the unloading rates achieved in a large established port. Moreover, such shallow-draft sealift ships would be challenging to develop. When loaded, a ship with a large payload and a transoceanic range will be very heavy and thus will have to displace a great deal of water, making shallow draft a difficult objective. CBO did not include such an option in this analysis because of the uncertainty about when or even whether those ships could be developed.

Alternatively, concern about future access to foreign ports has led the Navy and Marine Corps to explore new sea-

Figure 4-5.

Demand for Seaport Infrastructure Under Various Options

(Number of ships at debarkation ports)



Source: Congressional Budget Office.

Note: LMSR = large, medium-speed roll-on/roll-off ship.

basing concepts that try to avoid port constraints altogether. Sea basing would involve transferring cargo and personnel at sea from large strategic transports onto smaller, intratheater systems capable of operating without support infrastructure. However, the at-sea transfer and intratheater transit could themselves become a bottleneck to deliveries, compared with all but the most constrained scenarios. Plans for sea basing are still in the early stages of concept definition.

Length of the RSOI Stage

As described in Chapter 2, after a military unit is first unloaded in a theater, it goes through the process of reception, staging, onward movement, and integration before it is ready to operate where it is needed. RSOI includes activities such as marrying up equipment and personnel that arrive separately, converting equipment from its transport configuration to its combat configuration (if necessary), arming weapons and fueling vehicles, assembling into units, and marching to the final destination.

An ideal strategic mobility system could deliver combat-configured units with their personnel directly to where they were needed in the theater. Unfortunately, the different transport needs of humans and cargo, plus the requirement that most transportation systems have for fixed infrastructure support, make achieving an RSOI-less deployment impractical with today's transportation platforms.[4]

In general, RSOI times can be expected to range from a few days to more than a week depending on the distance from the debarkation point to the operations area and the quality of the local road or rail infrastructure in between. A RAND Corporation study of Stryker BCT deployments, for example, estimated road-march times that varied from almost nothing for an Indonesian scenario (where every location is near the coast) to slightly over a week for an intervention in Rwanda in central Africa.[5]

Because of that dependence on the specifics of a scenario, it is not possible to make absolute comparisons of RSOI times for different transportation options. Several general conclusions are possible, however. First, under most circumstances, cargo delivered by aircraft should arrive at least as close to a unit's final operations area as cargo delivered by ship. Most locations with port facilities large enough to support sealift ships will have large airfields nearby, and aircraft also have the possibility of making deliveries inland. Second, although aircraft may be able to deliver units closer to their destinations, the piecemeal arrival of equipment (a few tens of tons at a time) could make the staging process more inefficient and time consuming. In any large deployment, individual aircraft will experience delays because of factors such as poor weather or maintenance problems. The randomness that such delays can introduce into the flow of equipment to a theater can increase the time needed for reception and staging.[6] In contrast, a single ship load can contain large portions of a unit—if not the entire unit—easing the task of reception and staging.

Among CBO's options for improving strategic mobility, only the hybrid airships in Option 1B would have different implications for RSOI times than the transportation systems in the current force. The ships and aircraft in the other options would be delivering their cargoes to the same locations as the base-case force. An airship, by contrast, might be able to deliver its cargo to any open area large enough to accommodate its size and low approach speed. Such an open area need not have a runway and could potentially be as short as twice the length of the airship, depending on the local conditions and the airship's weight when loaded. Of course, the landing area would need to be far enough from the action that there was not a significant risk of ground fire against the airship. Although proponents claim that hybrid airships would be able to withstand some attacks, CBO has seen no suggestions that they might be suitable for assault landings under enemy fire. (That issue is discussed in the next section.)

Another characteristic that might allow airships to reduce RSOI times could be the ability to transport personnel together with their equipment, avoiding the step of marrying up troops with their vehicles and other equipment. Today, aircraft are the preferred means of transport for personnel, because a flight to the other side of the world can be completed in hours, whereas a sea voyage would take weeks. Equipment can be carried along with personnel on military airlifters, but only at the expense of substantially reducing payloads because of space and safety considerations for composite loads.[7] Because space should not be an issue on a hybrid airship, it might be able to provide shiplike accommodations for troops traveling with their equipment. Some airship proponents suggest that units could even conduct mission planning

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[4] Strategic brigade airdrops come close to having little or no RSOI, as do Marine Corps amphibious assaults, although the marines might need some time for onward movement if their objective was inland.

[5] See Alan Vick and others, *The Stryker Brigade Combat Team: Rethinking Strategic Responsiveness and Assessing Deployment Options,* MR-1606-AF (Santa Monica, Calif: RAND Corporation, 2002), available at www.rand.org/publications/MR/MR1606/.

[6] DoD is trying to ease that problem by improving the in-transit visibility of cargo—that is, being able to track cargo loads in transit, much as commercial customers can track the progress of packages on shippers' Internet sites. Knowing where a load of cargo is in the transportation system should allow for a smoother reception when the load arrives in the theater.

[7] The C-5 is an exception because it has an upper deck that can carry 73 people separately from the cargo hold below. The weight of the personnel must be factored into the allowable payload, however.

and tabletop rehearsals during transit, much as marines can do today on board amphibious assault ships. An objective of DARPA's Walrus airship program is to deliver units or portions of units—both equipment and personnel—that would be ready for combat operations within six hours of arriving in the theater. A future high-speed sealift ship could also be designed to carry troops with their equipment because of the shorter transit times relative to today's slower ships. Accommodations for people would come at the expense of space for cargo, however.

Survivability

Although strategic transportation forces are usually responsible for delivering cargo and troops to secure locations, situations can arise in which airlifters and sealift ships are sent into harm's way. For example, during Operation Iraqi Freedom, several airlift aircraft have been hit by ground fire while flying into Baghdad. In addition, the Iraqi naval mines that damaged the guided missile cruiser *U.S.S. Princeton* and the amphibious assault ship *U.S.S. Tripoli* during Operation Desert Storm could have damaged sealift ships delivering forces to Saudi Arabia, and the terrorist attack against the destroyer *U.S.S. Cole* in Yemen could just as easily have been directed against a sealift ship. In such situations, the ability of a transportation system to avoid being hit—or to survive if hit—can be important, especially since the cargo it carries may be critical to the success of operations on the ground.

To protect against attack, airlifters are often equipped with countermeasures, including missile warning systems to help them avoid threats and flares to try to fool infrared missiles (such as those launched by shoulder-fired surface-to-air missile systems). Additionally, in a threatening environment, airlifters might operate only at night, to make visual tracking more difficult for an enemy, and might fly much steeper approaches and departures, to stay out of the range of ground fire as long as possible. Sealift ships, for their part, are protected by security forces when in port and by naval forces when at sea (if the threat warrants an escort).

The options in this analysis that would rely on C-17s (Option 1A) or LMSRs (Options 2A, 3A, and 3B) would have much the same survivability as current strategic transportation forces. The high-speed sealift ships in Option 2B might be more survivable than slower ships because they could, for example, outrun any threatening submarines they encountered. However, most of the threats facing sealift ships would probably occur near the ship's destination, where even HSS ships would have slowed down prior to entering port.

As was the case with RSOI, the hybrid airships in Option 1B could have unique advantages in terms of survivability. On one hand, their large size, low altitude, and slow speed would make airships very easy to detect, track, and shoot at. On the other hand, proponents argue that although an airship might be easy to hit, it could operate successfully in a threatening environment for several reasons:

- A large airship could easily carry an extensive set of defensive systems, such as missile countermeasures and even air-to-air missiles to defend against hostile aircraft.
- The cargo compartments could be armored with materials that are too heavy or bulky for use on conventional aircraft.
- The low speed of an airship means that if it was hit, it would not be susceptible to the large dynamic stresses that can cause conventional aircraft to break up in flight when damaged.
- The helium in the compartments of the hull would be at only a slightly higher pressure than the ambient atmosphere, so it would leak very slowly out of any holes shot in the hull. Consequently, if an airship was hit by ground fire, it would not pop like a rubber balloon but rather lose buoyancy slowly like a mylar balloon.

Investigating the feasibility of those proposed characteristics would be an important part of any program to develop a heavy-lift hybrid airship.

Other Considerations

Besides affecting promptness, throughput capacity, infrastructure dependence, RSOI times, and survivability in a strategic deployment, the options in this analysis would have implications for the military's ability to support peacetime missions and to modernize current strategic transportation forces.

Support for Peacetime Missions

The U.S. military uses its mobility systems to support missions around the world on a daily basis. Options that could contribute substantively to those day-to-day activities would have a usefulness not reflected in CBO's analysis of a major deployment. Although the additional forces in any of the six options could be used to support smaller operations, those in the airlift alternatives—especially the C-17s in Option 1A—would probably have the greatest day-to-day utility.

Sealift ships and prepositioned sets of unit equipment are less likely to be called on frequently because they represent relatively large increments of combat power and because, if they were used for small operations, they would need a fairly long period to return to a state of readiness for a major operation. (Prepositioned equipment would have to be serviced and reloaded on ships, and the ships would have to steam to where they were needed.) In contrast, airlift aircraft, especially C-17s, offer smaller increments of power that are better matched to peacetime needs and that can be rapidly redirected to support a major operation, should one arise.

For the two airlift options (1A and 1B), the estimates of operation and support costs described in Chapter 3 and the appendix are based on historical data for C-17 operations that include peacetime missions. CBO included those costs under the assumption that if the Air Force had the additional planes or airships, it would use them. More C-17s or airships could be purchased within the spending target if the airlift options were artificially assigned lower annual support costs to more closely match those of the sealift options. For example, if the estimated support costs for Option 1A were reduced by half, nine additional C-17s could be purchased. Such differences would not affect the broad conclusions of this analysis, however.

Impact on the Base-Case Strategic Mobility Force

Because this study focused on options for improving strategic mobility, it did not look at what actions might be necessary over the next few decades to maintain the capabilities already in hand. Current plans suggest little need for concern about the C-17 and C-5 fleets, since the C-17s are relatively young and the C-5s are scheduled for extensive modernization. The situation is not as clear for sealift, however. Both the roll-on/roll-off ships in the Ready Reserve Force and the Military Sealift Command's fast sealift ships are quite old and may need to be replaced or refurbished in coming years.

The sealift options (2A and 2B) and the prepositioning option that would purchase additional LMSRs (3A) would substantially increase throughput capacity in a deployment as well as improve promptness. Thus, those options could serve as at least a part of any program to replace the existing strategic mobility force. If the additional average throughput capacity was not needed, those options could allow older ships to be retired without replacement, greatly reducing the costs for operating and maintaining the base-case force. The extent to which such savings might offset the costs of the options would depend on what DoD defined as its future requirements for strategic mobility.

APPENDIX

A

How CBO Estimated the Costs of the Options in This Study

The cost estimates for the options described in this analysis have two major components: one-time investment costs that would arise over the next decade or so when the airlift or sealift systems were being developed and built, and operation costs that would be incurred over 30 years once the first new system was delivered. This appendix describes the methods that the Congressional Budget Office (CBO) used to estimate the costs of development efforts, equipment purchases, and operations. The estimates represent incremental costs—the expenses that would occur in addition to the total cost of maintaining current strategic mobility capabilities. All of the cost estimates are in 2006 dollars; they are summarized in Table A-1.

Significant uncertainty exists about the capabilities, technologies, and costs associated with developing, purchasing, and operating the airships and high-speed sealift ships envisioned in Options 1B and 2B, respectively. Programs such as those, which are either in the early stages of development or are conceptual in nature, entail a greater risk of cost and schedule overruns than do programs that are better defined and based on proven technologies. CBO's cost estimates for those options represent one possible outcome, calculated under specific assumptions. Although the estimates take such risk into account to some extent, CBO expects that its estimates would change, perhaps significantly, as the design of a particular system was more fully defined.

Methods for Estimating the Costs of C-17 Aircraft

CBO estimates that buying and operating another 21 C-17s to enhance airlift capacity (Option 1A) would cost a total of $11.3 billion: $4.4 billion for procurement and $6.9 billion for operations. Since the option would simply purchase more units of an aircraft that is already in production, there would be no additional costs for research and development.

Procurement Costs

CBO estimated the procurement costs for 21 additional C-17 aircraft by extrapolating the actual costs of the 143 C-17s purchased between 1992 and 2005. On average, those aircraft cost approximately $300 million apiece in 2006 dollars—although the last 15 C-17s ordered by the Air Force in 2005 cost just over $215 million each—including the costs of support equipment, simulators, and spare parts. CBO estimates that the unit production cost for an additional 21 C-17s would average about $210 million. CBO assumed that 15 of the aircraft would be purchased in 2008 and the other six in 2009 (the years immediately following completion of currently planned production) and would enter the inventory in 2010 and 2011.

Operation Costs

CBO based its estimates of operation and support (O&S) costs for the additional C-17s on actual O&S costs for the aircraft as reported in the Air Force's Total Ownership Costs (AFTOC) database. Those data indicate that operating a C-17 costs about $12 million a year, including costs for military pay, fuel, and maintenance that are directly associated with the operations of the C-17 fleet as well as costs for indirect activities such as training and base support. CBO assumed that 19 of the 21 additional C-17s would be part of the operational inventory, and the other two would serve as reserves in case any of the primary aircraft were lost or otherwise unavailable. The reserve aircraft would have minimal annual operating costs.

Table A-1.

Costs of the Options for Improving Strategic Mobility Forces

			Costs (Billions of 2006 dollars)			
Option	Description	Quantity	Development	Procurement	Operations[a]	Total
1A	Buy more C-17s	21	0	4.4	6.9	11.3
1B	Develop and buy heavy-lift hybrid airships	16 14	3.0 (low) 4.0 (high)	4.8 4.3	3.4 3.0	11.2 11.3
2A	Buy more LMSRs	17	0	8.4	2.9	11.3
2B	Develop and buy advanced-technology high-speed sealift ships	6	2.0	7.2	1.9	11.1
3A	Buy Stryker brigade sets and LMSRs for prepositioning	4	0	8.0	3.5	11.4
3B	Buy Stryker brigade sets and preposition them on existing LMSRs	5	0	7.5	3.6 [b]	11.1

Source: Congressional Budget Office.

a. Operation costs are for 30 years from the year in which the first system is delivered.

b. Operation costs relative to Option 3A are not proportional to the number of brigades because ship costs include only the difference between LMSRs in the prepositioning force and LMSRs in the surge sealift force.

Methods for Estimating the Costs of Airships

For total costs of a little over $11 billion, the Department of Defense (DoD) could improve its airlift capacity by developing, buying, and operating 14 to 16 hybrid airships with a payload of 500 tons (Option 1B), CBO estimates.[1] That quantity range reflects ranges of estimates for development, procurement, and operation costs. As noted above, significant uncertainty exists about the capabilities and technologies associated with such a heavy-lift airship, which translates into significant cost risk.

Research and Development Costs

Analysts usually rely on previous analogous programs as the basis for estimating the cost of new systems. In this case, airships in operation today include various commercial blimps such as those of Goodyear and Fujifilm, and a handful of platforms from other countries. DoD's recent experience with airships is limited to a dozen aerostats (tethered balloons) operated by the Air Force. Development costs for both the commercial and DoD programs averaged less than $100 million. One exception was a commercial program to develop a lighter-than-air cargo lifter (referred to as the CL-160) that would be capable of carrying 160 tons. The program never entered production, but development costs totaled about $400 million at the time work on the aircraft ceased.

Existing blimps are smaller and less complex than the hybrid airship envisioned in Option 1B—the new airship would have 10 times the volume of those smaller platforms, significantly greater lift capability, and a different hull shape (designed to provide dynamic lift in addition to static lift). Lacking an appropriate analogous system, CBO had no basis on which to make an independent estimate of the costs to develop the new airship. Thus, for this study, CBO sought information from a variety of sources including aerospace industry contractors to guide its estimate of the costs for developing a 500-ton-payload airship.

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[1] The characteristics of CBO's notional airship are similar to the objective characteristics of the alternatives for heavy-lift airships being studied as part of the Defense Advanced Research Projects Agency's Walrus program.

CBO factored into its estimate the costs of building prototypes, conducting a vigorous program of testing and evaluation, the costs of government activities such as systems engineering and program management, and past rates of cost growth in DoD's aircraft programs. The costs to develop the hybrid airship would total between $3 billion and $4 billion, CBO estimates.

Procurement Costs

Similarly, CBO used information from contractors as a starting point to estimate procurement costs for Option 1B. As with the estimate of development costs, CBO included government costs and historical cost growth in its estimate. With those factors, CBO estimated that the first airship could be purchased in 2012 at a total cost of about $400 million and delivered three years later.

Depending on the amount spent on research and development, CBO estimates that DoD could buy 14 to 16 airships within the spending target of roughly $11 billion set for these options. CBO assumed that the remaining airships would be bought in successive years—at a peak rate of three per year—and that the cost per airship would decline by 10 percent each time total purchases doubled, because annual buy quantities are small. The 14 to 16 airships would have an average cost of roughly $300 million apiece, CBO estimates.

Operation Costs

Lacking data on comparable airship operations, CBO estimated O&S costs for the new airships by using actual costs for C-17 and C-5B airlifters. Although some types of operating costs will be higher for conventional aircraft than for airships, others may be lower. For example, fuel costs are likely to be higher for conventional aircraft because of their need for greater power and speed, but some maintenance costs are apt to be higher for airships because of their more-fragile skin and their need for specialized maintenance facilities.

Using information from the AFTOC database, CBO calculated that O&S costs per flight hour total about $9,000 for a C-17 and $26,000 for a C-5B, or an average of about $18,000 between the two. On the basis of that hourly cost, CBO estimated that operating one heavy-lift airship would cost about $8 million per year, assuming that the airship provided the same number of ton-miles of work (the payload carried times the distance moved) in that period as the average C-17. Thus, over 30 years, O&S costs for 14 to 16 hybrid airships would range from $3.0 billion to $3.4 billion.

Methods for Estimating the Costs of LMSRs

Three of the six options in this analysis feature large, medium-speed roll-on/roll-off ships (LMSRs). Option 2A would add 17 LMSRs to the surge sealift fleet, and Option 3A would buy four more of the ships for afloat prepositioning. Option 3B would shift five LMSRs that are now part of the surge sealift fleet to the prepositioning force. Since all three of those options would either continue production of a recently produced ship or reassign existing vessels, CBO estimates that they would not require any significant research and development costs.

Procurement Costs

For this analysis, CBO assumed that any new LMSRs would be similar to the Bob Hope class LMSRs built between 1993 and 2004, with a weight of roughly 36,000 tons. CBO estimated the procurement costs for those additional LMSRs by using the actual costs of the seven ships of the Bob Hope class. The lead ship of that class costs about $465 million (in 2006 dollars) to build, and the average cost of all seven ships was about $420 million. CBO converted the actual costs for those LMSRs into 2006 dollars using factors provided by the Navy that account for the real (after-inflation) growth that occurred in the cost of labor and materials in the naval shipbuilding industry over the 1985-2004 period and that the Navy expects to experience for the next decade. On the basis of that information, CBO estimated that such real growth averaged about 1.7 percent a year between 1993 and 2004; it is expected to average about 1.3 percent a year over the next decade.

For Options 2A and 3A, CBO assumed that the first additional LMSR would be purchased in 2007 and delivered five years later. Using the real growth rate of 1.3 percent a year mentioned above and accounting for the gap in production since 2004, CBO estimated that production costs for the first new LMSR would total about $470 million in 2007. Under Option 2A, the Navy would buy a second ship in 2008, two per year over the 2009-2015 period, and one in 2016, for a total of 17 new LMSRs. Under Option 3A, the Navy would buy only four of the ships, one per year from 2007 to 2010.

Analysis of past shipbuilding programs indicates that unit costs tend to remain fairly constant when production rates are low. Thus, applying the estimated real-growth factors mentioned above, CBO estimated that the LMSRs built during the 2008-2016 period would have a slightly higher unit cost than the first new ship. As a result, the 17 additional LMSRs in Option 2A would cost an average of about $500 million each (including spare parts and shipboard maintenance tools), and the four new LMSRs in Option 3A would cost an average of about $490 million apiece.

Operation Costs

CBO's estimates of O&S costs for the additional LMSRs are based on actual operation costs for those ships as reported in the Navy's Visibility and Management of Operating and Support Costs (or VAMOSC) database. Those data show that an LMSR for prepositioning costs about $18 million a year to operate, whereas an LMSR for sealift, which is maintained at reduced operating status, costs less than half as much: $7 million annually. Those figures include costs for military pay, fuel, and maintenance that is directly associated with the operations of the LMSR fleet as well as costs for indirect activities such as training and base utilities.

Methods for Estimating the Costs of High-Speed Sealift Ships

Option 2B would expand sealift capability by developing an advanced-technology ship that was at least one-third faster than anything in today's surge sealift fleet. (LMSRs have a speed of about 24 knots, and existing fast sealift ships were originally rated at about 33 knots.) CBO assumed that the high-speed sealift (HSS) ship would have a monohull design and be propelled by high-power water jets to a speed of about 45 knots. Developing, buying, and operating six of those ships would cost a total of $11.1 billion, CBO estimates, although the extensive uncertainty surrounding their capabilities and technologies implies a significant risk of cost growth. Because the HSS ship would lack sufficient range to reach scenarios anywhere in the world, CBO included the purchase of two oilers (one for HSS ships crossing the Pacific and one for those crossing the Atlantic) to provide underway refueling. The oilers would be forward based (in Hawaii, for example) in a reduced operating status.

Research and Development Costs

Ordinarily, CBO uses the historical costs of developing similar ships to estimate the costs of developing a new ship. In this case, however, CBO determined that such comparisons would be inappropriate because the HSS ship would be so much faster than existing sealift ships. Therefore, to estimate research and development costs, CBO started with Navy estimates for two designs for high-speed sealift ships—one that would employ a traditional hull similar to those of current prepositioning ships but have a slightly higher speed (about 36 knots) and one that envisions a trimaran hull and a much faster speed (55 knots). The Navy estimates that the monohull ship would cost $150 million (in 2006 dollars) to develop, and the trimaran would cost $1.8 billion.

CBO added just over 15 percent to those estimates to account for the cost growth that has occurred in past research and development programs for Navy ships. With that adjustment, the estimates for the two ship designs would be $200 million and $2 billion. CBO concluded that research and development costs for the 45-knot sealift ship in Option 2B would be closer to the $2 billion estimate for the 55-knot ship because comparable technological hurdles would have to be cleared to achieve both speeds. Consequently, CBO used that higher figure in this analysis.

Procurement Costs

Given the $11 billion spending target for the options, the Navy could buy six of the new high-speed sealift ships, CBO estimates, at a total cost of $6.4 billion. CBO estimated procurement costs for those ships using a cost-per-thousand-tons methodology. On the basis of cost estimates by the Center for Naval Analyses of alternatives for the Maritime Prepositioning Force (Future) program, CBO estimated that the HSS ships in Option 2B would cost about $50 million per thousand tons to build, or an average of roughly $1.1 billion apiece.[2] That estimate includes the real growth in labor and materials costs mentioned above. It assumes that the first HSS ship would be bought in 2012 and delivered five years later. The other five ships would be purchased at a rate of one per year thereafter. CBO estimated an additional procurement cost of about $800 million for the two oilers based on the

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[2] Robert M. Souders and others, *MPF(F) Analysis of Alternatives: Final Summary Report*, CRM D0009841.A1/SR1 (Alexandria, Virginia: Center for Naval Analyses, February 2004).

costs of the fleet of oilers of the *Henry J. Kaiser* class built in the late 1980s and early 1990s.

Operation Costs

Estimated O&S costs for those high-speed sealift ships are based on actual costs for existing LMSRs. According to the Navy's VAMOSC database, fuel accounts for about one-third of the $7 million in annual operating costs for an LMSR in the surge sealift force. CBO compared the amount of fuel needed per mile traveled for existing LMSRs to the estimated fuel needed per mile traveled for the conceptual HSS ship. With fuel costs adjusted by the ratio of the two ships, but with other operating costs kept constant, CBO estimated that operating a high-speed sealift ship would cost a total of about $10 million annually. The annual O&S costs for the two oilers were assumed to be about $7 million, the same as LMSRs in ROS-4.

Methods for Estimating the Costs of Prepositioned Army Equipment

As noted above, the options to expand afloat prepositioning would either buy additional LMSRs for the prepositioning force (Option 3A) or transfer existing ones from the surge sealift fleet (Option 3B). In either case, the Army would need to buy more sets of equipment to deploy on those ships. Because those options would purchase equipment that is already being produced for the Army, CBO estimated that no research and development would be necessary.

Procurement Costs

For this analysis, CBO assumed that the Army would buy equipment for its new Stryker brigade combat teams to preposition on the LMSRs. Using Army budget data, CBO estimated that one additional set of equipment—including about 300 Stryker vehicles, various tactical and support vehicles, communications and navigational systems, and other necessary combat equipment and supplies—would cost about $1.5 billion to procure.

Operation Costs

Each new set of prepositioned equipment would cost about $5 million a year to maintain. CBO based that estimate on actual costs for the Army's and the Marine Corps' afloat prepositioned forces. In addition, as noted above, the LMSRs on which the equipment was stored would have annual operating costs of about $18 million apiece—or a total of $23 million per year for a ship and its prepositioned cargo. In the case of Option 3B, that annual figure would be offset by $7 million in savings from no longer operating the LMSR as a surge sealift ship.

Besides its LMSR, each prepositioned brigade set would include another cargo ship, because it is not certain that a single LMSR is large enough to carry a full brigade plus other equipment and sustainment supplies that would be needed for independent operations. Those additional ships—which need not be large RO/ROs—could carry miscellaneous equipment, small vehicles (if necessary), and sustainment supplies. CBO assumed that the cargo ships could be chartered for about $10 million per year, based on current costs for chartered prepositioned ships. That figure is included in the estimated operating costs for the prepositioning options.

Glossary of Abbreviations

AFTOC: Air Force Total Ownership Cost (database)

APS: Army Prepositioning Stock

BCT: brigade combat team

CBO: Congressional Budget Office

CRAF: Civil Reserve Air Fleet

DARPA: Defense Advanced Research Projects Agency

DoD: Department of Defense

FCS: Future Combat Systems

FSS: fast sealift ship

HSS: high-speed sealift (ship)

LMSR: large, medium-speed roll-on/roll-off ship

MOG: maximum on ground

MPF: Maritime Prepositioning Force

MPF(F): Maritime Prepositioning Force (Future)

NATO: North Atlantic Treaty Organization

NAVSEA: Naval Sea Systems Command

nm: nautical mile

O&S: operation and support

RO/RO: roll-on/roll-off ship

ROS: reduced operating status

RRF: Ready Reserve Force

RSOI: reception, staging, onward movement, and integration

USTRANSCOM: U.S. Transportation Command

VAMOSC: Visibility and Management of Operating and Support Costs (Navy database)