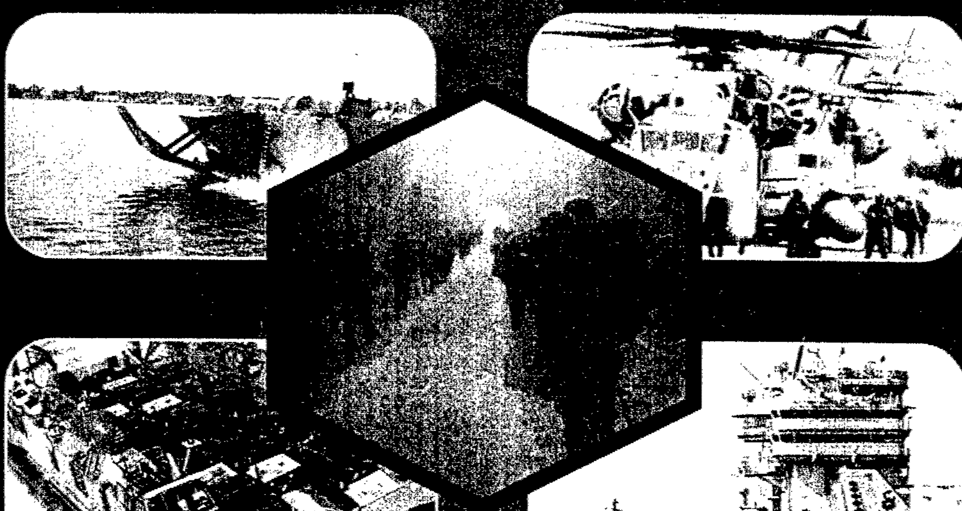
NAVAL EXPEDITIONARY LOGISTICS

Enabling Operational Maneuver From the Sea



NAVAL STUDIES BOARD

NAVAL EXPEDITIONARY LOGISTICS

Enabling Operational Maneuver From the Sea

Committee on Naval Expeditionary Logistics
Naval Studies Board
Commission on Physical Sciences, Mathematics, and Applications
National Research Council

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Preface

One of the core objectives of the President's national security strategy is to "enhance our [the nation's] security with effective diplomacy and with military forces that are ready to fight and win."[1] The Navy and Marine Corps play an essential role in the implementation of the strategy, which requires that U.S. interests be both promoted and protected worldwide. The challenge for the Navy and Marine Corps is not only to maintain the ready capability to support the national security strategy through deterrence, crisis management, and conflict resolution, but also to do so in a constrained budgetary environment in concert with the other military services.

Through their evolving strategies of Forward From the Sea[2] and Operational Maneuver From the Sea,[3] the Navy and Marine Corps have recognized that in any future conflict the team will likely be the first on the scene, that the situation must be contained until heavier forces and other military services arrive, that their mission calls for projecting forces inland from the littoral, that the conflict must be resolved rapidly with minimum casualties, and that forces withdrawn should be reconstituted for redeployment. As described, the mission calls for

[1]The White House. 1997. A National Security Strategy for a New Century, U.S. Government Printing Office, May. Available online at <http://www.whitehouse.gov/WH/EOP/NSC/Strategy/>.

[2]Department of the Navy. 1994. "Forward . . . From the Sea, Continuing the Preparation of the Naval Services for the 21st Century," U.S. Government Printing Office, Washington, D.C., September 19.

[3]Headquarters, U.S. Marine Corps. 1996. "Operational Maneuver From the Sea," U.S. Government Printing Office, Washington, D.C., January 4.

those units making the transition from sea to land to be lighter, more maneuverable, and more widely dispersed, and that, in addition to fire support, the sea-based forces be prepared to provide logistical support to rapidly moving inland forces on an efficient "on call" basis. Always recognized as the critical element in any military campaign (tacticians worry about battles; strategists worry about logistics), although often neglected, logistics must now evolve to accommodate the new strategy of the Navy and Marine Corps operating within a joint environment.

At the request of the Chief of Naval Operations (see Appendix A for a copy of the letter from Admiral Jay L. Johnson, USN), the National Research Council (NRC) conducted a study to determine the technological requirements, operational changes, and combat service support structure necessary to land and support forces ashore under the newly evolving Navy and Marine Corps doctrine. The Committee on Naval Expeditionary Logistics, operating under the auspices of the NRC's Naval Studies Board, was appointed to (1) evaluate the packaging, sealift, and distribution network and identify critical nodes and operations that affect timely insertion of fuels, ammunition, water, medical supplies, food, vehicles, and maintenance parts and tool blocks; (2) determine specific changes required to relieve these critical nodes and support forces ashore, from assault through follow-on echelonment; and (3) present implementable changes to existing support systems, and suggest the development of innovative new systems and technologies to land and sustain dispersed units from the shoreline to 200 miles inland.[4]

In the course of its study, the committee soon learned that development of OMFTS is not yet at a stage to allow, directly, detailed answers to many of these questions. As a result, the committee addressed the questions in terms of the major logistics functions of force deployment, force sustainment, and force medical support, and the fundamental logistics issues related to each of these functions.

The study began in late 1997 and lasted for approximately 8 months. During that time, the committee held the following meetings and visited the following military bases:

- December 10-11, 1997, in Washington, D.C. Organizational meeting. Navy and Marine Corps briefings.
- January 21-22, 1998, in Washington, D.C. Navy and Marine Corps briefings.
- March 11-12, 1998, in Oceanside, California. Site visit to learn more about logistics initiatives underway at Marine Corps Base Camp Pendleton.

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[4]Points (1), (2), and (3) are addressed in the report, although not necessarily in the order stated.

- March 13, 1998, in Port Hueneme, California. Subcommittee site visit to Naval Surface Warfare Center for tour and demonstration of underway replenishment.
- April 15-16, 1998, in Washington, D.C.
- April 22-23, 1998, in Jacksonville, North Carolina. Subcommittee site visit to observe medical field exercises at Marine Corps Base Camp Lejeune.
- May 13-14, 1998, in Washington, D.C. Army, Navy, Marine Corps briefings.
- June 17-18, 1998, in Washington, D.C.
- August 5, 1998, in Washington, D.C.

The resulting report represents the committee's consensus view on the issues posed in the charge.

Acknowledgment of Reviewers

This report has been reviewed by individuals chosen for their diverse perspectives and technical expertise, in accordance with procedures approved by the National Research Council's (NRC's) Report Review Committee. The purpose of this independent review is to provide candid and critical comments that will assist the authors and the NRC in making the published report as sound as possible and to ensure that the report meets institutional standards for objectivity, evidence, and responsiveness to the study charge. The contents of the review comments and draft manuscript remain confidential to protect the integrity of the deliberative process. We wish to thank the following individuals for their participation in the review of this report:

LtGen James A. Brabham, USMC (retired), Riverview, Florida,
Carol M. Jantzen, Westinghouse Savannah River Company,
John Neerhout, Jr., Union Railways Limited,
Daniel Savitsky, Stevens Institute of Technology (retired),
James G. Wenzel, Marine Development Associates, Incorporated, and
Richard S. Wilbur, Institute for Clinical Information.

Although the individuals listed above provided many constructive comments and suggestions, responsibility for the final content of this report rests solely with the authoring committee and the NRC.

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APPENDIXES

Executive Summary

Operational Maneuver From the Sea (OMFTS) provides the Marine Corps vision for conducting 21st-century naval expeditionary operations.[1] This vision, which seeks to exploit the sea as maneuver space, involves projecting naval expeditionary forces and power directly from the sea onto operational objectives well inland, obviating the traditional need to first seize and secure a beachhead and build up a support base ashore before pushing out to accomplish inland operational objectives.

Naval expeditionary logistics, which is about moving naval forces and sustaining their operations in a broad array of environments, figures prominently in the new vision. The role of maritime prepositioning will be expanded from the current at-sea warehousing of Marine Corps equipment to include at-sea arrival and assembly of forces, thereby eliminating the need for airfields and ports in the immediate area of operations. To reduce logistics demand and the logistics "footprint" ashore, many of the functions traditionally accomplished in secure rear areas on land, such as command and control, aviation support, and logistics, are to be based at sea. The sea base itself, probably a collection of amphibious assault ships, prepositioning ships, and various auxiliary support ships, is to remain over the horizon, where logistics and other supporting functions can be performed under the security umbrella of the fleet. Rather than off-loading large quantities of supplies and equipment ashore, logistics operations will deliver

[1]Headquarters, U.S. Marine Corps. 1996. "Operational Maneuver From the Sea," U.S. Government Printing Office, Washington, D.C., January 4.

tailored support packages from the sea base or from small detachments ashore to widely dispersed, highly mobile combat forces operating up to 200 miles inland.

TODAY'S FRAMEWORK IN PERSPECTIVE

The OMFTS vision has stimulated innovative thinking, shaped ideas, focused debate, and led to the publication of a series of implementing concepts.[2] Collectively, this evolving conceptual framework of visions and new ideas represents the important first step in a strategic planning process that will define future U.S. naval forces.

Shaping the logistics capabilities of the Navy and Marine Corps to meet the needs of the evolving OMFTS conceptual framework will be an enormously complex undertaking. It will entail examining how well and at what costs various combinations of force structure, equipment, and operating concepts—both combat and logistics—might meet future naval expeditionary needs. In such a process, warfighting and logistics capability are inseparable. For while warfighting needs set logistics requirements, the logistics capabilities available will in the end limit warfighting potential and the courses of action available to field commanders.

Today, the Navy and Marine Corps, in such documents as "Operational Maneuver From the Sea" and its supporting papers, are formulating the concepts that will lead to future naval force capabilities.[3,4] Figure ES.1 depicts the process. The path from the present to the future is an iterative process of postulating desired operational capability, determining the logistics capability needed to support those operations, and adjusting both in a search for a balance among warfighting needs, logistics requirements, implementation costs, and risks. At each cycle of the process, senior Navy and Marine Corps leaders, selecting among packages of realistic, coherent options, will make the key decisions that step progressively closer to the reality of future forces and set in motion the next iteration of the process.

LOGISTICS IMPLICATIONS OF OMFTS— KEY FEATURES TO BE RESOLVED

Some of the broad logistics implications of OMFTS are clear from the current set of implementing concepts (see Box ES.1). For example, by maneuvering from assault ships over the horizon at sea directly to objectives well inland,

[2]See Box ES.1, Marine Corps Implementing Concepts for OMFTS.

[3]Department of the Navy. 1992. "... From the Sea," U.S. Government Printing Office, Washington, D.C., September.

[4] Department of the Navy. 1994. "Forward ... From the Sea, Continuing the Preparation of the Naval Services for the 21st Century," U.S. Government Printing Office, Washington, D.C., September 19.

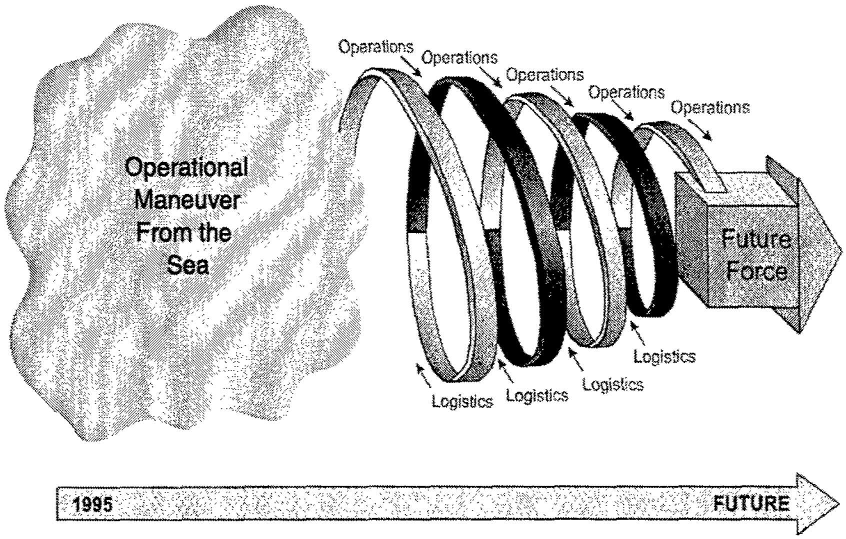

FIGURE ES.1 Operational Maneuver From the Sea, from concept to reality: an iterative process.

BOX ES.1 Marine Corps Implementing Concepts for OMFTS

"Maritime Prepositioning Force 2010 and Beyond," February 1997*
"A Concept for Future Military Operations on Urbanized Terrain," October 1997*
"A Concept for Ship-to-Objective Maneuver," November 1997*
"Casualty Care Concept for Marine Corps Operational Maneuver From the Sea (Working Draft)," January 1998**
"MAGTF Sustained Operations Ashore," October 1998*
"A Concept for Advanced Expeditionary Fire Support—The System After Next," April 1998*
"Sea-Based Logistics: A 21st Century Warfighting Concept," May 1998*

SOURCES: *Published by *Marine Corps Gazette,* Marine Corps Association, Quantico, Va.; **published by Marine Corps Combat Development Command, Quantico, Va., and Naval Doctrine Command, Norfolk, Va.

ground task forces may leave unsecured the land supply routes that normally are essential to logistics operations. That will shift the emphasis from ground transport to air transport. The basing of many supporting functions at sea will dramatically reduce the demand for logistics support ashore but will require that many of the logistics functions usually performed on land be performed at sea, long distances—over both water and land—from the forces being supported. Logistics communications will have to reach well beyond the radio-line-of-sight distances that now predominate, and new logistics information systems will have to be developed to provide the real-time data and decision support capabilities that logistics commanders will need to plan and control fast-paced, complex logistics operations. At-sea arrival and assembly of maritime prepositioning forces will eliminate the need for ports and airfields in the vicinity of operations but will generate requirements for at-sea arrival and assembly facilities and some means to transport the Marines to those facilities.

The specific logistics implications of OMFTS are much more difficult to discern. For, at its current stage of development, OMFTS is open to a wide range of interpretations, both within the naval services and beyond. Resolving the various interpretations of six key features, in particular, is essential to defining future OMFTS logistics needs:

1. Composition of combat and logistics forces ashore,
2. Role of naval fire support vis-à-vis ground artillery,
3. Availability of overseas ports and airfields,
4. Sea-base standoff distances and duration,
5. Operating distances ashore, and
6. Transition to shore-based logistics.

Composition of Combat and Logistics Forces Ashore

Logistics needs derive from combat capability, which, in turn, derives from the forces and concepts employed to attain that capability. Although OMFTS outlines the broad concepts, at this stage it stops short of sizing or characterizing the forces, either combat or logistics forces, that could be ashore.

Some insight can be obtained from examining today's forces. For example, Table ES.1 shows the implications of sea basing, that is, supporting only a land-

TABLE ES.1 Marine Expeditionary Force (Forward) Daily Resupply Requirements

	Marines Ashore	Tons Needed
Full MEF (FWD)	17,800	2,235
MEF (FWD) with aviation at sea	10,460	848
MEF (FWD) with aviation and command at sea	9,660	785
Landing force only	6,800	490

SOURCE: McAllister, Keith R. 1998. *MPF 2010 Ship-to-Shore Movement and Seabased Logistics Support, Volume I: Report* and *Volume II: Appendices,* Center for Naval Analyses, Alexandria, Va., March.

TABLE ES.2 Task Force Building Blocks' Daily Resupply Requirements (Short Tons)

	Water	Fuel	Ammunition	Other	Total
Headquarters Battalion	4	9	<1	2	15
Infantry Battalion	27	2	1	5	38
Artillery Battalion	23	54	20	6	103
Advanced Amphibious Assault Vehicle Battalion	15	26	2	3	46
Engineering Battalion	6	16	3	1	26
Light Armored Reconnaissance Company	4	3	1	1	9
Tank Battalion	23	38	2	5	68

ing force ashore instead of a full marine expeditionary force (forward) MEF (FWD): the daily resupply requirements drop from over 2,000 tons per day to under 500 tons per day. The landing force ashore, however, is today's force, not tomorrow's, and it is still a relatively heavy, mechanized force with substantial resupply requirements. Table ES.2 shows approximate daily resupply requirements of the major ground-combat units from which today's commanders create task forces. It illustrates the large difference in support requirements between an infantry battalion and some of the heavier elements of the force, in particular, the tank battalion and the artillery battalion. (The artillery battalion's large fuel requirement is for trucks carrying ammunition.)

Clearly, "lightening" the ground-combat forces could have a dramatic effect on logistics requirements, and some interpretations of OMFTS assume that the concept applies to a future force much lighter than today's. Others are reluctant to speculate on possible changes to Marine Corps forces. For example, war games and analytical work conducted thus far to support assessments of OMFTS logistics have tended to project today's forces operating under what are thought to be the new OMFTS concepts, thereby resulting in a combination of "old think/new think" that confuses both the interpretation of OMFTS and the assessment of logistics needs.

Role of Naval Fire Support Vis-à-Vis Ground Artillery

The Navy is making large investments in the development of long-range naval guns, land-attack missiles, and precision guided munitions. The purpose is to provide the fleet with a substantial capability to support ground operations, and some interpretations of OMFTS postulate a decreasing role for ground artillery. The OMFTS "Concept for Advanced Expeditionary Fire Support," however, states that Marine Corps ground forces will retain organic fire support capability, and the Marine Corps is developing a new lightweight howitzer. Thus, how the new, sea-based fire support capabilities will affect ground artillery force structure (i.e., number of guns ashore) and artillery ammunition requirements is unknown. This issue has significant implications for logistics, because artillery is such a large consumer of fuel and munitions (as shown in Table ES.2).

Availability of Overseas Ports and Airfields

Today, the United States uses overseas ports and airfields routinely for deploying and sustaining naval forces. Many military leaders are concerned about the growing reluctance of foreign nations to allow U.S. forces to use their territory for military operations and believe that the future availability of overseas facilities is uncertain. If large Marine Corps air-ground task forces are to be deployed and sustained without the benefit of overseas facilities, some substitute for those facilities, such as a mobile offshore base, may be needed for assembly of maritime prepositioning forces and for transshipment of sustainment supplies from container ships and cargo aircraft. Thus, decisions about whether or not to rely on overseas facilities could have a major impact on the design and cost of the future naval expeditionary logistics system.

Sea-Base Standoff Distances and Duration

OMFTS implies over-the-horizon operations, 25 to 50 miles at sea, both to make use of the sea as maneuver space and to maintain safe distances from shore-based threats. It is unclear, however, whether OMFTS operations are to be launched only from over the horizon or whether the over-the-horizon distances are to be maintained indefinitely, that is, throughout landing, sustainment, and reconstitution of the force. If one assumes that the ships can close to a port or to over-the-shore distances (within 6 miles) early in an operation, current logistics over-the-shore capabilities—such as the offshore petroleum distribution system, slow landing craft, and lighterage (floating causeway sections)—should be adequate. If one assumes that support ships must stay over the horizon indefinitely, these current systems will be of little use. Although the landing craft (air cushion) (LCAC) has the high speed necessary to provide ship-to-shore transport from over-the-horizon distances, it has insufficient capacity and durability to land and sustain a large force; the naval services would need a new high-speed landing craft.

Operating Distances Ashore

The terms of reference for this study call out a need to support ground forces up to 200 miles inland. This need, in the context of the ship-to-objective maneuver concept portrayed by OMFTS, implies a dominant role for resupply by air,

TABLE ES.3 Percent of Resupply Requirements Met by Air Deliveries

Portion of Force Supported	250 Miles	125 Miles	55 Miles
Full MEF (FWD)	15	34	55
MEF (FWD) less ACE	40	89	100
MEF (FWD) less ACE and CE	43	96	100
Landing force only	69	100	100

NOTE: See Appendix C for data and computations. MEF (FWD), Marine expeditionary force (forward); ACE, air combat element; CE, combat element.
SOURCE: Adapted from Table C.1, McAllister, Keith R. 1998. *MPF 2010 Ship-to-Shore Movement and Seabased Logistics Support, Volume I: Report* and *Volume II: Appendices*, Center for Naval Analyses, Alexandria, Va., March, and Tables C.2 and C.3 by David Kassing, committee member.

for to assume that road networks and rear areas will be secure enough for routine truck convoys is unrealistic.[5]

Deciding the alternatives and limits of resupplying ground elements by air is an important element in defining OMFTS and future expeditionary warfare capabilities and limitations. For example, Table ES.3 shows that if the OMFTS force ashore approaches today's in its need for fuel, ammunition, and other supplies, the rotary-wing and tiltrotor aircraft planned for the future (CH-53Es and V-22s) will be insufficient, and additional air transport will be required. (These calculations do not consider the possibility of adverse weather or threat conditions.) The potential distances and payload requirements suggest that short takeoff and landing (STOL) aircraft, not vertical takeoff and landing aircraft (such as helicopters), would be more appropriate for this purpose.

It is important to note, also, that OMFTS likely will require much greater allocation of available air assets to logistics missions than has been the case in the past. Not only will logistics, including medical support, be an integral part of maneuver operations, but the support concept for a task force will also need to be fully integrated with aviation support planning and air mission tasking.

Transition to Shore-based Logistics

Sea-based logistics is one of the foundation concepts of OMFTS: By keeping much (though not necessarily all) of the supplies and support activities at sea, naval expeditionary forces could both reduce the vulnerability of logistics

[5]Although this study did not address the combat-related issue of protecting the logistics force, it is apparent that both the support ships at sea and the lines of supply (including air routes) might need substantial protection in a hostile environment.

operations to enemy attack and allow greater maneuverability of forces ashore. OMFTS, however, does not rule out a transition to shore-based support. Such a transition implies retaining many of today's land-oriented combat service support capabilities with today's large logistics footprint ashore. This raises a fundamental question: Are OMFTS capabilities in addition to, or in lieu of, today's capabilities? The answer has a profound effect on the future combat service support structure of both the Marine Corps and the Navy.

INTERPRETING OMFTS

The ranges of interpretation for the six key issues presented above are summarized in Table ES.4. By selecting either the first option on every issue or the second option on every issue, two completely different OMFTS logistics requirements can be generated.

For example, the set of first options yields a light force, with no organic artillery, using overseas facilities to deploy, resupply, and reconstitute, closing to over-the-shore distances early in the operation, supporting large forces only 50 miles inland, and making a transition to shore-based support. That type of force and operation probably could be supported more easily than today's operations. At the other extreme, the set of second options yields a relatively heavy force, much like today's, with organic artillery, unable to use overseas facilities, operating 200 miles inland, supported from over the horizon, but retaining the option to transition to shore-based support. For that type of force and operation, major new investments probably would be needed to provide needed logistics support: a mobile offshore base (MOB); large STOL aircraft-capable logistics ships; ship-capable STOL transport aircraft; and high-speed landing craft.

The sets of options listed in Table ES.4, however, lend themselves to 64 different combinations, not counting the numerous possibilities if neither extreme is selected for each issue. Despite listening to numerous Navy and Marine Corps briefings, studying the published documents about OMFTS and its implementing concepts (see Box ES.1), and discussing the matter at length, members of this committee have no common interpretation of OMFTS. Nor did the

TABLE ES.4 Interpreting OMFTS

Issue	Range of Options
Forces	Light or heavy?
Naval fire support	Replace or augment?
Overseas facilities	Available or unavailable?
Stand-off distances	Over-the-shore or over-the-horizon?
Distances ashore	50 miles or 200 miles?

committee discern a common interpretation among the Navy and Marine Corps personnel who were supporting this study effort. This wide variation in possible interpretation of OMFTS poses two risks—greatly underestimating the true logistics needs of OMFTS or making large investments to acquire or retain unnecessary capability.

MAJOR RECOMMENDATIONS

Because logistics will be so central to implementing OMFTS, the time has come for the Navy and Marine Corps to define the desired end state and planning horizon in sufficient detail to enable reasoned and consistent assessments of logistics requirements and capabilities. In reference to Figure ES.1, they must start down the path to defining future capabilities. An integrated Navy and Marine Corps OMFTS concept of operations, supplemented by a common baseline of planning imperatives and assumptions, is essential to determining the limits of currently programmed capabilities and the relative costs and merits of the new capabilities required to implement OMFTS. Such specificity is essential also to understanding logistics needs and developing a supporting logistics concept of operations.

Recommendation: *The Navy and Marine Corps, using an iterative, strategic planning process, should create an OMFTS concept of operations that integrates tactical and logistical considerations. Key factors to be addressed in defining such a concept should include (1) required combat capability, in terms of the tactical and logistics forces ashore; (2) use of naval fire support; (3) capabilities of the sea-basing ships, aircraft, and surface craft; (4) ranges of sea-base standoff distances and duration; (5) operating distances ashore; and (6) use of overseas facilities as staging bases and resupply points.*

A sound operating concept cannot be formulated independently of the logistics concept supporting it. Contemporary combat service support concepts, forces, capabilities, and processes are designed for shore-based logistics operations. The new OMFTS warfighting concepts and the emphasis placed on sea basing to reduce the logistics footprint ashore are likely to require a materially different logistics concept of operations and supporting set of forces, capabilities, and processes. A defined logistics concept is needed both to guide assessment of organizational, procedural, and equipment needs and to influence, through the iterative process, design of the overall OMFTS concept of operations and operational imperatives. Both the Navy and Marine Corps must participate in creating this logistics concept, and it should be a complete, integrated concept, spanning the full set of combat service support functions, reaching from the Marine at the outer edge of the battle space, back to the Continental United States (CONUS) sustaining base.

Key factors to be considered in developing the logistics concept should include operational requirements for the ships, aircraft, and surface craft needed for sea-based logistics, for the combat service support units ashore, and for the material-handling and throughput capabilities needed at each node in the system to efficiently transfer material from one transport mode to another. In creating this concept, the Navy and Marine Corps should critically assess the impact of precision guided munitions, naval guns, and ship-launched missiles on requirements for artillery and artillery ammunition; emphasize the use of aircraft, both fixed and rotary wing, rather than truck transport; and seek to create an anticipatory, end-to-end distribution-based logistics system that minimizes material handling and the need for requisitions.

RECOMMENDATION: *The Navy and Marine Corps should create an end-to-end, OMFTS logistics concept that supports the concept of operations at each stage in the iterative process of defining future forces and their capabilities.*

Designing the support concept or concepts that best fit the needs of future logistics operations is not a trivial task. The number of variables is large, consistency in assumptions and methodology is key to interpreting results, and the costs of experimenting much with large units (e.g., a MEF (FWD) or larger unit) is prohibitive. This type of analysis is best done with modeling and simulation, rather than ad hoc studies.

RECOMMENDATION: *The Marine Corps should invest in modeling and simulating OMFTS logistics operations to assess logistics needs, capabilities, and alternative support concepts.*

Another large change in the concept of support prompted by OMFTS involves the need for combat casualty care. The current military health service support strategy, which was designed to meet Cold War needs, focuses on providing definitive medical care in-theater in order to maximize the return of personnel to duty. This strategy results in a large medical infrastructure ashore—field hospitals, extensive care capabilities, and lengthy patient holding times. The emerging new strategy, now in its early stages of development, focuses on providing only essential care in-theater, with the injured being evacuated rapidly via enhanced aeromedical evacuation capabilities to definitive care facilities in CONUS and elsewhere throughout the world.

The approach outlined in "Casualty Care Concept for Marine Corps Operational Maneuver From the Sea"[6] (draft) is consistent with the emerging new strategy. It emphasizes the need to minimize medical forces ashore and suggests three primary nodes of theater medical activity: one with the combat units, the

[6]"Casualty Care Concept for Marine Corps Operational Maneuver From the Sea (Working Draft)." 1998. Marine Corps Combat Development Command, Quantico, Va., and Naval Doctrine Command, Norfolk, Va., January.

second on board amphibious assault or sea-based vessels, and a third at the aeromedical port of debarkation for movement to definitive care facilities. In this model, casualties would receive only essential, lifesaving care on the battlefield and would then be evacuated rapidly to a sea-based care facility where they would receive the minimum additional care needed to stabilize them for evacuation out of the theater.

The potential implications of this concept and model are profound. They include the need to redirect medical training, research and development, infrastructure and equipment investments, and management to the critical features of the new system: Marines who are trained to stop bleeding and aid breathing of a wounded "buddy," corpsmen who are trained and equipped to provide simple but effective lifesaving trauma care on the battlefield; forward surgical teams who are trained and equipped to practice combat trauma care in small, austere, deployable medical facilities; and means of aeromedical evacuation that provide essential en route patient monitoring and care.

Recommendation: *The Navy and Marine Corps should reengineer the casualty care system to match the warfighting concepts of OMFTS, giving highest priority to improving first-responder care, developing a forward surgical unit, handling and caring for patients contaminated by biological, chemical, or radiological agents, and evacuating patients to at-sea care facilities and onward to points of strategic aeromedical evacuation.*

OTHER RECOMMENDATIONS

Other recommendations are offered throughout the report. They are best understood in the context of the discussions accompanying them but are listed here for the reader's convenience.

- *The Navy and Marine Corps should reassess the composition of prepositioned equipment sets as they consider future naval maritime prepositioning needs.*
- *Before deciding future maritime prepositioning ship requirements, the Navy and Marine Corps should explore the feasibility of using rapidly deployed amphibious warfare ships to facilitate landing maritime prepositioning forces.*
- *In long-term planning for future amphibious shipping, the Navy should consider the feasibility of a common ship design for assault, prepositioning, and sea-basing missions.*
- *If a goal is to deploy and sustain forces without dependence on overseas facilities, the Navy and Marine Corps should continue research and development of the mobile offshore base as an option for future naval capability.*
- *The Navy should investigate the design and development of a high-speed, high-capacity landing craft to complement the landing craft (air cushion) (LCAC).*

- *The Marine Corps should assess the roles of main battle tanks and artillery in future force structure, giving particular attention to the impact of precision guided munitions and naval guns and missiles on artillery ammunition requirements.*
- *The Marine Corps should examine the capabilities and limitations of various options for delivering by means of air transport the sustaining support required by large ground forces over various operating distances from the sea base. The Marine Corps should adjust the evolution of OMFTS concepts, maneuver force design, and aircraft and shipbuilding programs to ensure that operational and logistics capabilities are appropriately sized and balanced.*
- *The Navy and Marine Corps should determine the technical feasibility, costs, and operational value of a ship-capable, fixed-wing STOL transport aircraft and a complementary, fixed-wing-capable logistics ship that could substantially increase the naval forces' capability to support large ground units long distances from a sea base.*
- *The Marine Corps should start developing the logistics and medical information systems, displays, and automated decision aids it will need to manage fast-paced, complex support operations in tomorrow's warfighting environment.*
- *The Navy and Marine Corps should work together to craft a common approach to the resupply of all naval forces at sea.*

1

A Time of Change for U.S. Naval Forces

NEW CONCEPTS FOR WARFIGHTING AND LOGISTICS

When the Soviet Union collapsed, the national security threats to the United States changed dramatically. For 45 years, the Cold War had presented a constant possibility of worldwide conflict, probably centered in central Europe. The ensuing environment has been characterized by varying degrees of regional confrontation and instability, with great uncertainty about the future development of more formidable and direct threats to U.S. security. As the United States has adjusted its national security strategy to the new environment, the Navy and Marine Corps have been adjusting their priorities and concepts of operation to deal with current and potentially new military threats. In 1992, without abandoning any traditional naval warfare areas, the Navy and Marine Corps, in a white paper entitled "... From the Sea," announced a shift of strategy away from open-ocean warfighting toward expeditionary operations conducted from the sea: "The *new* direction of the Navy and Marine Corps team, both active and reserve, is to provide the nation naval expeditionary forces shaped for joint operations operating forward from the sea, tailored for national needs."[1] Two years later, the Navy and Marine Corps expanded on the concepts with a second white paper, "Forward . . . From the Sea," which emphasized ". . . the unique contributions of naval expeditionary forces in peacetime operations, responding to crises, and in regional conflicts."[2]

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[1]Department of the Navy. 1992. "... From the Sea," U.S. Government Printing Office, Washington, D.C., September.

[2]Department of the Navy. 1994. "Forward . . . From the Sea, Continuing the Preparation of the Naval Services for the 21st Century," U.S. Government Printing Office, Washington, D.C., September 19.

BOX 1.1 Marine Corps Implementing Concepts for OMFTS

"Maritime Prepositioning Force 2010 and Beyond," February 1997*
"A Concept for Future Military Operations on Urbanized Terrain," October 1997*
"A Concept for Ship-to-Objective Maneuver," November 1997*
"Casualty Care Concept for Marine Corps Operational Maneuver From the Sea (Working Draft)," January 1998**
"MAGTF Sustained Operations Ashore," October 1998*
"A Concept for Advanced Expeditionary Fire Support—The System After Next," April 1998*
"Sea-Based Logistics: A 21st Century Warfighting Concept," May 1998*

SOURCES: *Published by *Marine Corps Gazette,* Marine Corps Association, Quantico, Va.; **published by Marine Corps Combat Development Command, Quantico, Va., and Naval Doctrine Command, Norfolk, Va.

Building on the foundation set by the concepts in these two white papers, the Marine Corps began developing its vision of a new capability that would enable amphibious operations to exploit the sea as maneuver space and focus directly on operational objectives, rather than first seizing and securing a base of support ashore, and then pushing out to objectives. This vision, Operational Maneuver From the Sea (OMFTS),[3] is the cornerstone of the Marine Corps efforts to shape its fighting doctrine, forces, and weapon systems of the future. More recently, the Marine Corps has published several implementing concepts supporting OMFTS (see Box 1.1). Collectively, the OMFTS vision and set of supporting concepts serve to stimulate thinking, focus debate, and shape ideas. They represent the first steps in an evolutionary, iterative process of defining the future doctrine, tactics, and capabilities of the Marine Corps.

Shaping the logistics capabilities of the Navy and Marine Corps to meet the needs of the evolving OMFTS conceptual framework is an enormously complex undertaking. It entails examining, in an integrated strategic planning process, how well and at what costs various combinations of force structure, equipment, and operating practices—both combat and logistics—might meet future needs for naval expeditionary forces. In such a process, combat and logistics capability are inseparable, for while the needs of combat set logistics requirements, the limits of logistics constrain combat. As always, the importance of desired combat capabilities must be weighed against their logistics implications and costs.

At this stage in the evolution of OMFTS concepts, OMFTS still leaves

[3]Headquarters, U.S. Marine Corps. 1996. "Operational Maneuver from the Sea," U.S. Government Printing Office, Washington, D.C., January 4.

much to interpretation. How the concepts are interpreted, however, can dramatically influence the set of logistics capabilities needed.

This report helps to set the stage for addressing some of the tough choices affecting logistics. It explores the major features of the emerging OMFTS framework and their broad implications for logistics. It calls attention to those aspects of OMFTS that need more definition before logistics needs can be determined. It examines each of the major nodes of logistics activity, highlighting why change will be needed. Throughout the report, the committee also highlights the options that are available—in terms of combat service support structure, operating practices, or technology—for satisfying future requirements. The committee's goal is to provide useful insights that will assist senior Navy and Marine Corps leaders in setting the future direction of our nation's expeditionary warfare capabilities.

STUDY SCOPE

Naval expeditionary logistics is about moving naval forces and sustaining their operations in a broad array of environments (including political and military)—from benign environments with relatively well developed infrastructures to more stressful situations involving forcible entry and limited infrastructures. An enormously broad topic, naval expeditionary logistics reaches from the national, and sometimes international, industrial base to our maritime forces afloat and ashore throughout the world. In keeping with the committee's charter, however, the report is limited to the new features of OMFTS as they relate to deployment of Marines and their logistical support in the theater of operations. Moreover, since the purpose of the study is to help determine the set of capabilities that future naval forces should have, one assumes that the Navy and Marine Corps must be able to logistically support their own tactical operations, drawing help only from such national assets as strategic lift, strategic intelligence, global command and control, and global navigation aids.

Most of the initial thinking about and experimenting with OMFTS concepts by the Marine Corps have focused on small units. In addition, a recent study, complementary to this report, by the Naval Research and Advisory Committee addressed how technology can help meet the resupply requirements of small units—dismounted infantry teams, squad to company size (6 to 250 Marines).[4] Given the logistics focus of this study, the committee believed that concentrating on small units had the potential to mask conditions that become problems with larger forces. For that reason, and to provide needed insights on the unique

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[4]Naval Research Advisory Committee, Office of the Assistant Secretary of the Navy (Research, Development, and Acquisition). 1997. *Ship-to-Warfighter Logistics for Small Unit Operations,* Outbrief by Ship-to-Warfighter Logistics for Small Unit Operations NRAC Panel to the Commandant, U.S. Marine Corps, Washington, D.C., August 26.

challenges associated with managing and moving large quantities of equipment and supplies during amphibious operations, most of the committee's effort focuses on logistically supporting a Marine expeditionary force (forward) a much larger task force composed of about 19,000 Marines.

REPORT OUTLINE

In previous studies,[5,6] the Naval Studies Board addressed some of the logistics problems involved in supporting OMFTS. The present report provides a more complete and up-to-date discussion.

In the next chapter, OMFTS is outlined and described in general terms along with the major logistics implications. Also highlighted are those key features of OMFTS that are open to interpretation and that illustrate why much of the discussion in later chapters must be conditioned on how the Navy and Marine Corps eventually decide to implement the new concepts.

Chapters 3 through 5 focus on major logistics activities that will be affected by OMFTS, i.e., deploying forces, sustaining the forces ashore with supplies and maintenance, and providing medical care to combat casualties. In each, the committee concentrates on those aspects of future logistics operations that warrant near-term planning and analysis priority. Chapter 3 deals primarily with the concepts described in "Maritime Prepositioning Force 2010 and Beyond":[7] the types and uses of ships and landing craft used to deploy and close the force, and the role an intermediate staging base could play in the operation. In Chapter 4, the implications of sea basing the logistical support for forces ashore and supporting them over very long distances from the sea base are explored. In Chapter 5, the radical changes in medical care motivated by the concepts of OMFTS are discussed. Closing comments are given in Chapter 6. Supplemental information is provided in the appendixes.

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[5]Naval Studies Board. 1996. *The Navy and Marine Corps in Regional Conflict in the 21st Century,* National Academy Press, Washington, D.C.

[6]Naval Studies Board. 1997. *Technology for the United States Navy and Marine Corps, 2000-2035, Volume 8: Logistics,* National Academy Press, Washington, D.C.

[7]Marine Corps Combat Development Command. 1997. "Maritime Prepositioning Force 2010 and Beyond," Quantico, Va., October.

2

Logistical Implications of Operational Maneuver From the Sea

SUPPORTING CURRENT AMPHIBIOUS OPERATIONS

In amphibious assaults today, a Marine air-ground task force (MAGTF) would secure a beachhead and establish a support base on land as quickly as possible, and then push out from that base to other objectives. The assault, conducted largely from amphibious ships close to shore (usually within about 6 miles[1]), would be supported by minimal supplies accompanying the assault waves. Within minutes, shore party teams and helicopter support teams would move ashore to organize and establish beach and landing zone support areas. Forward arming and refueling points would provide essential replenishment to aviation units. What starts as on-call waves of support packages would yield quickly to scheduled waves of support equipment and supplies and soon become a general off-loading of amphibious ships onto the beach.

For a large MAGTF, the materiel carried on the amphibious ships and off-loaded to the beach would provide minimal sustainment. Within days, cause-ways, barges, and lighters would be discharging additional units, equipment, and supplies (the follow-on echelon) from cargo ships and tankers. When fully developed, the combat service support area might spread over a 30 to 40 square mile area; hold thousands of tons of ammunition, thousands of containers of supplies, and millions of gallons of petroleum and water; and house such support services as equipment maintenance and medical care.

If an area is secure from hostile operations, and an airport is available near either a seaport or a coastline suitable for logistics over-the-shore operations,

[1]Unless noted otherwise, "miles" refers to statute miles.

today's maritime prepositioning forces (MPFs) can be employed. The Navy maintains three maritime prepositioning squadrons, 13 ships total (3 additional ships are being procured). Each squadron holds the unit equipment and 30 days' sustaining supplies for one Marine expeditionary force (forward) (MEF [FWD]) (see Table 3.1). The squadrons, stationed in the Mediterranean Sea and at Guam and Diego Garcia, can deploy, unload, integrate equipment to Marines who have been flown into the theater of operations, and stand up a combat-ready MAGTF in about 15 days. Once the maritime prepositioned force is landed, it is supported the same as any other MAGTF.

SUPPORTING OPERATIONAL MANEUVER FROM THE SEA

The evolving concept of OMFTS depicts a very different type of amphibious operation, with very different logistics requirements. Instead of amphibious warfare ships moving close to shore to disembark the assault echelon, the assault would be launched from over the horizon, 25 to 50 miles at sea. Instead of the first objectives being to establish a beachhead (a logistics base) and secure it from enemy direct and indirect fire, the first objective might be to attack enemy critical positions up to 200 miles inland. Instead of the units ashore being supported by a general off-loading of supplies onto the beach, units would be logistically supported to the extent possible from ships at sea. Instead of the MPFs being dependent on secure airfields and ports in the immediate vicinity of the objectives, Marines would integrate with their equipment at sea and move directly from the prepositioning ships to their areas of operation ashore.

Most importantly, instead of a full task force moving ashore, it is envisioned that many of the supporting functions would be based at sea, for example, command and control, administration, fire-support coordination, and logistics. Conducting much of the activity of these functions at sea not only would change how they are accomplished, but also would reduce substantially the size and support requirements of the force ashore.

For the logistician, OMFTS would entail doing largely at sea many of the tasks that traditionally have been done from a large, shore base. For example, the receipt, storage, breakout, and repackaging for distribution of bulk shipments of rations, fuel, munitions, and spare parts are normally done by logistics units ashore. These operations typically entail the use of large container-handling equipment, involve several hundred containers, and require significant real estate in order to gain access to, sort, and process the materials for distribution to ground-combat elements via truck convoys. The situation is similar for maintenance operations, medical care, and other logistics services. Under OMFTS, those functions would be done largely in the continental United States (CONUS) at sites remote from the theater of operations or at sea, likely dispersed among at least a half dozen or more ships that compose the sea base for the operation (e.g.,

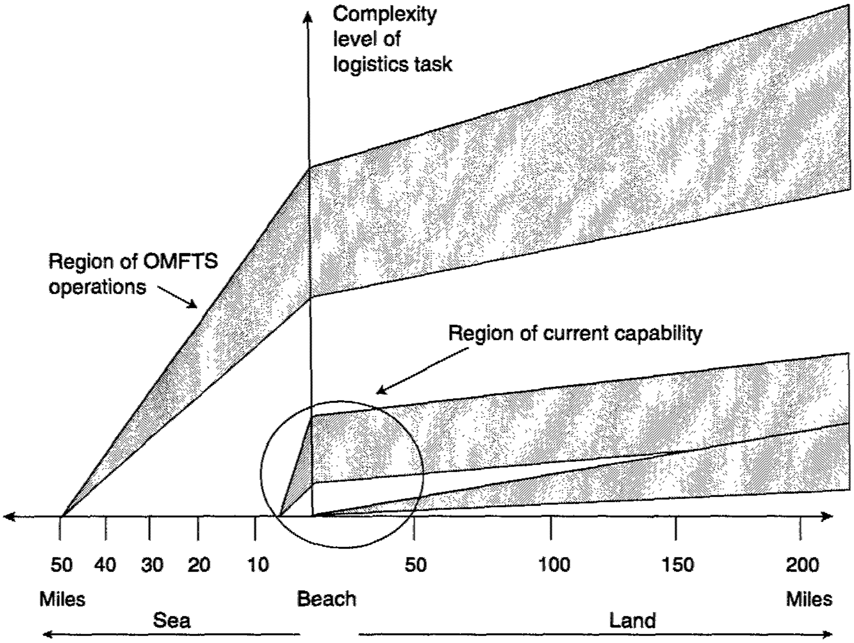

FIGURE 2.1 Impact of range on logistics complexity.

amphibious warfare ships, maritime prepositioning ships, and various auxiliary support ships).

Additionally, the expanded depth and breadth of the battlefield and the rapid pace of maneuver operations portrayed by OMFTS would require that logistics operations be conducted over very long distances, probably without the assurance of secure rear areas ashore and land lines of communication. Figure 2.1 depicts conceptually the challenge facing logisticians.

Whereas current logistics operations, once established ashore, encompass an area of operations nominally 50 miles deep by 50 miles wide, future operations will start with the movement of equipment and supplies from 25 to 50 miles at sea to units as far as 200 miles inland and 200 miles apart—a four-fold increase in the ranges over which forces must be logistically supported. Whereas today's concept of military operations includes clearing and securing rear areas from which forces can be safely operated and logistically supported, OMFTS envisions combat units moving directly from ships to operational objectives, avoiding built-up shore defenses and minefields but also leaving unsecured the areas in between, the areas in which logistics activities normally take place.

Thus, the general logistical implications of OMFTS are discernible: smaller but more mobile forces ashore are to be supported over longer distances from a logistics base that is at sea. The specific implications, however, are not as clear, for they depend on key features of OMFTS that are not yet fully defined by the implementing concepts. It is to these features of OMFTS and their logistics implications that the committee turned its attention.

KEY UNDEFINED FEATURES OF OMFTS

Although some would argue that logistics is more an art than a science, it is fundamentally based on quantification: How much? How far? How fast? For how long? Yet at this stage in their development, OMFTS and its implementing concepts lack the information needed to define and size logistics operations. The ambiguity leaves the concepts open to a broad range of interpretation. For example, at one extreme, the concepts may be viewed as modest extensions of current practices aimed at merely exploiting the capabilities of planned new systems, such as the V-22 aircraft and the advanced amphibious assault vehicle (AAAV). At the other extreme, they may be viewed as ambitious blueprints for radical changes in the role of naval expeditionary forces—the way they operate, the way they are equipped, the way they are organized, and the way they are supported. The ultimate goal, which may be somewhere in between, is not yet clear. In the following paragraphs the key unresolved aspects of OMFTS that have major logistical implications are highlighted.

Maneuver Forces Ashore

The major question left unanswered is the required combat capability, especially in terms of the size and composition of the maneuver forces ashore. The central issues are to what extent tomorrow's force will provide for both light infantry and mechanized task forces, as today's does, whether tanks and howitzers will be part of that force mix, and how large a task force (battalion, regiment, division, or corps) will employ the OMFTS concepts. As will be discussed in subsequent chapters, how those issues are resolved will have substantial impact on the capabilities needed for prepositioning, deploying, landing, and sustaining the force.

Overseas Facilities

The assumption one is willing to make about the availability of overseas facilities also greatly influences logistics needs. The Marine Corps already has stated, in its concept of Maritime Prepositioning Force 2010 and Beyond (MPF 2010+), the goal of being able to deploy MPFs without the use of airfields or ports in the immediate vicinity of an objective. The OMFTS concepts are silent, however, about the use of other overseas facilities that could aid deployment and sustainment efforts by serving as staging bases or resupply points. Although the

Navy today depends on overseas supply points for replenishing ships at sea, military leaders are concerned about the growing hesitancy of foreign governments to allow U.S. forces access to their territories. A capability to deploy and sustain large naval expeditionary forces without the use of overseas facilities would be a large and likely an expensive step from today's deployment and sustainment practices.

Naval Fire Support

The Navy is developing long-range naval guns and missiles that will be capable of supporting ground forces widely dispersed ashore. Figure 2.2 shows that planned naval guns are expected to have maximum ranges up to about 100 nautical miles, the land-attack standard missile up to 150 nautical miles, and the Tomahawk and close air support over 200 nautical miles. The OMFTS concept for advanced expeditionary fire support, however, does not call for abandoning current artillery. In fact, the concept is explicit in stating that ground forces will have their own organic fire support, and the Marines Corps is developing a new lightweight howitzer.[2] Since artillery is the ground force's highest consumer of ammunition and the trucks that move the ammunition are large consumers of fuel and maintenance services, a decision to include or exclude artillery from future force structure has a large impact on logistics requirements. (That decision, of course, would not be independent of others shaping the combat capability.)

Sea-Base Standoff Distances and Duration

A key tenet of OMFTS is that amphibious operations are to be conducted and supported logistically from over the horizon at sea, not only providing an element of surprise to a landing, but also permitting ships space for maneuver and self-defense. The Marines Corps, in acquiring the LCAC, V-22 tilt-rotor aircraft, and the AAAV, has been acquiring capabilities that permit such over-the-horizon operations. OMFTS, however, does not specify the ship-to-shore distances for landings and sustainment, does not make clear whether naval forces must have the capability to maintain the standoff indefinitely, and does not clarify the roles of amphibious and maritime prepositioning ships. The standoff distances and duration are important because transit time is a key input to logistics system throughput capability—a major determinant of closure times and sustainment capacity. If logistics planners can assume that ships, at some point

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[2]The lightweight howitzer will be transportable to about 100 nautical miles by the MV-22 and 200 nautical miles by the CH-53E, unescorted. Escorted, the range is limited to that of the escort, typically an AH-1 attack helicopter, which has a combat radius of about 150 nautical miles. See Appendix B for additional discussion.

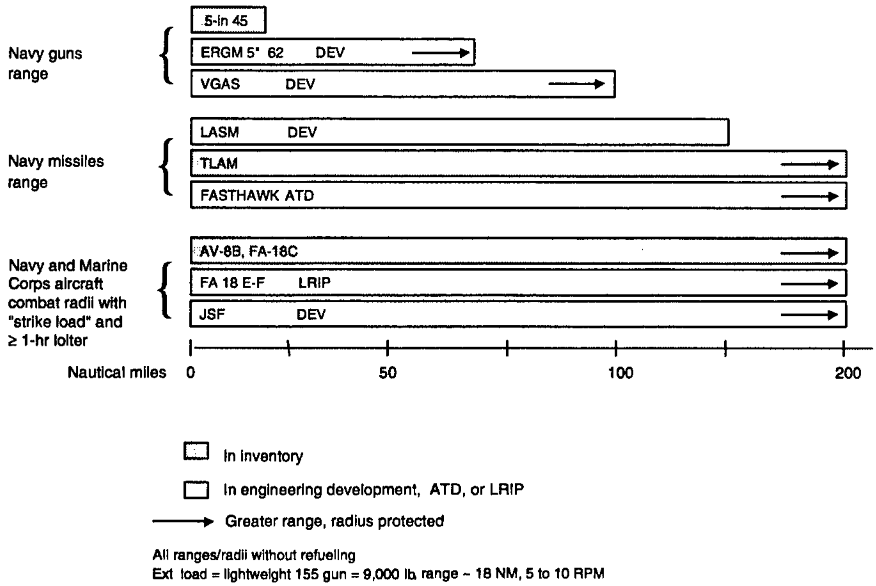

FIGURE 2.2 Ranges and aircraft combat radii relevant to naval fire support for Marines. More detail is given in Appendix B. ERGM, extended-range guided missile; VGAS, vertical gun (advanced) system; LASM, land-attack standard missile; TLAM, Tomahawk land attack missile; JSF, joint strike fighter; ATD, advanced technology demonstration; LRIP, low rate initial production.

in an operation, can use ports or logistics over-the-shore capabilities to land forces, sustain supplies, or reconstitute forces, the logistics task is much simpler than if ships must remain over the horizon.

Operating Distances Ashore

The terms of reference for this study specify landing and sustaining ". . . dispersed units from the shoreline to 200 miles inland . . . ." With the V-22, the Marines Corps is acquiring a capability to land and sustain forces at that distance or longer. In fact, the operating radii of the V-22 and CH-53 that commonly are used for planning purposes such as those shown in Figure 2.2 do not represent the full reach of the aircraft when possibilities for aerial refueling or return-route refueling are considered.[3] How large and what type of force the Marines want to

[3]For example, a V-22 fully loaded with Marines (an internal load of about 7,200 lb) has an operating radius of about 400 miles (800-mile range). The aircraft could fly 600 miles to an objective, insert the Marines, fly 200 miles to a refueling point, and then fly up to 1,100 miles home.

land and sustain 200 miles inland are not clear, however, and it makes a big difference to the logistics capabilities that naval forces will need to support OMFTS. For example, if only small teams are deployed at very long distances inland, and major units (battalion sized or larger) remain within the 50-mile doctrinal range of today's operations, today's logistics structure and practices might meet much of OMFTS logistics needs. If, however, large mechanized units are to operate 200 miles inland, substantial changes to logistics capability will be needed to support them and to permit rapid force reconstitution.

Transition to Shore-based Logistics

A key feature of OMFTS is that many support functions, such as aviation, command and control, medical services, and logistics, are to be based at sea, presumably aboard amphibious warfare ships, maritime prepositioning ships, and various auxiliary support ships. This will reduce dramatically not only the number of personnel and the amount of equipment that must be landed to support an operation, but also the logistics requirements generated by the forces ashore. Reduced requirements will translate, in turn, into a smaller or reorganized combat service support structure. At least that should be the logical result if the Marine Corps were to tailor its logistics organizations and procedures to a sea-based concept of support. If, instead, the Marine Corps must retain its ability to establish a shore-based logistics operation, the combat service support structure needed to maintain such rear area activities as hospitals, fuel dumps, container yards, and maintenance points must be retained. This is a fundamental issue of OMFTS: Is sea basing to be an additional capability of naval expeditionary forces or is it to be a replacement for today's shore-basing capabilities? The answer has implications for the composition of maritime prepositioning assets, the size and organization of the force service support groups, the need for logistics over-the-shore capabilities, and the relationship between the Marine Corps and the Army in providing joint theater logistics capabilities.

OMFTS CONCEPT OF OPERATIONS NEEDED

Without definition of these key features of OMFTS—size, locations, and composition of the forces ashore; support-ship standoff distances and support durations; and the degree of dependence on and the location of intermediate bases—the temptation when trying to assess future logistics requirements and options for naval expeditionary forces is to make assumptions that facilitate the analysis, essentially interpreting OMFTS. The risk in such interpretation is that the conclusions then rest on assumptions that may not represent the future capabilities that naval expeditionary forces need to fulfill their role in a national security strategy. In the following chapters, the temptation is resisted to make facilitating assumptions when their impact on logistics requirements seems substantial. Instead, the committee tries to explore how choices among options are affected by these undefined key features of OMFTS.

In the context of defining the future capabilities and logistics requirements of naval expeditionary forces, however, these issues cannot be left unresolved. Because logistics could be such a major challenge in implementing OMFTS, the time has come for the Navy and Marine Corps to define the desired end states and planning horizons in sufficient detail to enable reasoned and consistent assessment of logistics requirements and capabilities. A defined OMFTS operational concept is needed, a concept that integrates tactical, logistical, and operational considerations. Such a concept should include definite statements regarding the following features: (1) required combat capability, including the size and composition of the tactical and logistical forces ashore; (2) use of naval fire support in relation to organic artillery ashore; (3) characteristics of the sea-basing ships, aircraft, and surface craft; (4) sea-base standoff distances and duration; (5) operating distances ashore; and (6) use of overseas facilities, staging bases, and resupply points. This concept of operations and common baseline would provide the basis for studies, analyses, war games, and exercises to determine the limits of currently programmed capabilities and the relative costs and values of new investments in meeting future goals. Without such specificity, different interpretations of OMFTS concepts risk underestimating the logistics implications of OMFTS or rationalizing investments that may not be essential.

Recommendation: *The Navy and Marine Corps, using an iterative, strategic planning process, should create an OMFTS concept of operations that integrates tactical and logistical considerations. Key factors to be addressed in defining such a concept should include (1) required combat capability, in terms of the tactical and logistics forces ashore; (2) use of naval fire support; (3) capabilities of the sea-basing ships, aircraft, and surface craft; (4) ranges of sea-base standoff distances and duration; (5) operating distances ashore; and (6) use of overseas facilities as staging bases and resupply points.*

3

Force Deployment

THE DEPLOYMENT DILEMMA

Rapid deployment of forces from CONUS, or from overseas bases, to their theater of employment is a tenet of the U.S. military strategy. The dilemma in executing that part of the strategy is both frustrating and simple: Speed is important, making air transport desirable; Marine Corps forces can be large and heavy, making movement by sea necessary (see Table 3.1).

If the Marine Corps were to rely only on the fleet of amphibious ships to deploy its forces from CONUS, arrival in-theater would be slow, taking 30 days or more, because of the time required to move to embarkation ports, embark the troops, their equipment, and ammunition, and move to the theater of operations. Furthermore, only a small portion of the force could be transported at one time—significantly less than one of the four MEFs the Marine Corps maintains (three active and one reserve).

Today, that dilemma is resolved in two ways. First, Marine expeditionary units, special operations capable (MEU[SOC]) are forward deployed with amphibious-ready groups (ARGs), providing almost immediate crisis response capability. Second, equipment is prepositioned aboard ships of the maritime prepositioning squadrons, which can be moved quickly from their overseas stations to the theater of employment. Marines are then transported by air to the theater, where they marry up with their equipment.

The value of the forward-deployed ARGs is demonstrated regularly. It is they who are called upon routinely to rescue U.S. civilians from unstable situations in foreign countries, to deliver humanitarian aid, or to demonstrate by their

TABLE 3.1 Representative Marine Air Ground Task Force Sizes (Current Force Structure, Not Tailored for Sea Basing)

	MEU	MEF (FWD)	MEF
Personnel	2,800	18,800	54,600
SqFt Vehicle Stow	62,000	620,000	1,554,000
CuFt Cargo Stow	160,000	2,450,000	11,478,000
Total Vehicles	150	4,300	13,900
Tanks	4	58	62
Advanced amphibious assault vehicles	12	109	187
M198 howitzers	6	30	54
MV-22 tilt-rotor aircraft	12	36	96
CH-53 helicopters	4	8	36
UH-1N helicopters	3	6	18
AH-1W helicopters	6	18	54

NOTE: Partial listing of vehicles shown above; vehicle numbers are approximate.
MEU, Marine expeditionary unit; MEF (FWD), Marine expeditionary force (forward); MEF, Marine expeditionary force.

presence and readiness the resolve and capability of the United States to intervene militarily in a crisis.

The maritime prepositioning forces (MPFs), too, have demonstrated their value both in military conflicts, such as the Persian Gulf War, for which they provided the first substantial ground-combat forces, and in humanitarian and peacekeeping missions. Employment of today's MPFs, however, depends on having available in the immediate vicinity of the objective area both an airfield to receive the personnel and light equipment that are flown in and either a port for unloading equipment from the prepositioning ships or coastline suitable for over-the-shore logistics operations. Importantly, the arrival of troops and equipment and their assembly into combat-ready units require a benign environment, free from hostilities.

Future military operations may not be afforded the luxury of convenient airfields and ports or benign environments. MPF 2010+ is a concept for exploiting the rapid deployment capabilities of maritime prepositioning without depending on airfields, ports, or benign conditions in the immediate area of intended force employment. The MPF 2010+ concept calls for four functions not provided by the current MPF:

1. At-sea arrival and assembly of units, eliminating the need for airfields and ports in the immediate vicinity of the objectives;
2. Reinforcement of the assault echelon of an amphibious task force;
3. Indefinite sea-based sustainment of the forces ashore; and
4. In-theater reconstitution and redeployment of the force.

These new functions are intended to create a "triad of new capabilities: fast deployment, reinforcement, and sustained seabasing":[1]

- *Fast deployment:* Capability to deploy the combat-essential equipment for a MEU or similarly sized special-purpose MAGTF, along with a limited amount of palletized cargo;
- *Reinforcement:* Capability to deploy the equipment and 30-days' sustainment for an MEF (FWD); and
- *Sustained sea basing:* Capability to furnish a full range of logistics support, as well as the conduit to strategic bases through which MPF 2010+ will provide indefinite sustainment for an MEF.

The timing of ideas on how to exploit maritime prepositioning is opportune. The leases for the ships now used to preposition Marine Corps equipment expire in about the year 2010. So the Navy and Marine Corps face a decision soon on what to do about replacing those ships, how best to design them, and how to use them.

CENTER FOR NAVAL ANALYSES STUDY

A mission area analysis is one of the key steps to take before making a decision about replacing the maritime prepositioning ship. The Center for Naval Analyses (CNA) is conducting that analysis and has published two reports documenting the first phase of its effort. The first report, *MPF 2010 and Beyond: Translating a Concept into Ship Requirements*,[2] outlines five conceptual ship alternatives for meeting future prepositioning requirements and sizes the lift requirements to be met by each alternative. The alternatives span a wide range of capability, reflecting alternative interpretations as to how the MPF 2010+ concept might be implemented from a strategic sealift ship, similar to the large, medium-speed, roll-on/roll-off ships now being procured, that has little aviation capability and little berthing or work space, to a mobile offshore base—a large, modular structure that could be assembled at sea to provide a C-17-capable air base, facilities for docking and unloading cargo ships, and ample space for storing supplies, maintaining equipment, berthing personnel, and providing medical and other services.

The companion CNA study, *MPF 2010 Ship-to-Shore Movement and Sea-*

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[1]Marine Corps Combat Development Command. 1997. "Maritime Prepositioning Force 2010 and Beyond," Quantico, Va., October.

[2]Milano, Vito R. 1997. *MPF 2010 and Beyond: Translating a Concept into Ship Requirements*, CRM 97-103, Center for Naval Analyses, Alexandria, Va., December.

based Logistics Support,[3] describes a detailed, scenario-based analysis of the capability of one of the ship alternatives to support the type of operation envisioned by the MPF 2010+ concept. In short, the scenario has the MPF ships, with the prepositioned equipment and supplies of an MEF (FWD) on board, embarking the personnel and fly-in equipment at an intermediate staging base, proceeding to the area of operations, and then reinforcing an amphibious task force that already has landed its embarked ground-combat element. The reinforcing operation consists of two task forces, launched and sustained from the MPF ships: one task force, composed of two infantry battalions and an artillery battery, which is moved by air to an objective 60 miles inland (85 miles from the ships) and the other, a reinforced mechanized battalion, which is moved by surface to the shore, from where it moves inland to the other objective. Only the ground-combat elements of the MEF (FWD), with minimal command and control and combat service support, go ashore. The fixed-wing component of the air-combat element is assumed to be at some unspecified base within supporting range.

The assumptions and results of the analysis are instructive, suggesting some of the factors that might limit MPF operations. First, by assuming that personnel were embarked at an intermediate staging base, the scenario omitted the concept of "at-sea arrival and assembly" of the MPF. Second, air movement of the two infantry battalions to their objective 85 miles from the ships took 12 hours, the outer limit of the time assumed to be acceptable for the landing. The air movement used all available V-22 and CH-53E rotary-wing aircraft (no medical evacuation, logistics, or other operational missions competing for the aircraft) and was conducted in a benign environment (no enemy, adverse weather, attrition, or equipment malfunctions). Third, if the ships remained 25 miles at sea, it took 5 days to land the mechanized task force, an unacceptably long time. The slow landing was attributed to insufficient numbers of high-speed landing craft. To move the force ashore in a reasonable time (2 days), the ships had to close to within 4 miles of shore after the first day.

The value of the CNA analysis was found to be much broader than the ship definition issue: By analyzing in detail one interpretation of the MPF 2010+ concept, it revealed some of the ambiguities, obstacles, and possible limitations to the concept. The committee made liberal use of that study. The committee discusses here, drawing largely from the CNA study, observations and recommendations related to composition of the prepositioned force, the MPF ship alternatives, and the need for high-speed landing craft. In the next chapter the committee deals with sea-based sustainment.

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[3]McAllister, Keith R. 1998. *MPF 2010 Ship-to-Shore Movement and Seabased Logistics Support, Volume I: Report* and *Volume II: Appendices*, Center for Naval Analyses, Alexandria, Va., March.

MARITIME PREPOSITIONING FORCE COMPOSITION

Today's prepositioning force, an MEF (FWD), is a large, heavy ground force (see Table 3.1; aviation assets are not prepositioned). Although nominally one-third of a full MEF, it has nearly a full MEF's complement of main battle tanks and more than half of an MEF's complement of amphibious assault vehicles and artillery. If the Marine Corps moves toward a lighter, more air mobile force structure, prepositioning requirements for ships, trucks, and supplies could change dramatically. The extent to which over-the-horizon sea basing becomes the predominant mode of operation also could change prepositioning needs. For example, much of today's container handling and lighterage may be unnecessary, as may be the large field hospitals. In any case, the assumption that the prepositioned force designed for OMFTS will be the same as today's should be accepted only after careful assessment of future force design intentions. Reconstitution should also be considered in MPF force design. The committee believes that such assessment should be an integral part of OMFTS and MPF ship replacement planning.

Recommendation: *The Navy and Marine Corps should reassess the composition of prepositioned equipment sets as they consider future naval maritime prepositioning needs.*

MPF 2010+ SHIP ALTERNATIVES

One of the most-difficult-to-achieve new functions of the MPF 2010+ concept is the at-sea arrival and assembly of the force. The assumptions one makes about the availability and role of an intermediate staging base determine how difficult this function will be. If the goal is to be completely independent of overseas airfields (that is, to fly Marines directly from CONUS to meet up with the prepositioned equipment at sea), some seagoing platform capable of landing large, long-range, fixed-wing aircraft (e.g., C-17 transport) will be needed. A mobile offshore base (MOB),[4] as now conceived, could meet such a need. In addition, a MOB could meet better than any ship alternative the need for an at-sea transfer point for resupply from tankers and container ships. Essentially, a MOB, once in place and assembled, could substitute for an overseas staging base for both deployment and resupply. However, the qualifier, "once in place and assembled," is important, for although a MOB could move or be towed into position, its speed of deployment would be slow, probably under 10 knots. For

[4]The concept of a mobile offshore base is to apply the technology of large, offshore drilling platforms to the construction of a large, floating, stable base at sea. Modules would be self-deployable and capable of being linked together to create an airstrip large enough to load the C-17 transport aircraft. The concept is in research and development.

that reason (plus its high cost and technical uncertainty), this committee has little enthusiasm for the concept of a MOB as a substitute for maritime prepositioning or sea-basing ships supporting early-entry expeditionary operations.[5] Nonetheless, if, in the future, U.S. naval forces must operate long distances from CONUS without the benefit of overseas ports or airfields, a MOB could be a valuable asset.

RECOMMENDATION: *If a goal is to deploy and sustain forces without dependence on overseas facilities, the Navy and Marine Corps should continue research and development of the mobile offshore base as an option for future naval capability.*

If suitable overseas airfields are available along the deployment route of the MPF ships, troops could be flown via strategic airlift to the airfields and then ferried to the ships by intratheater airlift. The transfer could be done by self-deployed V-22s and CH-53Es, with or without aerial refueling, depending on the distances—a feasible but hardly efficient process for a large force. A sea-basing ship capable of handling fixed-wing aircraft, complemented by a new-design, fixed-wing, STOL transport aircraft that has a larger payload and longer range than the V-22, could satisfy the requirement.[6] Other options are as follows: (1) the MPF ships, whatever their configuration, could delay their departure from their prepositioning home ports to await arrival, by air, of the Marine Corps contingent, or (2) the prepositioned ships, while en route, could be brought in to a roadstead or port (as the CNA study assumed) to pick up the troops and any equipment flown in. Either of these last two options would increase deployment time and may not meet the "at-sea arrival" feature of the MPF 2010+ concept. Clearly, deciding the importance to OMFTS of at-sea arrival and assembly, the size of the force arriving and assembling at sea, and the role, if any, for overseas facilities is essential to setting new MPF ship requirements.

Of the conventional ship configurations, the most capable ship for the MPF 2010+ mission in the CNA's study has a large flight deck capable of handling fixed-wing aircraft, ample billeting space, state-of-the-art material- and container-handling capability, spaces for maintenance activities, a well deck for landing

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[5]Previous Naval Studies Board reports also have advocated a cautious approach by the Navy and Marine Corps to the development of a mobile offshore base (see Naval Studies Board, National Research Council. 1996. *The Navy and Marine Corps in Regional Conflict in the 21st Century,* National Academy Press, Washington, D.C., and Naval Studies Board, National Research Council, 1997, *Technology for the United States Navy and Marine Corps, 2000-2035, Volume 8: Logistics,* National Academy Press, Washington, D.C.).

[6]In 1963, an unmodified KC-130 F made 20 touch/go landings and 21 unassisted landings/takeoffs on the aircraft carrier USS *Forrestal.* In 1961, preliminary studies of STOL modifications to the C-130H found that such a craft could transport 20,000 lb of cargo 3,500 miles, unrefueled, and land on an aircraft carrier unassisted in 430 ft; it could then, with 10,000 lb of cargo, take off unassisted in 625 ft and fly 2,000 miles without refueling. The safety constraint on operations was too little clearance between the aircraft's wing tip and the ship's island.

craft, and so on. Not surprisingly, the most capable sea-basing ship has much in common with today's large amphibious assault ships (LHA and LHD), though built to commercial rather than warship standards. That similarity suggests a confluence, in the future, in the design of amphibious assault and maritime prepositioning ships, permitting a single, efficient design that satisfies both missions.

RECOMMENDATION: *In long-term planning for future amphibious shipping, the Navy should consider the feasibility of a common ship design for assault, prepositioning, and sea-basing missions.*

That similarity further suggests that, in the near term, perhaps the fleet of amphibious assault ships already in service could be used more than now envisioned in implementing the MPF 2010+ concept. Today, except for the amphibious-ready groups that are forward deployed, deployment of amphibious task forces from CONUS is slow because before deploying the ships must move from their home ports and then embark the Marines, their equipment, and ammunition. If the ships were to deploy on short notice without Marines embarked, perhaps taking only landing craft and any helicopters that could be flown on while the ships were en route, they could meet up with the deploying MPF ships and provide the command and control and the aviation and landing craft needed for the MPF operation. Using "empty" amphibious assault ships in this manner would allow the new ship requirements of MPF 2010+ to be met by the lower-capability and lower-cost alternatives postulated by CNA. Amphibious ships used in this manner would not, of course, be available for deployment of additional Marine Corps units. The committee believes that the idea is worth exploring before deciding MPF ship requirements and design.

RECOMMENDATION: *Before deciding future maritime prepositioning ship requirements, the Navy and Marine Corps should explore the feasibility of using rapidly deployed amphibious warfare ships to facilitate landing maritime prepositioning forces.*

HIGH-SPEED SEALIFT

The problem presented by the deployment dilemma is how to move large, heavy forces long distances quickly enough to meet military deployment needs. If ships could travel fast enough, prepositioning, with its problems of separate troop deployment, tactical assembly, and force landing, would not be necessary. The Army, facing the same deployment dilemma as the Marines Corps, has stated a requirement for high-speed lift of its heavy forces and is exploring nontraditional ideas, such as lighter-than-air craft and high-speed ships. The Navy actively researched fast-ship technology in the 1970s but recently has been more cautious, observing commercial developments but showing little enthusiasm for new initiatives of its own. Current technology can produce only moderate improvements in speed and provide only modest payload capacity and modest range, at a high operating cost. Current fast ships operating commercially are primarily in passenger and car ferry service over short ranges. None is in transoceanic service, although several companies have plans for transoceanic ships in the 40-knot range. At a recent Navy workshop[7] that explored the state of fast-ship technology, the consensus was that near-term technology promised ships of about 50 knots, 5,000-mile range, and 10,000-ton payload, or 50 knots, 10,000-mile range, and 5,000-ton payload, and that over the next 10 to 20 years at the same speed, a 10,000-mile range and 10,000-ton payload should be achieved. The near-term figures do not yet give enough range to substitute for prepositioning. However, as future combat forces become lighter, high-speed sealift will become more attractive. The long-term prospect of fast ships should not be discarded.

HIGH-SPEED LANDING CRAFT

One of the limitations revealed by the CNA analysis is the inability of the landing craft that likely would be available in an MPF operation to land the force in a reasonable time. A recent logistics war game conducted by Marine Corps Combat Developments Command had the same finding. Two assumptions drove those results: (1) the force landed was large and heavy (e.g., 58 tanks and 1,700 other vehicles in the CNA scenario), and (2) the MPF ships remained over the horizon, 25 miles from shore. At that range, only the high-speed landing craft (air cushion), the LCAC, is of much use, and it can transport only one main battle tank at a time. The Navy's lighterage, floating causeway sections, is so slow as to be useless at that distance, and other landing craft are slow enough to be of only marginal use.

If the goal is to land or reload a large, heavy force, similar to today's prepositioned MEF (FWD), from over the horizon, a substantial increase in high-speed landing craft capability will be needed. One option is to ensure that more LCACs are at hand. This could be done by prepositioning them on or with the MPF ships, for example, on a sea barge (SeaBee) ship. It also could be done by rapidly deploying additional amphibious assault ships, as the committee already has suggested. Alternatively, a new-design, high-speed, high-capacity landing craft could be developed. (The Navy is evaluating concepts for an advanced

[7]Kennell, C., Naval Surface Warfare Center, Carderock Division, and D.R. Lavis, Lavis and Associates, High-Speed Sealift Technology Workshop, October 21-23, 1997, results and conclusions from Post-Workshop Analysis outbrief at Naval Surface Warfare Center, Carderock Division, West Bethesda, Md., March 25, 1998.

landing craft, the LCU(X)). The Naval Studies Board has previously suggested a need for a high-speed landing craft (a sea sled) to complement the LCAC.[8] The more recent analyses and war games have reinforced these earlier judgments.

RECOMMENDATION: ***The Navy should investigate the design and development of a high-speed, high-capacity landing craft to complement the landing craft (air cushion) (LCAC).***

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[8]Naval Studies Board. 1997. *Technology for the United States Navy and Marine Corps, 2000-2035, Volume 8: Logistics,* National Academy Press, Washington, D.C.

4

Force Sustainment

THE OMFTS LOGISTICS CHALLENGES

Traditional approaches to logistics will not meet future military requirements. Not only will large logistics bases ashore be unacceptably vulnerable to enemy attack, but their size and immobility will also make them incompatible with the rapidly paced, highly mobile warfighting concepts being developed. Moreover, having large stocks of materials in-theater has proven to be no assurance that the combat forces will get the supplies they need, when they need them. During Operation Desert Shield/Desert Storm, the inability to know what was in those stocks, to locate quickly the items needed, to track the status of requests, or to track shipments into or within the theater frustrated commanders and logisticians alike.

The Navy and Marine Corps are striving to revamp their logistics operations to correct current shortcomings and to meet future requirements. The goal is to replace slow, cumbersome logistics processes that are predicated on large volumes of materials that might be needed, with responsive, or, when possible, anticipatory processes that deliver only what is needed, when and where it is needed. The strategy is to use accurate, timely information and rapid transportation to create for the military the kind of efficient, effective logistics systems that leading commercial firms have developed under the labels of "supply chain management" and "just-in-time" logistics.

The Marine Corps, in particular, under its Precision Logistics program, is streamlining logistics management and business practices, gaining visibility and control of assets, and modernizing computer systems—all desirable actions to improve logistics irrespective of future operating concept. OMFTS, however,

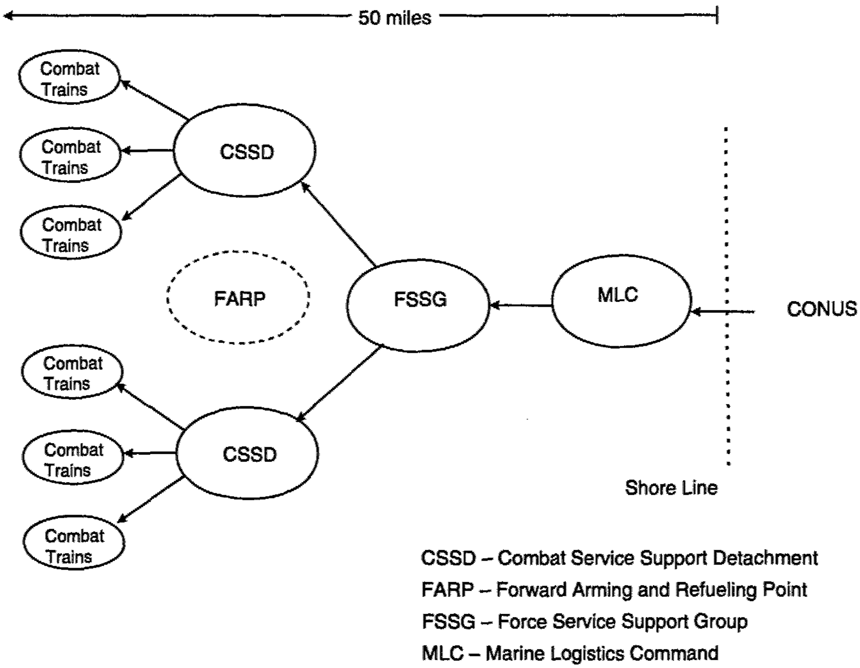

FIGURE 4.1 Principal nodes in today's logistics system.

will make these improvements essential. In addition, OMFTS will impose new demands on the logistics system, and it is to these new demands that the committee addresses its attention.

Figure 4.1 depicts a typical logistics structure for supporting today's Marine Corps operations. Combat units have, in their own combat trains, a capability to meet immediate needs for fuel, ammunition, and other supplies. That capability for most units is modest, consisting of several cargo trucks and trailers and a 1,200-gallon fuel tanker that are usually in a battalion's headquarters and services company. For some units, however, the capability is substantial: for example, in an artillery battalion it includes forklifts and trucks for hauling ammunition; in a tank battalion it includes mobile assault bridging and several fuel tankers.

The combat service support detachment (CSSD) is an ad hoc, mission-tailored organization created from the supply, maintenance, engineering, transport, and medical battalions of a force service support group. It provides the forward logistics support to deployed units. The flexibility inherent in the CSSD concept allows many variations in organizational makeup and employment: large or small, ground- or air-deployed, mobile or stationary.

A forward arming and refueling point, another ad hoc activity, provides limited replenishment of operating supplies, usually for helicopters, well forward in the area of operations. It permits the helicopters to operate for extended periods without returning to a base.

The force service support group (FSSG) is the major logistics organization in a Marine expeditionary force. In addition to being the parent of the elements composing the combat service support detachments, the FSSG is the base for most in-theater logistics activity. When the distances from ports to combat units are long (e.g., over 50 miles), a Marine Logistics Command (MLC) may be added, as depicted in Figure 4.1. An MLC conducts port activities, receives and stores incoming materiel, and provides long-haul land transport to the FSSG.

As with most aspects of its operations, the Marines Corps is adept at tailoring logistics support to the mission at hand, and the basic techniques employed provide a great deal of flexibility. OMFTS, however, suggests that even if the basic techniques may endure, significant changes in emphasis and organization may be needed to support future operations. Figure 4.2 depicts the principal nodes, as seen by the committee, in the OMFTS logistics system. The major differences are a reduction of the logistics presence, or "footprint," ashore; the

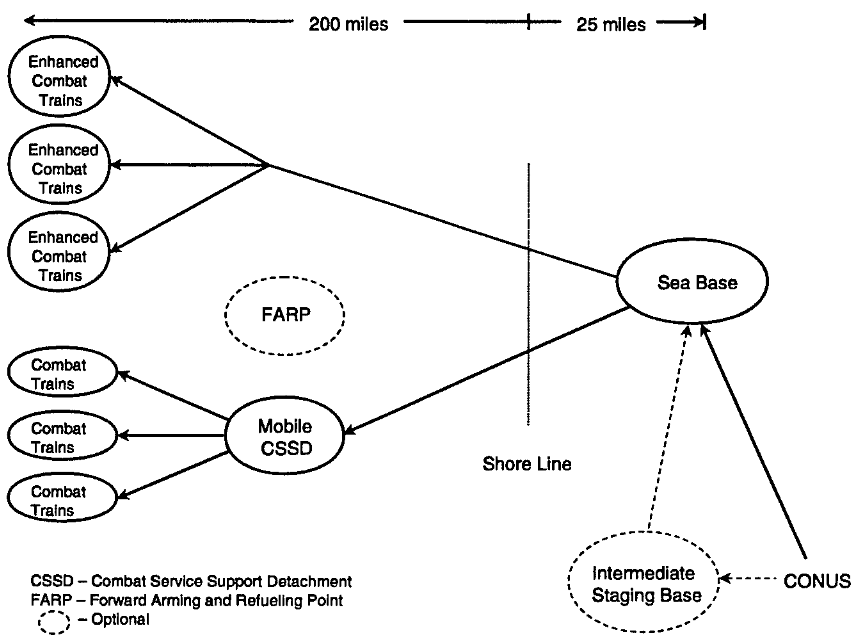

FIGURE 4.2 Principal nodes in OMFTS logistics system.

potential for very long distances between the combat units and their base of logistics support; and the introduction of a sea base. The implications of these differences are difficult to separate, for all aspects of a logistics system are interrelated. Nonetheless, for convenience in discussion, they are addressed in the following three sections.

REDUCING THE LOGISTICS FOOTPRINT

The major determinants of the logistics footprint ashore are the support requirements of the forces ashore and the support concept.

Reducing Forces Ashore

Basing major support functions at sea (or performing them in CONUS or other locations remote from the theater of operations), as envisioned by OMFTS, would be the first and most dramatic step to reducing support requirements ashore. For example, Table 4.1 illustrates how the number of Marines ashore and tons of supplies required per day ashore would change as various elements of a full, prepositioned MEF (FWD) are sea based. Sea basing the air-combat element clearly buys the most reduction in requirements. Putting only the landing force ashore reduces requirements by almost 80 percent.

The landing force in Figure 4.2 is composed primarily of the prepositioned, ground-combat units of an MEF (FWD), with some minimal command and combat service support. Table 4.2 breaks out the landing force's resupply requirements by unit. A quick glance at the bottom row, "Percent," reveals what every Marine Corps logistician knows well: water and fuel are the largest resupply requirements. Water requirements are usually a function of the number of personnel being supported but can vary widely, depending on such factors as the climate, availability of local supplies, and need to decontaminate equipment.

TABLE 4.1 Marine Expeditionary Force (Forward) Daily Resupply Requirements

	Marines Ashore	Tons Needed
Full MEF (FWD)	17,800	2,235
MEF (FWD) with aviation at sea	10,460	848
MEF (FWD) with aviation and command at sea	9,660	785
Landing force only	6,800	490

SOURCE: McAllister, Keith R. 1998. *MPF 2010 Ship-to-Shore Movement and Seabased Logistics Support, Volume I: Report* and *Volume II: Appendices,* Center for Naval Analyses, Alexandria, Va., March.

TABLE 4.2 Landing Force Daily Resupply Requirements

	Personnel	Food Requirement (Short Tons)	Water Requirement (Short Tons)
Command Element	365	0.80	10.18
Ground Combat Element	5,694	12.53	158.86
Headquarters Battalion	158	0.35	4.41
Infantry Regiment	2,993	6.58	83.50
Artillery Battalion	835	1.84	23.30
AAAV Battalion	521	1.15	14.54
Engineering Battalion	224	0.49	6.25
Light Armored Reconnaissance Company	138	0.30	3.85
Tank Battalion	825	1.82	23.02
Combat Service Support Element	747	1.64	20.84
Military Police Company (–)	89	0.20	2.48
Landing Support Battalion	360	0.79	10.04
Military Transportation Battalion	298	0.66	8.31
Total	6,806	14.97	189.89
Percent		3.10	38.80

*Not included by CNA. Other cargo, added at 7.8 lb/Marine/day, includes an austere level of construction material, medical, and parts resupply.

The largest consumers of fuel among combat forces are the artillery battalion (primarily trucks hauling ammunition), and the AAAV and the tank battalion, together accounting for over half of the landing force's fuel requirements. Although technology may eventually produce more-fuel-efficient power plants for this heavy equipment, the only near-term route to reducing requirements lies in lightening the force. In particular, the Marine Corps should examine carefully the roles of tanks and artillery in future force structure. Logistics requirements of forces ashore would be cut dramatically if the Marine Corps eliminated both, or, in the case of artillery, determined that precision guided rounds and new naval guns and missiles could substitute for artillery enough to reduce conventional artillery ammunition requirements substantially.

Recommendation: *The Marine Corps should assess the roles of main battle tanks and artillery in future force structure, giving particular attention to the impact of precision guided munitions and naval guns and missiles on artillery ammunition requirements.*

Fuel Requirement (Short Tons)	Ammunition Requirement (Short Tons)	Other Cargo* (Short Tons)	Total	Percent
15.90	0.53	1.42	28.84	5.9
152.23	32.07	22.21	377.90	77.1
8.96	0.20	0.62	14.54	3.0
6.53	3.76	11.67	112.05	22.9
54.13	20.19	3.26	102.71	21.0
25.86	2.28	2.03	45.86	9.4
16.25	2.50	0.87	26.36	5.4
2.59	1.44	0.54	8.72	1.8
37.91	1.71	3.22	67.66	13.8
56.87	0.88	2.91	83.15	17.0
0.71	0.10	0.35	3.84	0.8
10.67	0.23	1.40	23.13	4.7
45.50	0.55	1.16	56.19	11.5
225.01	33.48	26.54	489.89	100.0
45.90	6.80	5.40		100.0

SOURCE: Adapted from McAllister, Keith R. 1998. *MPF 2010 Ship-to-Shore Movement and Sea-based Logistics Support, Volume I: Report* and *Volume II: Appendices*, Center for Naval Analyses, Alexandria, Va., March.

Designing the Support Concept

In Table 4.1, the second largest reduction, signified by the differences between the last two rows (from 9,660 personnel to 6,800 and from 785 short tons to 490) is attributable to leaving most of the combat service support element at sea. The extent to which that is feasible depends in large measure on the support concept.

The new warfighting concepts and the emphasis placed on minimizing the logistics footprint ashore suggest that the OMFTS theater logistics system should be based to the extent possible on two primary nodes—the sea base and the combat forces ashore. Several variations on this theme are possible. Although all are used from time to time by the Marines Corps today, they should become more prevalent under OMFTS.

- *Direct unit delivery.* Direct air delivery from the ships in the sea base to combat units ashore significantly reduces the need for disembarking considerable numbers of combat service support personnel and equipment. This concept inherently requires intensive use of air assets such as the V-22 and CH-53E, but other means such as air drop, parafoil, and unmanned air vehicles could also prove to be indispensable, particularly for resupply of small, light infantry units.

- *Enhanced combat trains.* Combat units typically can sustain themselves for a few days without support from a combat service support detachment. Giving a combat unit the capability to sustain itself longer, by either enlarging its organic logistics capabilities or by assigning combat service support elements in a direct support role, could eliminate the need for a separate combat service support detachment. An enhanced combat train could provide a greater safety margin, for example, by having enough trucks and trailers to carry about 5 to 10 days of supplies for the unit instead of just 2 to 3 days. It could also be resupplied directly from the sea base and move with the combat element.

Although enhanced combat trains could provide a greater margin for safety, they could result in a larger logistics footprint than is deemed advisable in a combat unit. Their projected pros and cons would have to be balanced against those associated with employing traditional techniques and the use of mobile but separate combat service support detachments located in close proximity to the supported unit(s).

- *Forward arming and refueling points (FARPs).* The primary needs of a combat unit on the move are fuel and ammunition. A highly mobile, arming and refueling capability that could rendezvous with a combat unit, refuel and rearm it, provide other quick services, and then leave would potentially be invaluable because it could enable the fighting forces of the future to have smaller combat trains and to resume operations with minimal delay.

If designed for rapid insertion, setup, breakdown, and removal, FARPs could provide essential support services and enough fuel, ammunition, and other supplies to sustain operations for a short period of time, say 2 to 3 days. The temporary positioning of such detachments by either watercraft or air for a few hours at most would reduce their vulnerability to enemy attack. The tactical bulk fuel delivery systems that can be inserted in the CH-53E are designed specifically for such missions.

- *Mobile combat service support detachment.* Under a sea-based logistics concept, combat service support detachments are likely to be the major logistics footprint ashore. To support the highly mobile, widely dispersed operations and long ranges envisioned by OMFTS, they frequently will have to be mobile. That is, they will deploy rapidly, set up service units in their areas for one to several days, be quickly dismantled, and be moved to new locations. Their modes of deployment, distribution to supported units, and resupply will be tailored to the mission and circumstances. For example, a mobile combat service support detachment might move inland via road as part of a maneuvering task force, and then be resupplied by rotary-wing aircraft from the sea base. Or such a detachment might be established near the shore, where it could be deployed and resupplied by surface craft, or at an airfield, possibly an expeditionary airfield, where it could be deployed and resupplied by intratheater airlift. Distribution of sup-

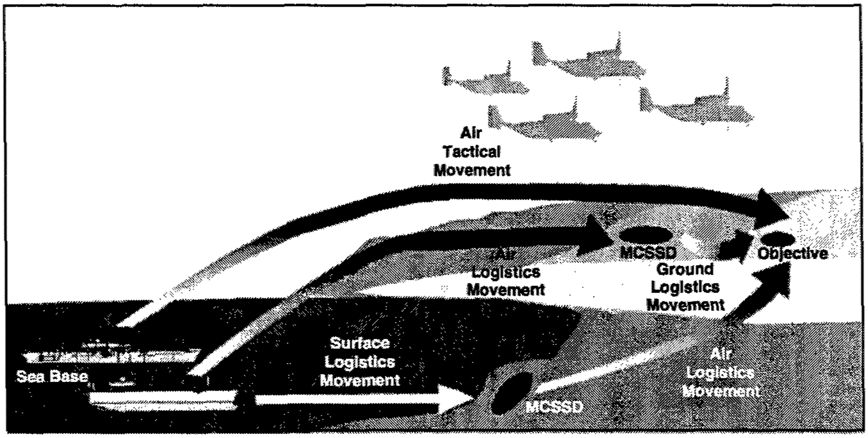

FIGURE 4.3 Mobile combat service support detachments (MCSSDs).

plies and services from the mobile combat service support detachment to supported units might be by either air or truck, depending on distances and terrain. In all cases, the need will be to minimize the vulnerability of the detachments by keeping them small, dispersed, well camouflaged, and secure from enemy attack, but, at the same time, providing sufficient hedge against the risks created by relying on an at-sea logistics base many miles away. An example of possible uses of such mobile combat service support detachments is depicted in Figure 4.3. The example shows two mobile detachments. One is near the shore, where it can be deployed and resupplied by surface craft. The other is well inland, where it is deployed and resupplied by air.

Packaging and Containerization

An important issue in deciding future support concepts is the role of containers. The general principal in streamlining logistics operations is to minimize the handling of material. The ideal is to package at the origin for end use and deliver directly to users without any repackaging.

To facilitate such origin-to-destination movements of material, industry has developed a highly efficient, worldwide transport system for moving cargo in standard containers. The standard unit of measure is 20-foot equivalent unit (TEU), meaning an 8 ft × 8 ft × 20 ft container, but the industry trend is to 40-ft containers. The system is intermodal, permitting the containers to be moved, without reconfiguration, via truck, railcar, and ship. The advantages of using standardized containers are many: security of contents, protection from the elements, efficiency in handling, and efficiency in movement.

Both the Marine Corps and the Army are developing capabilities to make greater use of containers in supporting their forces. The Marine Corps maritime prepositioning force, except for rolling stock, is largely containerized, and Marines have the capability to off-load and move the containers either at ports or over the shore. The motivation for using containers has been, in part, to gain the same efficiencies in handling and moving cargo that industry has enjoyed; in addition, the breakbulk ships traditionally used to transport most military materiel overseas have largely disappeared from commercial service, and container ships are dominating commercial trade.

The dilemma the Marine Corps will face in supporting OMFTS is that while extensive use of containers is essential to efficient support of heavy forces, their use requires a substantial footprint ashore (capabilities for moving them ashore, handling and transporting them, and breaking out their contents for delivery to using units). Moreover, fully loaded 20-ft containers are too heavy to be moved by the V-22 and can be moved only short distances by the CH-53 (40-ft containers are difficult for the Marine Corps to transport and handle by any means). Thus, OMFTS operations probably will dictate that containers be used no further forward than the sea base and that material be repackaged, if necessary, for end use by logistics personnel on board ships. However, if the Marine Corps intends to maintain capabilities to make a transition from sea-based logistics to conventional land-based logistics, and then reverse the process for force reconstitution, container-handling and transport assets must remain in the force.

Designing the support concept or concepts that best fit the needs of future logistics operations is not a trivial task. It involves assessing not just logistics requirements and capabilities, but also the costs and risks of each alternative. Since the number of variables is large and the cost of experimenting much with real units the size of an MEF (FWD) would be prohibitive, this type of analysis is best done by modeling and simulation. The committee believes that the potential logistics implications of OMFTS justify the use of such analytic tools.

***Recommendation:** The Marine Corps should invest in modeling and simulating OMFTS logistics operations to assess logistics needs, capabilities, and alternative support concepts.*

PROVIDING SUPPORT OVER EXTENDED DISTANCES

If battles of the future are fought as the conceptual designers of OMFTS envision, highly mobile combat units will be widely dispersed, possibly well inland, focusing only on key objectives with high military value; they will not be clearing and securing the areas through which or over which they move en route to their objectives. In some relatively benign situations, establishing traditional land lines of communication, i.e., moving sustaining supplies, equipment, and services by truck convoy, still will be possible. However, having the capability to sustain and reconstitute the combat forces over very long distances without dependence on secure road networks and rear areas seems fundamental to the

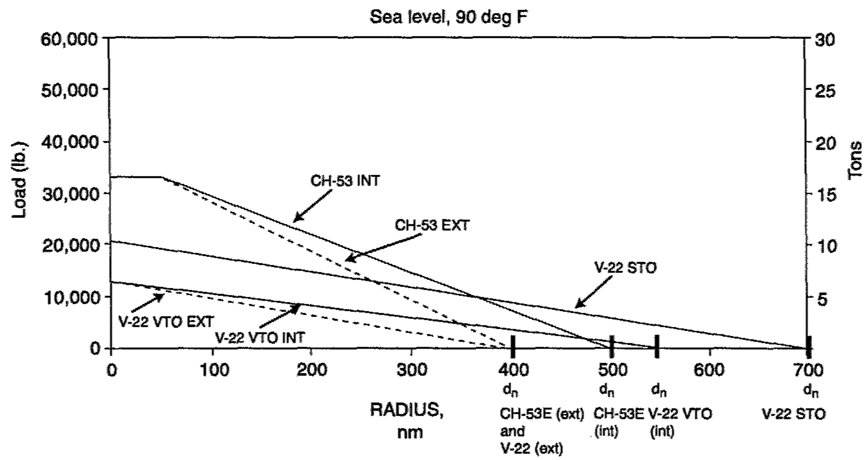

FIGURE 4.4 Performance of some existing transport aircraft. Fuel usage rate is constant, regardless of speed, load, or flying conditions. NOTE: External loads are notional. Ranges vary for different external loads.

OMFTS operating concepts. That means a much greater reliance on air transport than has been the practice for Marine Corps ground-force logistics.

With procurement of the V-22 and extension of the life of the CH-53E, the Marine Corp is gaining the capability to move substantial quantities of material by air. Figure 4.4 shows the approximate relationships between payload and range for the aircraft, with either internal or external loads.[1] As can be seen from Figure 4.4, both the V-22 and CH-53E aircraft extend the reach of a landing force far beyond the shore, and, with aerial refueling, both can reach even further with internal loads than shown here. The maximum payloads, however, decrease with distance, especially for external loads. If the effect of distance on flying time is combined with its effect on maximum load, its effect on productivity (the tons of material that can be transported in a day) is dramatic. This decline in aircraft delivery productivity as a function of distance is depicted in Figure 4.5. For example, an aircraft could deliver 10 times as much at 10 percent of the aircraft's maximum no-load radius as it could at 50 percent of the radius. The issues are whether those two aircraft can meet the needs of the types and sizes of forces envisioned over the distances envisioned and, if not, what alternatives the Marine Corps should explore.

The CNA study, in an analytic excursion, sought to gauge the outer limits of the V-22 and CH-53E in supporting the ground-combat element of today's pre-

[1]See Appendix D for derivation of payload-distance and productivity relationships.

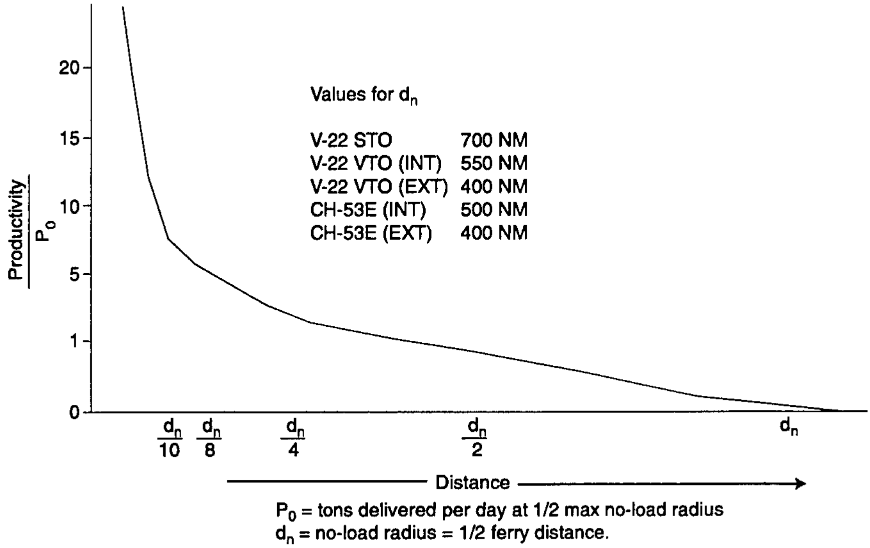

FIGURE 4.5 Aircraft transport productivity as a function of distance.

positioned MEF (FWD), a force of about 7,000 Marines ashore. The finding was 175 nautical miles from the sea base, assuming the numbers of V-22s and CH-53Es normally associated with that size MAGTF and no other missions for the aircraft.[2]

The committee's own rough assessment, drawing largely on CNA's data, is depicted in Table 4.3. It, too, shows that a large, heavy force will be difficult to support entirely by air over long distances even when the force's entire complement of V-22s and CH-53Es is devoted to logistics missions. In fact, because the committee's analyses assumed ideal conditions—fair weather, calm seas, no enemy interdiction of air routes, a continuous 10 hours of operations per day, 100 percent aircraft availability, and direct routing—the break point is probably well under 125 miles.[3] Similar limitations are expected to affect force reconstitution. Reducing the ground-combat element's fuel and ammunition requirements would be one approach to bringing air transport needs and capabilities into better balance. Long-term research and development should be focused on that goal. But, for the foreseeable future, reductions in fuel and ammunition

[2]McAllister, Keith R. 1998. *MPF 2010 Ship-to-Shore Movement and Seabased Logistics Support, Volume I: Report*, Center for Naval Analyses, Alexandria, Va., March, p. 98.

[3]The committee was unable to locate any substantial information accounting for adverse conditions and their effect on OMFTS requirements. As a necessary next step, unfavorable conditions (e.g., difficult weather) should be addressed once all logistics parameters under ideal conditions have been established.

TABLE 4.3 Percent of Resupply Requirements Met by Air Deliveries (7,000-Marine Landing Force Using All Planned V-22 and CH-53 Aircraft)

Portion of Force Supported	250 Miles	125 Miles	55 Miles
Full MEF (FWD)	15 percent	34 percent	55 percent
MEF (FWD) less ACE	40 percent	89 percent	100 percent
MEF (FWD) less ACE and CE	43 percent	96 percent	100 percent
Landing force only	69 percent	100 percent	100 percent

NOTE: See Appendix C for data and computations. MEF (FWD), Marine expeditionary unit (forward); ACE, air combat element; CE, combat element.
SOURCE: Adapted from Appendix C, Table C.1, McAllister, Keith R. 1998. *MPF 2010 Ship-to-Shore Movement and Seabased Logistics Support, Volume I: Report* and *Volume II: Appendices,* Center for Naval Analyses, Alexandria, Va., March, and Tables C.2 and C.3 by David Kassing, committee member.

requirements, as already suggested, probably require changes in the structure of the combat force.

If the OMFTS concept is to be implemented with large, mechanized task forces operating long distances inland, additional air transport capabilities will be needed. Several alternatives are possible: more V-22s and CH-53s; reliance on intratheater airlift; development of a new-design, ship-capable, fixed-wing STOL transport; or development of a new-design, longer-range, heavy-lift helicopter.

- *More V-22s and CH-53Es.* More means either buying additional aircraft or committing a larger proportion of planned purchases to sustainment needs. In either case, sufficient ships for basing the aircraft would need to be factored into the equation.
- *Intratheater airlift.* C-17 and C-130 aircraft provide the joint intratheater airlift capabilities available to naval forces. The Marines should be prepared by organizational structure and training to fully exploit these capabilities. The issue here, however, is the extent to which naval expeditionary warfare doctrine and capabilities should depend on joint capabilities. Furthermore, if support of large forces well inland requires use of intratheater airlift, then an airfield or suitable terrain for rapid creation of a suitable airstrip must be an early planning objective in operational planning, and lack of such an airfield or suitable terrain will constrain the type of operations that can be supported.
- *Heavy-lift helicopter.* Although the CH-53 can lift heavy loads, its capability drops off quickly with distance. A new, heavy-lift helicopter—perhaps a crane-type design—could provide the heavy-lift capability at longer ranges, say 15 to 20 tons at an operating radius of 250 miles.

- *STOL transport.* If the Navy and Marine Corps determine that a ship-to-shore aircraft capability is required to support large forces well inland, they should consider developing a new-design, ship-capable, fixed-wing STOL aircraft for that purpose. Such a decision carries with it complementary decisions and costs associated with having an at-sea basing capability for the aircraft (aircraft carrier, amphibious assault ship, mobile offshore base, or a sea-based logistics ship) and a capability to rapidly create suitable airstrips ashore. The Army also has an interest in such an aircraft and should be offered the opportunity to collaborate on the design.

Deciding the alternatives to be examined and the limits to sustaining ground-combat elements by air transport means is critically important to refining the OMFTS conceptual framework. Gaining insight into the size and type of forces that can be supported over long distances and the conditions under which they can be supported with an acceptable level of risk must receive priority effort. Appendix D shows a committee member's approach to quantifying the logistics productivity of aircraft in terms of an aircraft's design features, assumed performance, and distance. Using such an analytical aid could help in making initial assessments.

It is important to note also that OMFTS will likely require a much greater allocation of available air assets for logistics missions than has been the case in the past. Not only will logistics be an integral part of maneuver operations, but the support concept for a task force, including command and control, will also need to be fully integrated with aviation support planning and air mission tasking.

Recommendation: *The Marine Corps should examine the capabilities and limitations of various options for delivering by means of air transport the sustaining support required by large ground forces over various operating distances from the sea base. The Marine Corps should adjust the evolution of OMFTS concepts, maneuver force design, and aircraft and shipbuilding programs to ensure that operational and logistics capabilities are appropriately sized and balanced.*

Recommendation: *The Navy and Marine Corps should determine the technical feasibility, costs, and operational value of a ship-capable, fixed-wing STOL transport aircraft and a complementary, fixed-wing-capable logistics ship that could substantially increase the naval forces' capability to support large ground units long distances from a sea base.*

SUPPORTING FORCES FROM A SEA BASE

Sea basing requires doing at sea, often under severe weather and sea-state conditions, many of the functions traditionally performed at logistics bases on shore (or transferring the function out of theater). This has implications for organizational design, shipboard distribution operations, integration of sustainment efforts, and strategic resupply.

Organizational Design

While the Marine Corps is adept at tailoring organizations to meet mission needs, the standard organizational structures are designed for operations ashore. Simply adapting those organizations to operations at sea may not be the optimal solution. For example, while standard organizations might adapt well to operations aboard a mobile offshore base, which houses all activities in a central location, spreading those same activities among a number of ships of different types may call for different specialization and division of labor.

In addition, under new Department of Defense policy, many of the product support responsibilities for military equipment are to be performed by contractors. To facilitate effective support of their products, these contractors may need to establish forward operations at an intermediate support base near the theater or, possibly, on ships composing the sea base. This is a matter the Navy and Marine Corps should think through carefully, for using civilians in this manner would have cost, legal, and labor union implications. Nonetheless, civilians may be able to do on ships many of the logistics functions normally done by rear-area military personnel. For example, the warehousing functions of receiving, breaking out, and repackaging supplies for distribution to forces ashore, as well as much of the equipment maintenance, could be done by civilians. Since civil mariners of the Military Sealift Command are likely to be operating many of the ships of the sea base, having other civilians on board performing support functions for the Marines would not be discordant.

Shipboard Distribution Operations

Sustaining OMFTS operations from a sea base will require the ability to rapidly locate, select, package, and deliver supplies to units ashore. These are the traditional functions of a distribution center—pick, pack, and ship—but performed in an at-sea shipboard environment.

Selective off-loading will involve unpacking cargo from containers (with single or mixed loads), repackaging it, and moving the newly packaged cargo from below decks to elevators to the staging area on the flight deck for air transport. Industry-based automated warehousing is done daily on land, but doing it in the confined spaces aboard a ship that has continuous, random motion due to the seaway while cargo is being extracted from containers is a major challenge. Severe weather and rough seas could slow or halt operations. Creating a capability to conduct efficient, effective shipboard distribution operations will require an integrated effort between industries involved in warehousing, shipbuilding, ship dynamics, crane and deck machinery stabilization, and information systems.

Integrating the Sustainment Effort

One of the central defining features of the new OMFTS conceptual framework is the requirement to deliver tailored loads from the sea base to highly mobile, widely dispersed combat elements in the battlespace. Achieving the OMFTS goal will require the skillful integration of a multitude of diverse activities. Moreover, the scope and complexity of the sustainability integration task under OMFTS is likely to increase exponentially with increases in both (1) the size and dispersion of the forces ashore and (2) the separation distances between them and the sea base.

Today's sustainment operations include a large beach-support area and several layers of stocks ashore, and they rely predominantly on truck convoys. Under the OMFTS framework, once a unit's needs ashore are identified or projected, crews afloat must assemble, possibly from several different ships, a tailored load for delivery to the unit. To facilitate responsiveness and promote better use of available delivery means, pickup times, delivery routes, and mission completion times will have to be preplanned and integrated into the overall operation, particularly along the delivery route to the unit and its immediate area of operations. Reconstitution of forces will pose similar challenges. Moreover, if the threat ashore warrants, V-22 and CH-53 logistics flights may have to be accompanied by suitably armed escorts, further complicating the overall integration effort.

The Marine Corps has given little attention to the information systems needed to control and integrate combat service support activities in the sea-based OMFTS environment. Today's bootstrap efforts in operating units to create logistics command-and-control systems are well motivated and creative but have limited resources, use today's communications and computer capabilities, and are focused on today's modes of operation.

RECOMMENDATION: The Marine Corps should start developing the logistics information systems, displays, and automated decision aids it will need to manage fast-paced, complex support operations in tomorrow's warfighting environment.

Resupplying Ships of the Sea Base

If indefinite sustainment from a sea base is to be attained, resupply of the sea base will be necessary. Unless the sea base includes a mobile offshore base, which by its design is capable of handling strategic airlift and sealift craft, all options have their limitations. The following discussion assumes that the sea base is composed of ships, e.g., amphibious warfare ships, maritime prepositioning ships, and various auxiliary support ships.

Consider, first, resupply of small, high-priority items, such as spare parts. The movement of such items from CONUS overseas usually will be by strategic airlift. So, how best to link the sea base to arrival airfields is an important issue. A carrier battle group makes that link with its carrier on-board delivery aircraft or, over short distances, helicopters. Some limited resupply of the sea base could be done using the carrier on-board delivery capabilities of the carrier battle group, but probably not much resupply would be possible because the capabilities of those aircraft are consumed supporting the carrier's needs. Most likely, the Marines would use their own CH-53Es and V-22s—another mission for those two overworked assets. At long distances, aerial refueling would be needed.

Resupply of fuel, although the toughest problem for forces ashore, is probably the easiest of the tasks at sea. Ships of the sea base would be resupplied with fuel for both their own use and for use by the Marines the same ways ships normally are resupplied: either in port or by underway replenishment.

Replenishing the sea base with dry cargo (ammunition, equipment, and supplies) will be the most difficult task. In the future, most dry cargo will be moved to the theater of operations by container ships. Transferring the containers or their contents to ships of the sea base is a critical link in the sea-basing concept. Several options exist:

- *Transfer of containers at an intermediate staging base.* The simplest approach would be to transfer containers at a port that has container-handling capabilities. However, the ship to be resupplied would have to leave its station, temporarily quitting its mission as part of the sea base, and proceed to the port for the cargo. At best, the process would take several days, probably longer.
- *Direct transfer of containers at anchorage.* Containers could be transferred directly from a container ship to a sea-base ship using either the cranes of the sea-base ship or an auxiliary crane ship. Today, such transfers would have to take place in calm waters, at sea state 2 or less. Research on crane technology is seeking to develop stabilized cranes that could make such transfers at sea state 3 or possibly higher.[4] In either case, of course, the specific containers to be transferred would have to be readily accessible on the container ship, on the deck, or on the first or second layer, but not in the holds.
- *Container shuttle.* If a shuttle ship, designed to handle and transport containers, had a well or other feature for interfacing with landing craft, containers could be loaded on the shuttle ship at an intermediate staging base, shuttled

[4]An Advanced Technology Demonstration project entitled Advanced Shipboard Crane Motion Control System is planned for Fiscal Year 2000 to demonstrate the feasibility of combining advanced control system technologies with existing shipboard cranes to reduce or eliminate cargo pendulation during lift-on/ lift-off operations.

to the sea base, and then transferred to ships of the sea base using surface craft, such as the LCAC or other landing craft. Such a ship could be stationed initially as part of the MPF and then could serve as a shuttle as other ships of the sea base need replenishment.

- *Conventional underway replenishment.* The Navy for years has used underway replenishment techniques to sustain its ships at sea. Shuttle ships move pallets of cargo from overseas supply points to the ships and transfer the pallets by both vertical replenishment, using helicopters, and alongside replenishment. The ships of the sea base could be resupplied with Marine Corps material using the same techniques. Containers would first be moved to an intermediate staging base, off-loaded, and emptied of their pallet loads, and the pallets would then be shuttled to the sea base.
- *Underway transfer of containers.* This option is not feasible with today's equipment. However, preliminary calculations done by engineers at the Port Hueneme Division, Naval Surface Warfare Center, California, indicate that transferring 20-ft containers by alongside underway replenishment techniques is not out of the question.[5] Greater high-line tensions and hauling-winch differentials would be needed, but, from an engineering standpoint, it could be done. (Theoretically, even 40-ft containers could be transferred, but that is an even greater step from today's capabilities. Of course, container-handling capabilities would have to be resident in both the shuttle and receiving ships. Force reconstitution, again, will have similar requirements.

Like other logistics problems related to OMFTS, deciding how best to resupply the sea base (other than a mobile offshore base) is not a straightforward matter. Much depends on the makeup of the sea base, but also on whether overseas ports are available and on how Navy logistics assets are used. Clearly, this is not an issue for the Marine Corps alone.

RECOMMENDATION:* *The Navy and Marine Corps should work together to craft a common approach to the resupply of all naval forces at sea.

TOTAL LOGISTICS CONCEPT

In summary, some of the important issues that must be addressed in redesigning the logistics system to sustain forces ashore are reducing prepositioning, deployment, and resupply requirements through redesign of the forces ashore; shifting the support concept to two primary nodes (unit and sea base); shifting the emphasis from truck transport to air transport; building the information capabilities to effectively integrate sustainment operations; resupplying the sea base;

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[5]Naidu, Anil, Underway Replenishment, Port Hueneme Division, Naval Surface Warfare Center, "Seabased Combat Logistics Concept," briefing to the committee, March 12, 1998.

and reconstituting the force. These issues, however, must not be approached or resolved piecemeal. They must be addressed in the context of a systems concept of combat service support for future expeditionary operations.

Such a concept, which does not yet exist, is needed both to guide assessment of organizational, procedural, and equipment needs and to influence, in an interactive, integrated, strategic planning process, the design of the operating concept. Both the Navy and the Marine Corps must participate in creating this support concept, and it should span the full set of combat service support functions, reaching from the Marine at the outer edge of the battlespace back to the CONUS sustaining base.

Recommendation: *The Navy and Marine Corps should create an end-to-end OMFTS logistics concept that supports the concept of operations at each stage in the iterative process of defining future forces and their capabilities.*

5

Force Medical Support

A NEW CONCEPT OF CASUALTY CARE

Historically, military forces have been supported by a large complex of in-theater, health service support facilities. As with other logistics functions, there was a system of progressively more capable facilities, stretching from combat units rearward to CONUS. The focus was on returning patients to duty from the lowest possible echelon of care. Patients who could not be returned to duty within prescribed times were evacuated to the next higher echelon. Patients could spend from 30 to 120 days in the theater health care system before being evacuated to hospitals outside the theater; by then, patients were stable and required little care en route.

The concept of casualty care supporting OMFTS is dramatically different from the traditional approach (see Figure 5.1).[1] The concept places emphasis on early trauma care on the battlefield; rapid tactical aeromedical evacuation to a casualty-receiving and casualty-care facility (in most cases an amphibious assault ship); minimum, essential care and hospitalization in-theater; and rapid evacuation of casualties from the theater. In short, save life and limb, stabilize, and evacuate.

Implementing the concept requires a carefully structured balance among

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[1]Marine Corps Combat Development Command. 1997. "A Concept of Casualty Care for Operational Maneuver from the Sea (Working Draft)," Marine Corps Combat Development Command, Quantico, Va., and Naval Doctrine Command, Norfolk, Va., November. Available online at <http://ndcweb.navy.mil/concepts/ccc/ccc1.htm>.

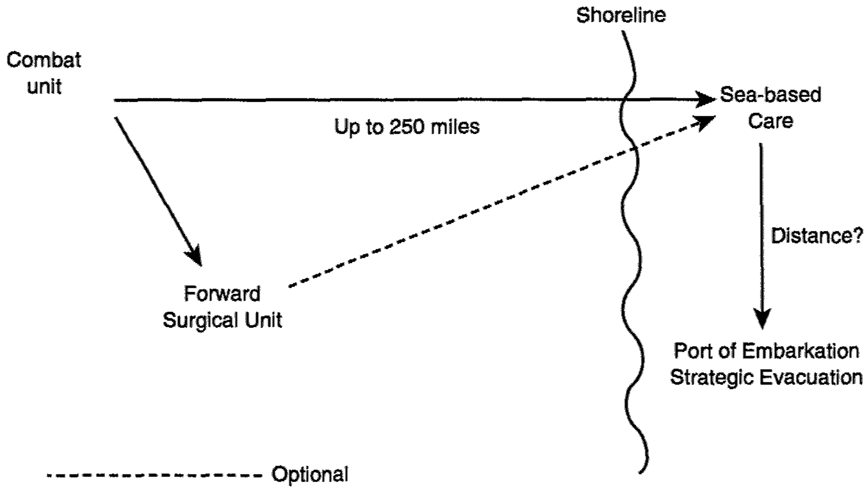

FIGURE 5.1 OMFTS casualty-care concept.

shore-based care, ship-based care, and evacuation capabilities. If shore-based medical capabilities are minimal, evacuation, en route care, and sea-based capabilities must compensate. If evacuation times are long, shore-based capabilities must be sufficient to stabilize the patient before movement.[2]

The long distances implicit in the OMFTS vision of combat operations mean that tactical aeromedical evacuation from the battlefield to ship-based care could take 1 to 2 hours. Thus, the keys to casualty survival will be effective first aid and lifesaving emergency surgery on the battlefield.

FIRST-RESPONDER CARE

Hemorrhage and inability to breathe require immediate attention at the site of injury. Other Marines (buddy care) and corpsmen offer the first opportunity to apply lifesaving procedures. Better training and medical equipment are needed to provide those first responders with the skills and tools they need to be effective.

Injuries to the extremities are the most common wartime wounds. A study of Vietnam War casualties found that management of such wounds and associated bleeding was inadequate. Corpsmen were not trained to handle life-threatening injuries, and they lacked such simple field equipment as effective tourniquets.

[2]Experience from the Vietnam War underscores the value of early trauma care. In that war, 78 percent of those killed in action died within 5 minutes, 16 percent in 5 to 30 minutes, and 6 percent in 1/2 to 2 hours. Eight to 10 percent of combat casualties required lifesaving surgery.

Most thoracic injuries do not require immediate surgery, but do require temporary closure of wounds and the ability to expand the lung and control hemorrhaging in the chest cavity. Current field dressings do not provide adequate sealing of the chest cavity, and no device exists for field use in reexpansion of the lung and drainage of hemorrhaged blood. Pain management is important if evacuation is delayed or circumstances make it necessary to keep the casualty functional, for example, to perform self-care or unit duties. Current painkillers cannot be administered by untrained personnel and often leave the patient with impaired cognitive functions.

FORWARD SURGICAL UNIT

Some minimal surgical capability will be needed to support the ground-combat units. The mission will be to stabilize casualties, including selected emergency surgery, prior to evacuation to ship-based care. The medical facility should be small, easily deployable, reconfigurable for transport by air or ground vehicle, and sustainable with water, oxygen, blood products, and recyclable non-consumables. Staffing would be tailored to the circumstances, but the minimum would be about ten medical personnel, among them at least two general surgeons, one orthopedic specialist, and two nurse anesthesiologists or anesthetists. Most importantly, the type of medicine practiced in an austere, forward surgical unit will be dramatically different from that taught in medical schools and practiced in hospitals or in previous conflicts. The staff should be trained to practice combat casualty care in that type of deployable facility, with the limited equipment, personnel, supplies, and time available.

AEROMEDICAL EVACUATION

Timely evacuation from the battlefield to ship-based medical care and from the ship to a hospital or hospital ship is a critical element in the OMFTS casualty-care concept. For these evacuations, the Marine Corps probably will not use dedicated medical evacuation aircraft but will assign aircraft to medical evacuation missions as needed, i.e., aircraft of opportunity. To increase casualty survivability during prolonged evacuation flights, an "en route care kit" should be designed. Such a kit should include equipment for monitoring a patient's vital signs and easy-to-use, life-sustaining emergency equipment. For example, the following minimum needs for transport of trauma patients should be met: monitoring of oxygen and carbon dioxide; respirator support for patients who can and cannot breathe on their own; multiple port suction equipment; electrical power to connect the equipment; and drugs specific for the type of patients. To increase the number of aircraft that could perform medical evacuation missions, the Navy should explore the feasibility of fixing man-rated evacuation pods to a proportion of the light helicopter fleet; such pods could be useful in evacuating casualties contaminated with chemical, biological, or radiological agents.

Although the large amphibious assault ships have excellent casualty-care capabilities, they have little critical-patient holding space.[3] To ensure that the ship does not become a bottleneck in the care system, the flow of casualties to more appropriate facilities must be maintained. Once emergency care has been provided, patients must be moved from the ships to hospitals that can continue the care. Current ship-capable aircraft, including the V-22, lack suitable en route care capabilities for long, medical evacuation flights; in-theater hospital care, a hospital ship, or transfer to strategic medical evacuation must be readily available. A ship-capable STOL transport would relieve this potential bottleneck in the casualty care system.

CHEMICAL AND BIOLOGICAL DECONTAMINATION

Medical planning must assume that some casualties will be contaminated with chemical or biological agents. Current planning and the capability to manage such an eventuality are inadequate. Standard procedures are needed for the following tasks:

- Care, handling, and decontamination of contaminated casualties, both in the field and on-board casualty receiving and care ships;
- Decontamination of medical staff and equipment; and
- Medical evacuation of contaminated casualties and medical support personnel without risk to aircrew.

MEDICAL MANAGEMENT AND INTEGRATION

The concept of minimum essential care and rapid evacuation, and the wide dispersion of medical capabilities, call for a centrally planned and well-integrated medical management system. Short-term allocation and reallocation of medical assets, management of patient flows, and management of medical workload will be essential to keeping the system balanced and responsive to combat developments. Moreover, as with other functions of logistical support, it will be essential to fully integrate medical considerations into the planning and execution of all aspects of the tactical operation, including especially aviation support.

Medical personnel and the medical command structure must be trained to make decisions in the military medical care environment and must be provided the real-time data and information systems necessary to making those decisions.

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[3]Amphibious assault ships have ample capacity for patients suffering from short-term illness or minor injuries.

The "SMART card," a programmable, personal data file card worn by each Marine, is currently the best approach to capturing, quickly and accurately, essential casualty data from a forward surgical unit or ship-based medical treatment facility.

MEDICAL RESEARCH AND DEVELOPMENT

The Navy needs to mimic high-technology industry and put medical research and development on a requirements basis, i.e., targeted to specific needs of the combat casualty-care user for product functionality, reliability, cost-effectiveness, training, and support. The following are a few examples of the type of equipment that is long overdue in the field:

- Pneumatic tourniquets for each corpsman's kit;
- Portable device to take vital signs in a noisy, unlighted evacuation vehicle;
- Easy-to-use, life-sustaining emergency equipment for use on an "evacuation vehicle of opportunity";
- Pain management compounds that can be administered by untrained personnel;
- Wound-dressing material impregnated with clotting substances;
- Blood substitutes that are ready for field use without laboratory verification, refrigeration, or preparation;
- Infection control management;
- Shore-facility oxygen generator;
- Miniaturized, reusable monitor of physiological signs;
- Means for shipboard manufacturing of intravenous liquids and solutions;
- Imaging equipment for casualty care in an austere environment;
- Better tents or shelters for forward surgical units; and
- Gear for medical personnel treating contaminated patients.

Creating a balanced, effective casualty care system that will support OMFTS requires redirecting medical training, research and development, acquisition, and management to the critical features of the system: Marines who are trained to stop bleeding and aid breathing of a wounded "buddy," corpsmen who are trained and equipped to provide simple but lifesaving trauma care on the battlefield; forward surgical teams trained to practice combat trauma care in small, austere, deployable medical facilities; and aeromedical evacuation that provides essential en route patient monitoring and care. Throughout the system design, special attention needs to be given to procedures for handling and treating patients who have been contaminated with chemical or biological agents and to the management information systems needed to integrate all patient care activities in the task forces area of operations.

Recommendation: *The Navy and Marine Corps should reengineer the casualty-care system to match the warfighting concepts of OMFTS, giving highest priority to improving first-responder care, developing a forward surgical unit, handling and caring for patients contaminated by biological, chemical, or radiological agents, and evacuating patients to at-sea care facilities and onward to points of strategic aeromedical evacuation.*

6

Closing Comment

Shaping the logistics capabilities of the Navy and Marine Corps to meet the needs of the evolving OMFTS conceptual framework is an enormously complex undertaking. It inherently requires an origin-to-destination iterative planning approach that will enable the various elements of the warfighting and logistical communities to develop integrated options for senior leader consideration. Such options must depict how well and at what costs various combinations of force structure, equipment, and operating concepts—both warfighting and logistics—might meet projected naval expeditionary warfare needs. This type of integrated strategic planning process is essential to avoid inadvertently creating capability gaps or shortfalls and to facilitate development of cohesive planning options that identify the significant capabilities, costs and benefits, and tradeoffs involved in striving to implement the new conceptual framework.

Today's OMFTS conceptual framework lacks the specificity needed to define such options. Key matters, such as force size and composition ashore, operating distances and consumption rates, and the assumptions to be made regarding overseas infrastructure, are unclear and open to a broad range of interpretation with dramatically different implications for warfighting and logistics capabilities.

For example, if the goal is to rapidly deploy a large Marine air-ground task force (e.g., today's MEF [FWD]) without the use of overseas ports or airfields, equip and assemble the force at sea using maritime prepositioned assets, use the force to attack objectives 200 miles inland without securing a beachhead, and logistically support the operation indefinitely from ships over the horizon at sea, the committee believes that large capital investment in major new capabilities probably would be necessary. The likely investments would include the following:

1. *A mobile offshore base (MOB) to serve as a strategic, intermediate staging base, resupply point, and medical evacuation point.* An MOB should be considered as a substitute for an overseas base, not as a tactical sea base that directly supports maneuver forces ashore.
2. *A sea-basing logistics ship specifically designed for support of naval forces ashore.* Such a ship would need capabilities for the receipt, storage, and distribution of materiel of all commodity classes (e.g., food, fuel, munitions, and so on), container handling, equipment maintenance, and casualty care. It also would need capabilities for loading, unloading, and probably transporting surface craft, and for conducting rotary-wing and possibly fixed-wing cargo aircraft operations.
3. *A rugged, large-capacity, high-speed landing craft.* The landing craft should be designed to interface efficiently with amphibious assault ships, logistics ships, and logistics units ashore.
4. *A new-design logistics aircraft.* Such a vehicle, perhaps a fixed-wing STOL or a crane-type, heavy-lift helicopter, would need the capability to routinely move large loads (10 to 15 tons) efficiently from the logistics ship to forces at the outer edge of planned operating distances (e.g., 200 miles inland) without refueling.

Whatever the interpretation of OMFTS, certain issues essential to future logistics capability call for new study. The most prominent of those issues is the future combat capability of the Marine Corps and the extent to which that capability is supported from the sea. Other issues include the future of battle tanks in Marine Corps force structure, the extent to which new developments in naval guns, missiles, and aircraft can reduce ground-force requirements for artillery and artillery munitions, the composition of maritime prepositioning equipment and supplies, and the design of the casualty-care and evacuation system for critically wounded and contaminated personnel. Development of a capability to model and simulate expeditionary logistics operations would greatly aid assessment of these and other key issues.

Because logistics will be so central to implementing OMFTS, the Navy and Marine Corps must clarify today's broadly stated conceptual framework. Without more specificity, different interpretations risk underestimating what is really required to conduct future expeditionary operations or rationalizing investments that may not be essential to success.

Appendixes

A

Charge to the Committee

ADMIRAL JOHNSON'S LETTER OF REQUEST

CHIEF OF NAVAL OPERATIONS

NRC/CPSMA

25 April 1997

APR 30 1997

Dear Dr. Alberts,

In December 1995, at the request of this office, the Academy's Naval Studies Board initiated a study entitled "Technology for Future Naval Forces." As this effort draws to a close, I look forward to receiving the results of the study.

In addition to your current work, I would like you to consider undertaking two additional studies in the areas of "Improving Shore Installation Readiness and Management" and "Naval and Expeditionary Logistics Innovation." My staff will develop terms of reference for these two one-year studies in consultation with the Chairman and Director of the Naval Studies Board.

Thank you for all your support. I value our continuing and close working relationship with the National Academy of Sciences.

Sincerely,

JAY L. JOHNSON
Admiral, U.S. Navy

Dr. Bruce M. Alberts
President
National Academy of Sciences
2101 Constitution Avenue, N.W.
Washington, DC 20418

STATEMENT OF TASK

This study should determine the technological requirements, operational changes, and combat service support structure necessary to land and support forces ashore. A comprehensive evaluation of the packaging, sealift, and distribution network should identify critical nodes and operations that affect timely insertion of fuels, ammunition, water, medical supplies, food, vehicles, and maintenance parts and tool blocks. This study should determine specific changes required to relieve these critical nodes and support forces ashore, from assault through follow-on echelonment. Implementable changes to existing support systems and the development of innovative new systems and technologies to land and sustain dispersed units from the shoreline to 200 miles inland are needed.

B

Naval Gun, Missile, and Aircraft Ranges

Figure B.1 provides information on the range in nautical miles (NM) for an array of naval guns and missiles, strike radii for aircraft, and ferry radii for air transport of artillery that the Navy and Marine Corps will draw on to support Operational Maneuver From the Sea. Detailed information about each type of equipment is given below in the form of notes keyed to Figure B.1.

(1) 5-in. 45 guns: in inventory; range maximum, 13 NM; 70-lb shell; magazine, 500 rounds; 20 rounds per minute (RPM). With extended-range guided missile backfit; range extension to 45 NM, ~10 RPM (Friedman, Norman, 1997, "Section: Shipboard Guns and Gun Systems," *The Naval Institute Guide to World Naval Weapons Systems 1997-1998,* Naval Institute Press, Annapolis, Md., pp. 460-462; Naval Studies Board, 1997, *Technology for the United States Navy and Marine Corps, 2000-2035, Vol. 1: Overview* (p. 66) and *Vol. 5: Weapons* (p. 131), National Academy Press, Washington, D.C.).

(2) Extended-range guided missile (ERGM), rocket-assisted projectile (RAP) gun-fired round for 5-in. 62 guns: on new ships; 32-lb payload; magazine, estimated 200 to 250 rounds; 5 to 10 RPM; range, 65 NM; projected range extension to 100 NM (Guarneri, Jack, Applied Physics Laboratory, Johns Hopkins University, 1996, "NSFS Requirements to Support OMFTS," *Naval Surface Fire Support Road Map Study,* presented to the Panel on Weapons, Technology for Future Naval Forces (TFNF) study, December 9; Kennedy, Floyd D., Jr., 1998, "U.S. Navy Aircraft and Weapon Developments," *Naval Institute Proceedings,* May, pp. 120-124, 126, 128, and 130; Naval Studies Board, 1997, *Technology for the United States Navy and Marine Corps, 2000-2035, Vol. 1:*

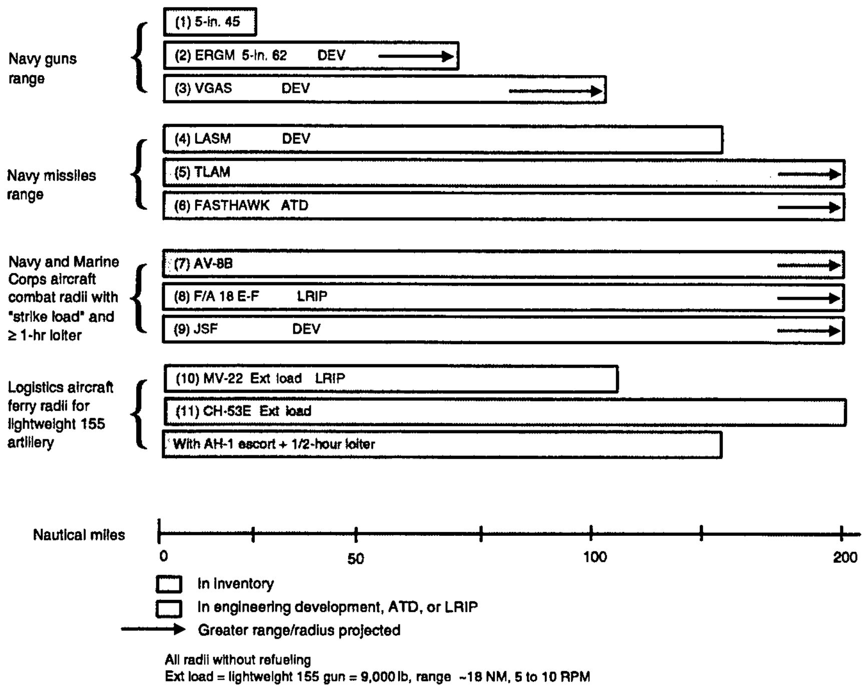

FIGURE B.1 Naval fire support for Operational Maneuver From the Sea.

Overview (p. 66) and *Vol. 5: Weapons* (p. 131), National Academy Press, Washington, D.C.). Status: in 6.4 budget.

(3) Vertical gun, advanced system (VGAS) or advanced gun system (AGS): 1 to 2 155-mm vertical guns in vertical launch system (VLS) box; automatic 6 to 24 RPM/gun; RAP with ~100-lb warhead, ~1,500 in SC21 magazine; projected range extension to 200 to 250 NM with 2-stage RAP (Belen, Fred C., 1998, "Tactical Information Technology . . . From the Sea," *Naval Institute Proceedings,* September, pp. 121-123; Kennedy, Floyd D., Jr., 1998, "Naval Fire Support Plans," *Naval Institute Proceedings,* June, p. 72; Mullen, RADM Michael, USN, 1998, "Where Surface Warfare Is Headed—and Why," *Naval Institute Proceedings,* October, p. 79). Status: part of DD21 contract.

(4) Land-attack standard missile (LASM): range, 150 NM; ~300-lb warhead; semiballistic; fired from VLS tubes (CG, 122 tubes; DDG, 90 to 96 tubes; DD, 61 tubes; FFG, 40 tubes; in battle group with 2 CGs, 2 DDGs, DD 485 tubes), flight time, ~5 minutes to 150 NM (Polmar, Norman, 1997, *The Naval Institute Guide to the Ships and Aircraft of the U.S. Fleet,* Naval Institute Press, Annapolis, Md.). Status: IOC FY 2003, integrated in DDG81 and new CGs.

(5) Tomahawk land attack missile (TLAM): ~3,700 missiles of all types in

inventory; range, 600 to 1,000 NM; 600- to 1,000-lb warhead; fired from VLS ~ Mach 1 (to be upgraded to 1.6), retargetable; flight time, ~15 to 20 minutes to 200 NM (Friedman, Norman. 1997. "Section: Missiles and Guided Bombs," *The Naval Institute Guide to World's Naval Weapons Systems 1997-1998,* Naval Institute Press, Annapolis, Md., pp. 259-261).

(6) FASTHAWK: Mach 4 to 5, air-breathing hypersonic missile; 700-lb warhead; 700-NM range; VLS-compatible; flight time, ~5 minutes to 200 NM (Dornheim, Michael A. 1997. "Missiles Lead Hypersonics Revival," *Aviation Week and Space Technology,* 147(15): 62-65). Status: part of High Speed Strike System program, IOC 2006.

(7) AV-8B: 189 in inventory (1998), remanufacturing >72 oldest to reach 150 aircraft inventory; with six 500-lb bombs, two 300-gal tanks, >1.5-hr loiter at 200 NM; typical LHA load, 6 to 8 AV8s (communication from Mr. Mike Thompson, NAVAIR AV8B, program office, November 18, 1998; Taylor, John W.R., and Kenneth Munson [eds.], 1986, "McDonnell Douglas/BAe [AV-8B Harrier II]," *Jane's All The World Aircraft, 1986-87,* Jane's Publishing Inc., New York, and Jane's Publishing Company Limited, London, pp. 120-122).

(8) F/A-18 C and D operational: 967 in 1996 inventory; E and F: in initial production (12 in January 1999), 548 aircraft planned procurement IOC 2002; three external tanks, strike load of four 1,000-lb bombs, and air-air missiles >1-hr loiter at 200 NM; CVN load (E and F), ~36 increasing to 60 ("F/A-18E/F, Super Hornet Strike Fighter Aircraft," *Sea Power,* October 1998, p. 36; Finneran, Patrick, and Chuck Allen, 1998, "Super Hornet: The Sailor's Aircraft Is on Track," *Naval Institute Proceedings,* May, pp. 81-85; Polmar, Norman, 1997, *The Naval Institute Guide to the Ships and Aircraft of the U.S. Fleet,* Naval Institute Press, Annapolis, Md., pp. 337 and 370; communication from Mr. Robert Walters, NAVAIR F/A 18 program office, October 10, 1998).

(9) Joint strike fighter (JSF): estimated loiter ~1 hr at 200 NM with >13,000-lb external load; 642 aircraft planned (Joint Strike Fighter Program Office, 1998, Joint Strike Fighter Program, September 16, available online at <http://www.jast.mil/html/aboutjsf.htm>; Net Resources International Ltd., 1998, the Website for Defence Industries—Navy; Current Projects: JSF, available online at <http://www.naval-technology.com/projects/jsf/index.html>). Status: IOC 2008.

(10) MV-22 for external 10,000-lb load (e.g., LWT 155), radius = 100 NM, estimated speed 250 knots. Status: OPEVAL October 1999. Total planned buy 360. Typical LHA load ~12 aircraft. Escort by AV8B if available (TFNF briefing by V-22 program manager, Col Garner, USMC, October 1996; Kennedy, Floyd D., Jr., 1998, "U.S. Naval Aircraft and Weapon Developments," *Naval Institute Proceedings,* May, pp. 121-122; discussion with LtGen Philip Shutler, USMC [retired]).

(11) CH-53E (MH-53E): 162 aircraft in inventory; 10,000-lb external load (LWT 155), radius > 200 NM at 130 knots; for CH-53Es escorted by AH-1-type

attack helicopters (225 in inventory, speed 140 knots), combined radius estimated ~120 NM; typical LHA load, 12 aircraft (CH-53-Class desk information sheet; discussions with LtCol R.E. Carney, USMC, MH-53 program manager; Kennedy, Floyd D., Jr., 1998, "U.S. Naval Aircraft and Weapon Developments," *Naval Institute Proceedings,* May, pp. 120-124, 126, 128, and 130; McAllister, Keith R., 1998, *MPF 2010 Ship to Shore Movement and Seabased Logistics Support, Volume I: Report,* CRM 98-19.09, Center for Naval Analyses, Alexandria, Va., p. 25; Polmar, Norman, 1997, *The Naval Institute Guide to the Ships and Aircraft of the U.S. Fleet*, Naval Institute Press, Annapolis, Md., p. 415).

C

Force Sustainment Data and Calculations

Table C.1 provides the resupply requirements of the command, ground combat, and combat service elements (i.e., the landing force). Tables C.2 and C.3 detail the daily air delivery capacity of the MV-22 and CH-53. All three tables are used in determining the percent of resupply requirements met by air deliveries as shown in Chapter 4, Table 4.3.

TABLE C.1 Landing Force Daily Resupply Requirements

	Personnel	Food Requirement (Short Tons)	Water Requirement (Short Tons)
Command Element	365	0.80	10.18
Ground Combat Element	5,694	12.53	158.86
Headquarters Battalion	158	0.35	4.41
Infantry Regiment	2,993	6.58	83.50
Artillery Battalion	835	1.84	23.30
AAAV Battalion	521	1.15	14.54
Engineering Battalion	224	0.49	6.25
Light Armored Reconnaissance Company	138	0.30	3.85
Tank Battalion	825	1.82	23.02
Combat Service Support Element	747	1.64	20.84
Military Police Company (–)	89	0.20	2.48
Landing Support Battalion	360	0.79	10.04
Military Transportation Battalion	298	0.66	8.31
Total	6,806	14.97	189.89
Percent		3.10	38.80

*Not included by CNA. Other cargo, added at 7.8 lb/Marine/day, includes an austere level of construction material, medical, and parts resupply.

Fuel Requirement (Short Tons)	Ammunition Requirement (Short Tons)	Other Cargo* (Short Tons)	Total	Percent
15.90	0.53	1.42	28.84	5.9
152.23	32.07	22.21	377.90	77.1
8.96	0.20	0.62	14.54	3.0
6.53	3.76	11.67	112.05	22.9
54.13	20.19	3.26	102.71	21.0
25.86	2.28	2.03	45.86	9.4
16.25	2.50	0.87	26.36	5.4
2.59	1.44	0.54	8.72	1.8
37.91	1.71	3.22	67.66	13.8
56.87	0.88	2.91	83.15	17.0
0.71	0.10	0.35	3.84	0.8
10.67	0.23	1.40	23.13	4.7
45.50	0.55	1.16	56.19	11.5
225.01	33.48	26.54	489.89	100.0
45.90	6.80	5.40		100.0

SOURCE: Adapted from McAllister, Keith R. 1998. *MPF 2010 Ship-to-Shore Movement and Sea-based Logistics Support, Volume I: Report* and *Volume II: Appendices*, Center for Naval Analyses, Alexandria, Va., March.

TABLE C.2 Daily Air Delivery Capacity at 12-hour Air Operations

Separation Distance	Payload	Speed	RTFT (hours)	RTFT (minutes)	Cycle Time (minutes)	Rounded Cycle Time (minutes)	Cycles @ 12 (hours)
50-200=250							
MV-22							
Int	3.27	240	2.08	125	170	170	4.24
Ext	0.00	180	2.78	167	212	215	3.35
CH-53E							
Int	7.23	130	3.85	231	276	280	2.57
Ext	7.23	100	5.00	300	345	345	2.09
25-100=125							
MV-22							
Int	4.46	240	1.04	63	108	110	6.55
Ext	3.91	180	1.39	83	128	130	5.54
CH-53E							
Int	9.78	130	1.92	115	160	160	4.50
Ext	9.78	100	2.50	150	195	195	3.69
5-50=55							
MV-22							
Int	4.93	240	0.46	28	73	75	9.60
Ext	4.93	180	0.51	37	82	85	8.47
CH-53E							
Int	11.05	130	0.85	51	96	100	7.20
Ext	11.05	100	1.10	66	111	115	6.26

NOTE: 12-hour day, 0.85 maximum payload, 36 MV-22, 8 CH-53E. RTFT, round-trip flight time; A/C, aircraft.

Cycles	Deliveries per A/C	Aircraft Availability	Number Aircraft	Available Aircraft	Number Aircraft	Daily Deliveries (short tons)
4	13.2	0.75	36	27	27	356
3	0.0	0.75	36	27	27	0
2	14.4	0.70	8	5.6	5	72
2	14.4	0.70	8	5.6	5	72
6	27.0	0.75	36	27	27	729
5	20.0	0.75	36	27	27	540
4	38.2	0.70	8	5.6	5	196
3	29.4	0.70	8	5.6	5	147
9	44.1	0.75	36	27	27	1,191
8	39.2	0.75	36	27	27	1,058
7	77.0	0.70	8	5.6	5	385
6	66.0	0.70	8	5.6	5	330

TABLE C.3 Daily Air Delivery Capacity at 10-hour Air Operations

Separation Distance	Payload	Speed	RTFT (hours)	RTFT (minutes)	Cycle Time (minutes)	Rounded Cycle Time (minutes)	Cycles @ 10 (hours)
50-200=250							
MV-22							
Int	3.27	240	2.08	125	170	170	3.53
Ext	0.00	180	2.78	167	212	215	2.79
CH-53E							
Int	7.23	130	3.85	231	276	280	2.14
Ext	7.23	100	5.00	300	345	345	1.74
25-100=125							
MV-22							
Int	4.46	240	1.04	63	108	110	5.45
Ext	3.91	180	1.39	83	128	130	4.62
CH-53E							
Int	9.78	130	1.92	115	160	160	3.75
Ext	9.78	100	2.50	150	195	195	3.08
5-50=55							
MV-22							
Int	4.93	240	0.46	28	73	75	8.00
Ext	4.93	180	0.51	37	82	85	7.06
CH-53E							
Int	11.05	130	0.85	51	96	100	6.00
Ext	11.05	100	1.10	66	111	115	5.22

NOTE: 10-hour day, 0.85 maximum payload, 36 MV-22, 8 CH-53E. RTFT, round-trip flight time.

Cycles	Deliveries per A/C	Aircraft Availability	Number Aircraft	Available Aircraft	Number Aircraft	Daily Deliveries (short tons)
3	9.9	0.75	36	27	27	267
2	0.0	0.75	36	27	27	0
2	14.4	0.70	8	5.6	5	72
1	7.2	0.70	8	5.6	5	36
5	22.5	0.75	36	27	27	608
4	16.0	0.75	36	27	27	432
3	29.4	0.70	8	5.6	5	147
3	29.4	0.70	8	5.6	5	147
8	39.2	0.75	36	27	27	1,058
7	34.3	0.75	36	27	27	926
6	66.0	0.70	8	5.6	5	330
5	55.0	0.70	8	5.6	5	275

D

Logistics Productivity of Aircraft

LtGen Philip Shutler, USMC (Ret.), Senior Fellow, Center for Naval Analyses

INTRODUCTION

One of the first considerations when planning military operations is to position superior force to overcome the threat with minimum losses to friendly units. Within the concepts of maneuver warfare, this is a dynamic process that responds to the uncertainties of combat with movement and directed fire on the threat, and continues until the threat has been overcome. The commander must use available transportation assets to make initial deployments of troop units, fighting vehicles, support vehicles, and supplies, and then readjust the deployments to defeat the threat while, at the same time, moving replacements and resupply materiel into position. As envisioned in Operational Maneuver From the Sea and Ship-to-Objective Movement, the bases for most of the force and materiel will be ships up to 25 miles at sea, and the objectives will be as far as 200 miles inland.

The transportation vehicles will include landing craft (air cushion) (LCAC) for ship-to-shore movement and trucks for overland movement, but, if fighting units are to be positioned and sustained at distances of 225 miles from the ships, and the safety of trucks on the road is uncertain, most of the unit movement and resupply must come from aircraft. The V-22 and CH-53E are capable of carrying limited loads to those distances and, more important, can land anywhere a zone can be established. The questions that need to be answered are as follows:

- What quantity of materiel can these aircraft deliver to selected distances?
- How long will it take to complete the initial delivery?
- What is the rate of resupply in tons per day?

Specific transportation planning to answer these questions is quite complex and depends on many variables. It is possible, however, if certain assumptions are made, to assess the transportation feasibility of a particular plan of action. The purpose of this appendix, then, is to present a simplified method for calculating productivity in tons/day accurately enough to determine feasibility. The way the calculations are structured also shows how the process can be adjusted to accomplish achievable results.

LOGISTICS PRODUCTIVITY

Logistics productivity is measured in tons per day and is dependent on three primary factors: (1) the number of mission aircraft that can be kept functioning throughout the day; (2) the mission load that can be carried on each round trip or sortie; and (3) the number of mission sorties each aircraft can make in a day. The general formula is

$$\left(\frac{\text{tons}}{\text{day}}\right) = (\text{mission aircraft}) \times \left(\frac{\text{mission tons}}{\text{sortie}}\right) \times \left(\frac{\text{mission sorties / aircraft}}{\text{day}}\right).$$

Mission Aircraft

The number of mission aircraft that can be kept functioning is the number of aircraft assigned adjusted by the average availability factor:

$$\text{mission aircraft} = \text{assigned aircraft} \times \%\ \text{availability}. \qquad [1]$$

Mission Load

For helicopters and tilt-rotor aircraft, there is a direct trade-off between useful load and fuel. Configured with a fuel-only maximum load, the aircraft can fly to the so-called "ferry range." The maximum round-trip range, with near-zero useful load, is here termed the "no-load distance," approximately half the ferry range. One could think of the no-load distance also as the maximum distance that a single passenger could be delivered under emergency conditions, and the aircraft returned without refueling. As shown in Figure D.1, the maximum useful load ≅ maximum "mission fuel" (≈ one-half the maximum all-fuel load). The fuel consumption per mile can be estimated as

$$\text{fuel consumption per mile} = \frac{\text{maximum (all fuel) load}}{\text{ferry range}}$$

$$\approx \frac{\text{maximum useful load} \approx \text{maximum ``mission fuel''}}{\text{no-load distance}}. \qquad [2]$$

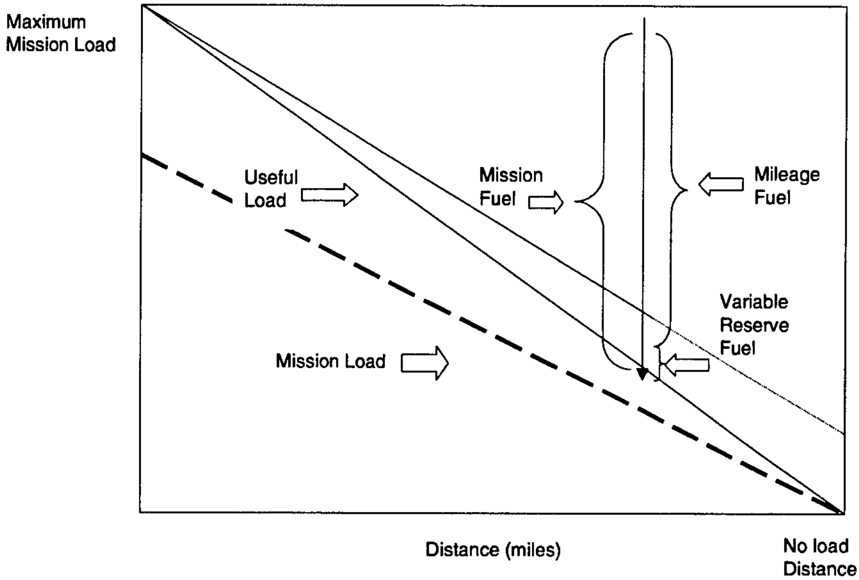

FIGURE D.1 Mission load derivation.

Figure D.1 illustrates that if the fuel weight is reduced to the minimum needed for fixed reserves, the aircraft can carry a useful load for very short distances. Figure D.1 also indicates that there may be an additional variable fuel reserve proportional to the "mileage fuel." The fuel carried on a mission is typically the mileage fuel plus variable and a minimum fixed reserve. Figure D.1 shows that mission fuel is proportional to distance:

$$\text{mission fuel} = \text{fuel consumption per mile} \times \text{mission distance}. \qquad [3]$$

As shown in Figure D.1, useful load = maximum useful load – mission fuel. Using [3], useful load = maximum useful load – fuel consumption per mile × mission distance, and substituting from [2]:

$$\text{useful load} = \text{maximum useful load}\left(1 - \frac{\text{mission distance}}{\text{no-load distance}}\right). \qquad [4]$$

One can also observe that in practice the full useful load often cannot be achieved because some cargo takes up the full space but does not weigh enough, or the particular mission does not require a full load. A mission load is defined as useful load adjusted by a percent efficiency factor:

$$\text{mission load/sortie} = \text{useful load/sortie} \times \%\ \text{efficiency}.$$

So,

$$\text{mission load / sortie} = \text{maximum load / sortie} \times \left[1 - \frac{\text{mission distance}}{\text{no-load distance}}\right] \times \%\ \text{efficiency}. \qquad [5]$$

Sorties Per Aircraft Per day

Sorties per aircraft per day can be calculated by dividing total available flight time per aircraft per day by the flight time per sortie:

$$\frac{\text{sorties / aircraft}}{\text{day}} = \frac{\text{hours / aircraft / day}}{\text{hours / sortie}}.$$

Available flight time is determined by outside factors such as spare parts, maintenance technician availability, and air crew manning levels, as well as daylight and dark as missions dictate. Flight time per sortie is determined by dividing total round-trip distance flown by cruise speed. It is assumed here that the hours/sortie is mostly due to the actual flight time to a single destination.[1] Thus

$$\text{hours / sortie} = \frac{2 \times \text{mission distance / sortie}}{\text{cruise speed}},$$

and

$$\text{sorties / aircraft / day} = \frac{\text{hours / aircraft / day} \times \text{cruise speed}}{2 \times \text{mission distance / sortie}}.$$

Here again, it is useful to use the construct of no-load distance. The number of sorties that could be flown to the no-load distance is

$$\text{no-load sorties / aircraft / day} = \frac{\text{hours / aircraft / day} \times \text{cruise speed}}{2 \times \text{no-load distance / sortie}}.$$

If it is assumed that the total available flight time remains constant regardless of the number of sorties flown, then the number of sorties is inversely proportional to distance, as shown in Figure D.2. That is to say, if you fly half as far, you can fly twice the number of sorties. This assumption is reasonably accurate for distances from one-eighth of the no-load distance to three-fourths of

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[1]The figures for cycle times (equivalent to hours/sortie) in Tables C.2 and C.3 in Appendix C allow for appreciable extra time over and above actual round-trip flight times.

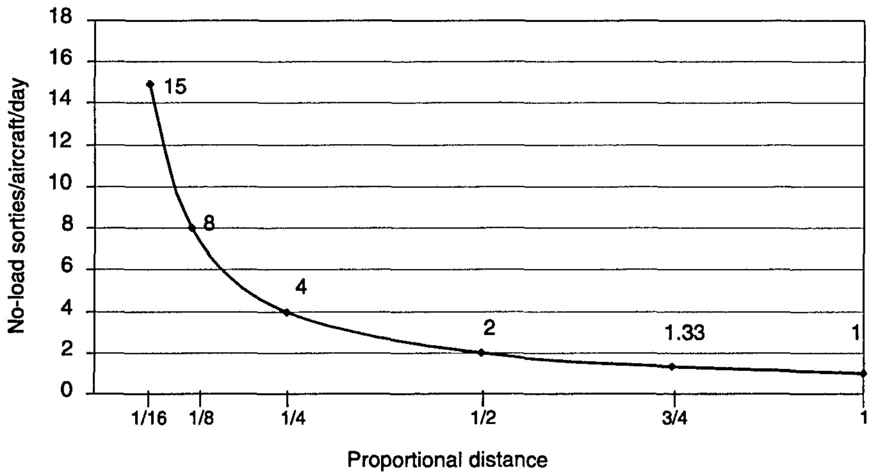

FIGURE D.2 Mission sorties per aircraft per day.

the no-load distance. At less than one-eighth of the no-load radius, turnaround and queue times can preclude maintaining fixed flight time. The curve may also be less useful at distances greater than three-fourths of the no-load distance because auxiliary fuel cells may use up cargo space.

Starting from the value at no-load distance in Figure D.2, since the mission distance is ≤ the no-load distance, the sorties will be increased by the proportion of $\frac{\text{no-load distance}}{\text{mission distance}}$:

$$\text{missions sorties / aircraft / day} = \text{no-load sorties / aircraft / day} \times \frac{\text{no-load distance}}{\text{mission distance}},$$

and

$$\frac{\text{mission sorties}}{\text{aircraft / day}} = \frac{\text{hours / aircraft / day} \times \text{cruise speed}}{2 \times \text{no-load distance / sortie}} \times \frac{\text{no-load distance}}{\text{mission distance}}. \quad [6]$$

Returning to the original formulation:

$$\text{tons / day} = [\text{mission aircraft}] \times [\text{mission tons / sortie}] \times \left[\frac{\text{mission sorties / aircraft}}{\text{day}}\right].$$

Substituting the values from equations [1], [5], and [6] for terms highlighted by brackets, and rearranging terms:

$$\frac{\text{tons / day}}{\text{assigned aircraft}} = \left[\frac{\text{maximum load / sortie} \times \text{cruise speed}}{2 \times \text{no-load distance / sortie}}\right]$$
$$\times \left[\% \text{ availability} \times \% \text{ efficiency} \times \text{hours / aircraft / day}\right]$$
$$\times \left[\frac{\text{no-load distance}}{\text{mission distance}} - 1\right]. \qquad [7]$$

The first term $\left[\frac{\text{maximum load / sortie} \times \text{cruise speed}}{2 \times \text{no-load distance / sortie}}\right]$ consists of three elements of aircraft design that remain constant for a particular aircraft configuration.

The second term [% availability × % efficiency × hours/aircraft/day] is determined from assumptions of future availability, efficiency, and flight time/aircraft/day. This term can vary from a high of 12 (100% availability × 100% efficiency × 12 hours/aircraft/day) under ideal conditions, with excess flight crews, to a low of 1 (50% availability × 50% efficiency × 4 hours/aircraft/day) under poor conditions, as might prevail at the end of prolonged surge activity.

The third term $\left[\frac{\text{no-load distance}}{\text{mission distance}} - 1\right]$ represents the diminishing effect of distance on productivity when both mission load and sortie rates are reduced with distance. A plot of this term is shown in the upper left-hand corner of Figure D.3.

APPLICATIONS

Payload Versus Mission Distance

There are five major aircraft configurations to be considered:

- V-22 short takeoff, internal load (V-22 STO);
- V-22 vertical takeoff, internal load (V-22 int);
- V-22 vertical takeoff, external load (V-22 ext);
- CH-53E vertical takeoff, internal load (CH-53E int); and
- CH-53E vertical takeoff, external load (CH-53E ext).

A plot of useful payload vs. mission distance is shown in Figure D.4. The information regarding V-22 STO, V-22 int, and CH-53E int is derived from briefing charts provided by the Naval Surface Warfare Center, West Bethesda,

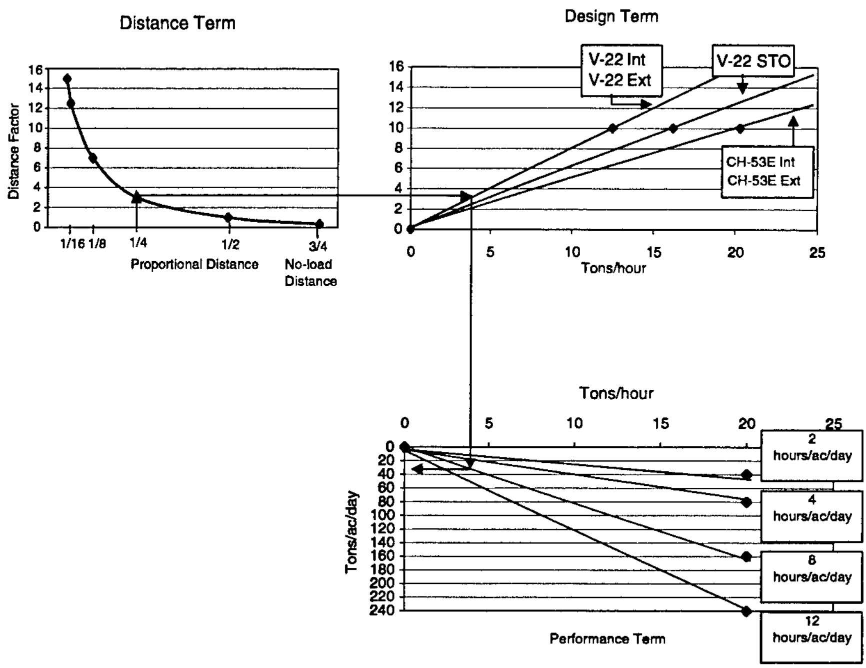

FIGURE D.3 Nomograph relating distance, design, and performance.

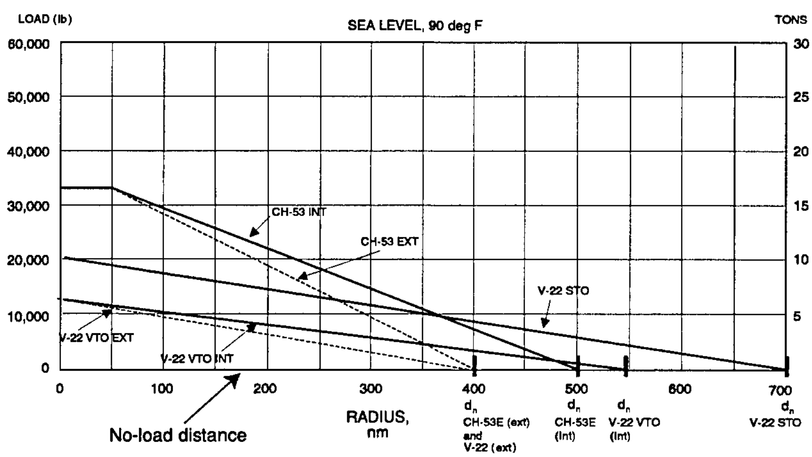

FIGURE D.4 Performance of some existing transports: payload vs. mission distance (radius), internal and external carry.

Maryland. The information regarding V-22 ext and CH-53E ext is estimated in accordance with the following methodology.

Effective Cruise Speed

An aircraft carrying an external load would go out at external-load cruise speed and return at internal cruise speed. Thus, the mission time for the out and in legs is

$$\text{mission time} = \frac{\text{mission distance}}{\text{external cruise speed}} + \frac{\text{mission distance}}{\text{internal cruise speed}}.$$

The effective round-trip cruise speed, then, is round-trip distance divided by mission time:

$$\text{effective cruise speed} = \frac{2 \times \text{mission distance}}{\text{mission time}}.$$

Or

$$\text{effective cruise speed} = 2 \times \left(\frac{\text{external cruise speed} \times \text{internal cruise speed}}{\text{external cruise speed} + \text{internal cruise speed}} \right). \quad [8]$$

"External No-load Distance"

As discussed above, the rotary-wing aircraft no-load distance for internal loads is the maximum round-trip distance. A "no-load distance for external loads" can be defined as the extrapolation, to zero load, of a linear fit to data for finite loads. These data and extrapolations can vary for different types of external loads, but this is ignored here. An approximate value of an "external no-load distance" can be obtained by assuming that the hourly fuel consumption rates, and so the times of flight for internal and external loads, are about the same.[2] Then the

$$\begin{aligned}\text{"external no-load distance"} &= (\text{external no-load time of flight} \\ &\approx \text{internal no-load time of flight}) \\ &\times (\text{effective external cruise speed}).\end{aligned}$$

[2]The fuel consumption rate (tons/hour) depends on power settings which in turn, depend on the nature of the load. Heavy, high-drag loads demand extra power and higher fuel consumption. However, because fuel flow with external loads is probably slightly less than fuel flow with internal loads, the flight time with external loads may be slightly higher. Thus, the "external no-load distance" estimated here may be conservative.

And substituting from [8],

"external no-load distance" =

$$\frac{\text{internal no-load distance}}{\text{internal cruise speed}} \times \frac{2\ \text{external cruise speed} \times \text{internal cruise speed}}{\text{external cruise speed} + \text{internal cruise speed}}.$$

So,

$$\text{"external no-load distance"} = \text{internal no-load distance} \times \frac{2 \times \text{external cruise speed}}{\text{internal cruise speed} + \text{external cruise speed}}. \quad [9]$$

Thus, if V-22 cruise speed with external load = 130 knots, and V-22 cruise speed with internal load = 230 knots, and V-22 internal no-load distance = 550 nautical miles, then from [9]:

$$\text{V-22 "external no-load distance"} \approx 2 \times \frac{130}{130 + 230} \times 550 \approx 400 \text{ nautical miles.}$$

Similarly, if CH-53E cruise speed with external load = 90 knots, and CH-53E cruise speed with internal load = 130 knots, and CH-53E internal no-load distance = 500 nautical miles, then from [9]:

$$\text{CH-53E "external no-load distance"} \approx 2 \times \frac{90}{90 + 230} \times 500 \approx 400 \text{ nautical miles.}$$

CALCULATING PRODUCTIVITY

It is, of course, possible to use formula [7] as stated in a straightforward fashion to calculate productivity. It is, however, much simpler and more instructive to use a nomograph similar to the one shown in Figure D.3 to relate the many factors involved in the calculation.

The nomograph is constructed as follows: (1) the distance term is plotted in the upper left corner of Figure D.3, (2) the aircraft design term $\left[\frac{\text{maximum load / sortie} \times \text{effective cruise speed}}{2 \times \text{no-load distance / sortie}}\right]$ calculated in Table D.1 is plotted in the upper right corner of Figure D.3, and (3) the performance term is estimated by assuming values for percent availability, percent efficiency, and flight time per day, as shown in Table D.2. These values are plotted as rate lines in the lower right corner of Figure D.3.

TABLE D.1

Types of Aircraft	Maximum Load/Sortie (in tons)	Effective Cruise Speed (in knots)	No-load Distance (in nautical miles)	Maximum Load/Sortie × Effective Cruise Speed / 2 × No-load Distance
V-22 STO	10	230	700	1.64
V-22 Int	6	230	550	1.25
V-22 Ext	6	167	400	1.25
CH-53E Int	16	130	500	2.1
CH-53E Ext	16	106	400	2.1

NOTE: Because, to the approximation used here, V-22 int and V-22 ext are the same, a single line represents both configurations. The same is true for both CH-53E configurations. These values are plotted as rate lines.

TABLE D.2

% Availability	% Efficiency	Flight Time/ Aircraft/Day	% Availability × % Efficiency × Flight Time/Aircraft/Day (approximate values)
1.0	1.0	12	12
.9	.9	10	8
.7	.7	8	4
.6	.6	6	2
.5	.5	4	1

An important problem that often must be solved is this: Can the number of aircraft available position and support the size force necessary at a stated distance from base to objective?

Solution:

Step 1. Divide distance by the no-load distance for the configuration and enter at the proportional distance. (In the marked example, configuration is V-22 ext, distance is 100 miles, no-load distance is 400 miles, and proportional distance is one-fourth). Read up to distance factor. (Example: Distance factor is 3.)

Step 2. Move to the right to the appropriate design configuration line. Note: the no-load distance and the design line must be for the same configuration. (Example: The line chosen is for V-22 ext. Value is 3.75 tons/hour.)

Step 3. Move downward from the design line to the appropriate performance line. (Example: Performance assumed is 8 hours/aircraft/day.)

Step 4. Move to the left and read tons/day/aircraft. (Example: 30 tons/day/aircraft.)

Step 5. Divide total planned tons/day by tons/day/aircraft to estimate the number of assigned aircraft required.

If the aircraft assigned are inadequate, the process can be reversed to estimate the distance to which the aircraft could sustain the force, or, alternatively, to estimate the distance from the objective where a temporary combat service support detachment (CSSD) should be positioned to support the second step to the final objective area. As seen in Figure D.5, the location of the temporary CSSD could be on land or at the coastline or at sea. If on land, the logistics flow to the CSSD site would be by air; on the coastline, by surface craft or air; and, if at sea, the ship itself could move to the location.

The stated purpose of this appendix is to provide a simplified method for estimating logistics feasibility of various courses of action in OMFTS and STOM. Figure D.4 satisfies that requirement, but it should be used with caution. Logistics requirement estimates are notorious for inaccuracy. Aircraft availability and efficiency of the loading process are often overestimated, particularly for the later stages of operations. The effects of night, weather, battle damage, and the fog of war further diminish the ultimate performance of the transportation systems.

Those cautions having been noted, however, the distances that can be reached by ground forces (up to 500 miles when returning to home base, and to a total flying mileage of 1,000 miles if fuel is available closer to the objective) and the time to accomplish the insertion ($2^1/_2$ hours to 500 miles) gives ground forces such as Marine reconnaissance, Army rangers, and small combat teams of all Services an operational reach approaching that of tactical aircraft. The vertical takeoff and landing characteristics permit basing, or at least refueling, at a wide variety of ships and small, hideable facilities ashore.

It is true for these operations, as it has always been, that a plan that is logistically infeasible is, in fact, not feasible, but the ways in which logistics support can be accomplished through temporary combat service support detachments, or forward arming and refueling points, or fuel caches ashore or at sea, or aerial refueling, have increased manyfold. The operational reach of land forces, whether starting from sea or from shore, has been increased and response times decreased to such an extent that land operations of all types must be reexamined and adjusted.

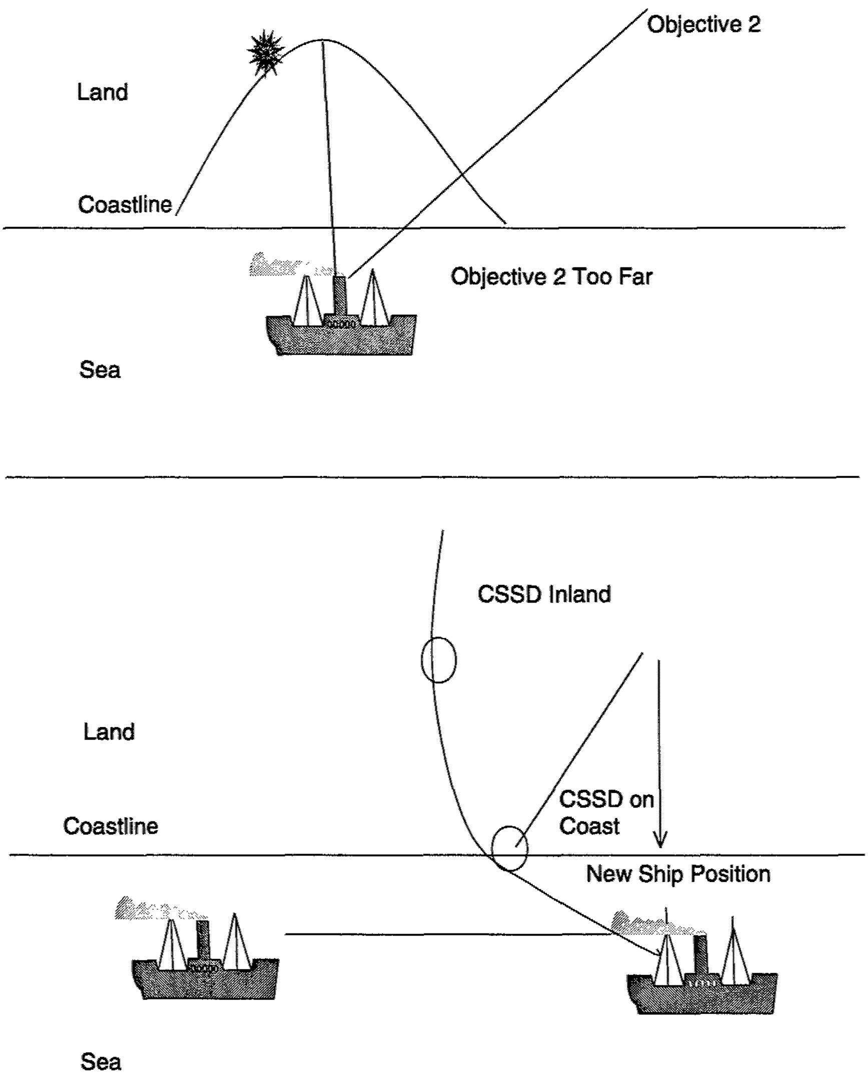

FIGURE D.5 Location of a temporary combat service support detachment (CSSD) at land, at the coastline, or at sea.

E

Committee Biographies

Norman E. Betaque ***(Chair)*** is senior vice president at the Logistics Management Institute, where he is responsible for the National Security Division. His research interests span a broad range of logistics topics, which include materiel management, weapons systems acquisition, deployment and sustainment of military forces, and readiness of military units. In addition, he is actively involved with other technology-based advances in logistics currently being used in the private sector. Mr. Betaque is a former member of the Defense Science Board and during his term contributed to the board's studies of tactical air warfare and manufacturing technology. He is a member of the Naval Studies Board of the National Research Council.

Norval L. Broome is director of San Diego operations at the Mitre Corporation. Prior to his becoming director, Dr. Broome was department head for projects specializing in tactical and strategic submarine communications technology. His areas of expertise include telecommunications systems engineering, naval communications systems, C^3I, and sonar target acquisition. Dr. Broome's research interests include Navy very low frequency/low frequency systems engineering, tactical digital data links, communication management, and advanced submarine communications. He is a member of the Naval Studies Board of the National Research Council and also chairs the Committee on Space Electronics for the American Institute of Aeronautics and Astronautics.

Roy R. Buehler is deputy director of the Surveillance and Command Aircraft Directorate at Lockheed Martin Aeronautical Systems, where he is responsible for meeting company objectives for antisubmarine warfare, antisurface warfare, and airborne early warning programs. Mr. Buehler has over 30 years of experience in industry and government as an experimental test pilot, business planner, and program manager in the start up of new aircraft programs such as the F-111, F-14, F-18, A-6, and F-22/Naval Advanced Tactical Fighter. He served in the Navy as a carrier fighter pilot and test pilot, as well as at the Naval Air Systems Command. Mr. Buehler has master's degrees in aeronautical engineering and management and is a graduate of the Navy's Test Pilot School. He is a member of the Society of Experimental Test Pilots.

Chryssostomos Chryssostomidis is department head of ocean engineering at the Massachusetts Institute of Technology. Dr. Chryssostomidis's expertise is in shipbuilding and marine issues. His publications display his wide range of interests, which include design methodology for ships, vortex-induced response of flexible cylinders, and abyssal-ocean option for waste management. Dr. Chryssostomidis established the MIT Sea Grant Underwater Vehicles Laboratory, and most recently, a multidisciplinary research team to address key issues underlying the design and fabrication of high-speed, high-performance surface ships. He has served on several National Research Council committees focusing on shipbuilding and marine issues.

William Fedorochko, Jr., a retired Brigadier General U.S. Army, is Senior Fellow at the Logistics Management Institute. Before retiring from the Department of Defense, General Fedorochko served in leadership and management positions in the Army, Joint Staff, and Office of the Secretary of Defense. General Fedorochko's research interests include operational and defense logistics management. He is currently authoring a white paper on future challenges and directions in defense logistics. In support of this effort, General Fedorochko has led seminars in theater logistics operations, Joint Vision 2010, and multinational logistics operations. His previous research included an assessment of the defense management process, which was included in the Report of the Commission on Roles and Missions.

Lynn G. Gref is program manager of the Flight Systems Office at the Jet Propulsion Laboratory (JPL). Dr. Gref has been involved with several efforts at JPL, including space flight systems analysis and software-intensive systems development. His interests include information systems and space hardware research. Dr. Gref has been active in the submarine ballistics missile program, ballistics systems for strategic and tactical applications, security of high-value assets, and Defense Advanced Research Projects Agency strategic and information systems research programs. Dr. Gref has served as a management consultant to several start-up technology-based companies. He currently serves as a board member and management consultant to a manufacturer of automated environmental controls for greenhouses.

Willis M. Hawkins is retired senior vice president of the Lockheed Martin Corporation, where he still consults. Throughout Mr. Hawkins's professional career, he has been involved with the design and development of aircraft, missile, and space systems. His broad range of expertise includes aerospace electronic systems, man-machine interfaces, operations research, composite materials, and naval architecture. Mr. Hawkins has served on numerous advisory council positions, including chairman of the Aerospace Safety Advisory Panel and member of the National Aeronautics and Space Administration Advisory Council. In addition, he is a member of the National Academy of Engineering, Fellow of the Royal Aeronautical Society, and Honorary Fellow of the American Institute of Aeronautics and Astronautics.

Lee D. Hieb, M.D., is a private-practice orthopaedic surgeon. Dr. Hieb's areas of expertise include military medicine. She has served in the U.S. Navy as a general medical officer and an orthopaedic surgeon, primarily specializing in general practice and spinal disorders. Through her naval training, she is familiar with U.S. Marine Corps operational medical needs and base medical issues. Most recently, Dr. Hieb was recalled for active duty during Operation Desert Storm. In addition, Dr. Hieb is a former member of the Naval Research Advisory Committee.

Michael R. Hilliard is the program manager for defense transportation and logistics in the Center for Transportation Analysis at the Oak Ridge National Laboratory. He is also currently the deputy project manager for the Airlift Deployment Analysis System Project, a major effort that has provided the U.S. Air Force's Air Mobility Command with state-of-the-art planning and scheduling tools. In this position, he is involved in algorithm development, user interface design, and database design. Dr. Hilliard has a broad background in the development of models for complex systems, design of optimization and artificial-intelligence-based algorithms, and the implementation of decision support systems for public agencies. His background includes combinatorial optimization, linear programming, game theory, and adaptive learning algorithms. Dr. Hilliard has published numerous articles in academic journals, trade publications, and conference proceedings.

Erwin F. Hirsch, M.D., is director of the Trauma Center at Boston University Medical Center. In addition, he is professor of surgery at Boston University School of Medicine, clinical professor of surgery at the Uniformed Services University of the Health Sciences, instructor in surgery at the Harvard Medical School, and lecturer in surgery at the Tufts University School of Medicine. Dr.

Hirsch has an extensive background in trauma care and military medicine. A retired Captain, U.S. Naval Reserve Medical Corps, Dr. Hirsch's military medical experiences range from a tour as staff surgeon in Vietnam to research medical officer at the Naval Medical Research Institute. During the Gulf War, he was recalled for active duty during Operation Desert Storm and Operation Desert Shield.

David B. Kassing is associate corporate research manager for Defense Planning and Analysis at RAND. Mr. Kassing's research interests include military logistics, deployment systems, planning and budgeting methodology, and naval capabilities. He has led analysis teams investigating reception, staging, onward movement, and integration of logistics support for Army mission performances. In addition, Mr. Kassing has evaluated deployment options for sealift operations conducting force reception and reviewed methodologies used by the armed services to set conventional munitions requirements and problems. Mr. Kassing is past president of the Center for Naval Analyses and has a continuing interest in the analysis of naval strategic, general-purpose, and support capabilities.

John B. LaPlante, a retired Vice Admiral U.S. Navy, is senior vice president for naval programs at Burdeshaw Associates, Limited, a domestic and international professional services company with over 600 executive-level associates, most of whom are retired flag officers and civilians from around the world. Admiral LaPlante has an extensive background in amphibious warfare and military operational logistics. Before retiring from the Navy in 1996, he served as director for logistics, J-4, Joint Staff. His military experience also included assignments as vice-director for logistics (J-4, Joint Staff), Commander of Naval Logistics Command Pacific, and head of the amphibious Warfare Branch in the Office of the Chief of Naval Operations. During Operation Desert Storm and Operation Desert Shield, he commanded all amphibious forces in the Gulf region, a force of some 43 ships and 34,000 men and women. On October 9, 1998, Admiral LaPlante joined McDermott International, Inc., as director, Mobile Offshore Base (MOB) Program Development.

Peter J. Mantle is senior analyst at Science Applications International Corporation. He was director of European Programs for Defensive Systems at Lockheed Martin Missiles and Space Corporation. Mr. Mantle has a broad range of experience in the private and public sectors with engineering and management responsibilities related to aerospace and marine research and development. As a past director of technology assessment for the Chief of Naval Operations, he managed the basic research and exploratory development program for Navy weapons systems, including ships, aircraft, submarines, and assorted sensors. In addition, he served in the Office of the Assistant Secretary of the Navy for Research, Engineering, and Systems as a special assistant for Navy planning in the areas of ships, strategic systems, aircraft, and advanced marine vehicles.

Henry S. Marcus is professor of marine systems and chairman of the Ocean Systems Management Program in the Ocean Engineering Department at the Massachusetts Institute of Technology. Dr. Marcus's broad range of expertise spans from the transportation and logistics of containerports to methods for improving performance in the U.S. Navy's acquisition process. Dr. Marcus served on sabbatical in the Office of the Assistant Secretary of the Navy, Shipbuilding and Logistics. He has written more than 50 articles, papers, and books in the field of transportation and logistics, and he is a former member of the Maritime Transportation Research Board and Committee on Productivity of Marine Terminals of the National Research Council's Marine Board.

Irwin Mendelson is retired president of the Engineering Division of Pratt & Whitney, a subsidiary of United Technologies Corporation. Prior to his retirement, Mr. Mendelson was responsible for the management and total operation of military and commercial aircraft engine design, test, and installation. He is an expert in several commercial and military aircraft engine designs, and he has been directly responsible for jet engine fuel controls, pyrophoric ignition systems, and thrust controls for rockets. Mr. Mendelson was previously manager of engine systems at the General Electric Company, where he was responsible for the design, development, and certification of turbofan engines and their installation in commercial transport aircraft. Earlier he was senior design manager for submarine systems at the Electric Boat Division of General Dynamics Corporation. Mr. Mendelson is a former member of the Naval Studies Board and the Aeronautics and Space Engineering Board of the National Research Council.

Philip D. Shutler, a retired Lieutenant General U.S. Marine Corps, is Senior Fellow at the Center for Naval Analyses and adjunct professor at the National Defense University. General Shutler has an extensive background in Marine Corps logistics and operational needs. He retired as director of operations, Joint Staff, J-3, after serving 33 years of active duty in the Marine Corps. His military career included combat duty with an assortment of ground and aviation forces, as well as the command of a Marine Corps aircraft group and an amphibious brigade. General Shutler is a former member of the Defense Science Board.

Robert A. Wilson is an independent consultant for PDI, a Division of Bird-Johnson. Mr. Wilson has an extensive background in air-cushioned vehicles and surface-effects ships. He is the former (retired) head of the Programs Department at the Naval Surface Warfare Center, Carderock Division. His primary responsibility was for the management of ship system programs in the areas of littoral and special warfare, surface combatants, SEALIFT, enabling technologies, SEAWOLF, and post-nuclear-power attack submarine technologies, unmanned undersea vehicles, and intelligence ships. Mr. Wilson also headed Carderock's Innovation Center in which he was responsible for assembling multidisciplinary teams for 6-month periods to develop high-risk/high-payoff solutions to Navy problems. Mr. Wilson is past president of the United States Hovercraft Society.

F

Acronyms and Abbreviations

AAAV	Advanced amphibious assault vehicle
ACV	Air-cushioned vehicle
ARG	Amphibious-ready group
CG	Guided missile cruiser
CNA	Center for Naval Analyses
CONUS	Continental United States
CSSD	Combat service support detachment
CVN	Nuclear-powered aircraft carrier
DD	Destroyer
DDG	Guided missile destroyer
ERGM	Extended-range guided missile
FARP	Forward arming and refueling point
FSSG	Force service support group
IOC	Initial operating capability
JSF	Joint strike fighter
LASM	Land-attack standard missile
LCAC	Landing craft (air cushion)
LCU(X)	Advanced landing craft
LHA	Amphibious assault ship (general purpose)
LHD	Amphibious assault ship (multipurpose)
MAGTF	Marine air-ground task force
MCSSD	Marine combat service support detachment
MEF	Marine expeditionary force
MEF (FWD)	Marine expeditionary force (forward)

MEU	Marine expeditionary unit
MLC	Marine Logistics Command
MOB	Mobile offshore base
MPF	Maritime prepositioning force
MPF 2010+	Maritime Prepositioning Force 2010 and Beyond
OMFTS	Operational Maneuver From the Sea
RAP	Rocket-assisted projectile
RPM	Rounds per minute
SES	Surface-effect ship
SOC	Support operations capability
STO	Short takeoff
STOL	Short takeoff and landing
STOM	Ship-to-objective movement
TAFDS	Tactical airfield fuel distribution system
TEU	Twenty-ft equivalent unit
TLAM	Tomahawk land attack missile
VGAS	Vertical gun (advanced) system
VLS	Vertical launch system
VTO	Vertical takeoff