Proceedings of the 2002 Winter Simulation Conference
E. Yücesan, C.-H. Chen, J. L. Snowdon, and J. M. Charnes, eds.

AN ANALYSIS OF STOM (SHIP TO OBJECTIVE MANEUVER) IN SEA BASED LOGISTICS

Keebom Kang
Kenneth H. Doerr

Graduate School of Business & Public Policy
Naval Postgraduate School
Monterey, CA 93943, U. S. A.

Kyle A. Bryan

U.S. Strategic Command (J411)
901 SAC Boulevard, Suite BA3
Offutt AFB, NE 68113, U. S. A.

Gregorio Ameyugo

NATO Modelling and Simulation Co-ordination Office
NATO Research and Technology Organisation
BP 25, 7 rue Ancelle
F-92201 Neuilly-Sur-Seine Cedex
Paris, FRANCE

ABSTRACT

Operational Maneuver From the Sea (OMFTS) and its implementing concept, Sea Based Logistics (SBL) stress the need for logistically supporting forces ashore directly from a sea base. This study analyzes the capability of a current LHD-class amphibious ship to sustain a force deployed ashore through direct *Ship-To-Objective Maneuver* (STOM) of replenishment and logistics support. We have developed a simulation model that can evaluate performance of STOM operations using an LHD-class amphibious ship as a sea base. Results indicate a substantial increase in the number of aircraft, and reliability of those aircraft, and/or a substantial reduction in sustainment requirements are needed in order to successfully accomplish the scenarios used in this study. The results of this study could support the design of future LHD-class ships.

1 INTRODUCTION

In order to adapt to the changes in the strategic and technologic environment following the end of the Cold War, the Marine Corps developed OMFTS (U. S. Marine Corps 1996). OMFTS targets the littoral regions of the world as the arenas where the most important conflicts of the future will occur. Littoral regions are those areas characterized by great cities, well-populated coasts, and the intersection of trade routes where land and sea meet. Littorals provide homes to over 80 percent of the world's capital cities and nearly all of the marketplaces for international trade.

OMFTS envisions rapid maneuver by assault forces from their ships directly to operational objectives ashore. Attacking objectives directly from the sea allows the Naval Commander to use the sea as maneuver space and turns the enemy's coastline into a vulnerable flank rather than a barrier to entry. Under OMFTS the landing force is expected to create and maintain operational surprise, generate overwhelming tempo, and overmatch enemy weaknesses with its power and rapid execution in order to keep the enemy off-balance resulting in a quick, successful assault. This replaces the current amphibious methods of beach assault that require operational phases, pauses, and reorganizations that impose delays and inefficiencies on the operation. Ship-To-Objective Maneuver (STOM) is one of the key implementing concepts to achieve the operational goals established by OMFTS. STOM defines the principles and tactics of forcible entry from the sea. Two key components of STOM are the tactical maneuver of forces and sea-basing. Historically, amphibious warfare sought to move forces ashore methodically from the ships onto a beachhead via a slow-moving shuttle system. Forces would then expand out from the beachhead to seize intermediate and final operational objectives. However, this method was slow and restricted in its maneuver space and extremely vulnerable to enemy counterattacks. Until sufficient forces could be lodged ashore and begin to develop operational momentum, the assault force was in a precarious position. STOM seeks to change this ship-to-shore movement to amphibious maneuver. The objective of STOM is to put combat units ashore either by air, surface or both means in fighting formation in sufficient force and in the decisive place in order to accomplish the mission. The capability to operate from over the horizon coupled with the ability to strike deep inland directly at centers of gravity will force the enemy to defend a vastly larger area and provide the attacking forces with tactical surprise (U. S. Marine Corps 1996 & 1997).

The success of STOM and OMFTS hinges on the ability to effectively seabase the logistic functions of the assault force. Employing logistics directly from the ship to the objective will eliminate the requirements for beachheads. This will eliminate the resulting operational pause while sufficient supplies build up on the beachhead and also the need for dedicated shore-based force protection for the logistics area. Additionally, expectations are that future battlefields will be characterized by coordinated speed of maneuver, increased operating ranges, and precision delivery of massed effects. Sea Based Logistics offers the unique capability to both sustain the future high optempo battlefield and exploit the advantages inherent in mobility and over the horizon standoff (U. S. Marine Corps 1998). In this paper we evaluate performance of STOM operations using an LHD-class amphibious ship (e.g., USS Bonhomme Richard, or USS Boxer) as a sea base to provide basic sustainment requirements (food, water, fuel, ammunition) to a Marine Expeditionary Unit (MEU) under the OMFTS concept.

2 SIMULATION MODEL

We have developed several simulation scenarios with different sizes of forces deployed, the number of aircraft, and the distance between the deployed forces and the sea base. The LHD can be considered as a floating distribution center. The ship replenishes its stocks via underway replenishment (UNREP) from supply ships. See Figure 1 for a screenshot of vertical replenishment (VERTREP) simulation model developed in ARENA (Kelton et al. 2002). Once a helicopter delivers pallets from a supply ship to the flight deck of the LHD, the pallets are disconnected from the helicopter. Then a 4K forklift picks them up and travels to either a cargo elevator or one of the deck edge elevators (aircraft elevators). This begins the "strike down" phase. The pallets are then moved to different holds for storage. Ammunition pallets are separately handled and stored in ammunition storage. See Curtin (2001) for more details of the UNREP simulation model. Once the UNREP process is complete the re-supply of the landing force will commence.

2.1 Mission Types and Force Size

We consider three different types of missions: (1) Humanitarian Assistance/ Disaster Relief (HA/DR), (2) Noncombatant Evacuation Operation (NEO), and (3) Enabling Force (EF). Additionally, there are two different ammunition requirements depending on whether the Marines were assaulting an objective or sustaining their position: an assault rate and a sustainment rate of ammunition consumption. Combining these two ammunition requirements results in five different scenarios: HA/DR, NEO-Sustain, NEO-Assault, EF-Sustain, and EF-Assault (Hagan 1998). There are no ammunition expenditure for the HA/DR mission. These five scenarios were simulated over the three different distances between the deployed forces and the sea base: 50, 100, and 150 miles. 50 miles are considered as the minimum distance for STOM from the sea base to a hostile shore when delivering assets via the air. 100 and 150 miles were chosen as round multiples of the minimum distance that would stretch the limits of the OMFTS concept.

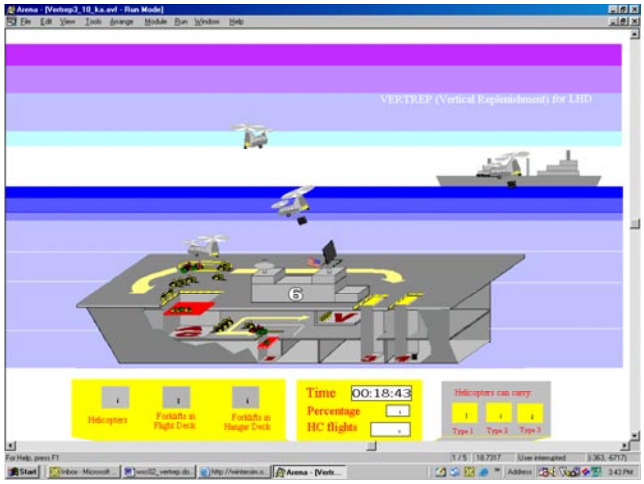

Figure 1: A Screenshot of VERTREP Simulation Model from a Supply Ship to an LHD-class Amphibious Ship

In each of the five scenarios, a Marine Expeditionary Unit (MEU) has been delployed ashore. The size of the MEU may vary from 400 to 1,500 personnel, depending on a mission type (see Table 1). The landing force maintains two days of supply (DOS) and requests a re-supply when they reach one DOS. At 2000 hours deployed forces relay their resupply request to the sea base. Requested items are removed from holds, palletized (MRE and ammunition) and prestaged on the flight deck before the STOM operation starts in the morning. This process is referred to as "strike up," which is the reverse of "strike down." They also fill bladders with water and fuel on the flight deck. Beginning at 0700 the following day, helicopters begin to deliver pallets and bladders to the troops ashore. The operation will last until 1900 or all requirements are delivered. Undelivered items would be added to the following day's delivery requirements. More details of the airlift operation will be described in the next subsection.

Table 1: Mission Type and Force Size

Mission	Force size
HA/DR	417
NEO	651
EF	1505

The daily quantity of each type of sustainment requirement is based on the number and type of the forces, vehicles and equipment deployed ashore by the force commander. This study uses current Marine Corps Logistic Planning Factors (LPF) published in the Marine Air-Ground Task Force (MAGTF) Data Library (1998). Supplies other than the four used in this study were considered not significant for the types of missions analyzed. Table 2 summarizes the daily requirements in pallets for food and ammunition, and bladders for fuel and water for each type of mission (Hagan 1998). Each bladder of water weighs 4,650 pounds. Each bladder of fuel weighs 3,685 pounds. A pallet of MREs weighs 1,100 pounds and an ammunition pallet, 2,200 pounds (Reitter 1999).

Table 2: Mission Daily Sustainment Requirements

Mission	MRE	Water	Fuel	Ammo-assault	Ammo-sustain
HA/DR	3	5	10	0	0
NEO	4	8	10	7	2
EF	8	19	20	29	7

2.2 Aviation Assets

The MEU Aviation Combat Element (ACE) is designated as a Composite Squadron. It is normally built around a Marine Medium Helicopter Squadron (HMM) of 12 CH-46 Sea Knights, a medium lift assault helicopter. However, the CH-46 is scheduled to be replaced by the MV-22 Osprey and therefore the characteristics of MV-22 are used in the simulation model. The HMM is augmented by four CH-53E Sea Stallions, three UH-1N utility helicopters and four AH-1W Sea Cobra attack helicopters, and six fixed-wing AV-8B Harriers. In this simulation model, we only use 12 MV-22s since other aircraft are used for combat or other heavy lift missions.

The MV-22 is a tilt-rotor aircraft, which can take off and land vertically like a helicopter, then fly like an airplane. Using this technology, the MV-22 will be able to travel further, at much higher speed and with a much larger payload than the CH-46. The MV-22 has not been introduced to the fleet yet and has recently encountered programmatic difficulties, but it is expected to be fully operational by 2010. MV-22 deliveries of cargo will be accomplished via external means because of constraints imposed by cabin dimensions and cargo floor weight limitations. The speed of a MV-22 carrying an external load is 167 knots. Unladen, the MV-22 flies at 230 knots (Naval Studies Board 1999). The external lift capability is shown in Table 3. The longer the mission distance the smaller the payload due to fuel consumption required for heavier lift. We are assuming that the MV-22 requires refueling if it has spent more than 4 hours on a lift mission before it begins a new one.

Table 3: Mission Radius vs. Cargo Payload. Source (Frey, 2000)

Mission Radius (miles)	MV-22 External Lift (lbs)
50	11,482
100	9,362
150	7,184

Table 4 provides the maximum number of pallets or bladders in the payload of a single MV-22 for each mission radius. The actual number of pallets of each type of requirement is based on the number and type of forces, vehicles, and equipment deployed ashore.

Table 4: Mission Radius (in miles) vs. Maximum Requirement Payload (in pallets or bladders)

Dist. (miles)	MRE	Ammo	Water	Fuel
50	10	5	2	3
100	8	4	2	2
150	6	3	1	1

Over time, aircraft experience breakdowns and require maintenance. This maintenance can be either routine, minor organizational-level maintenance or major AIMD (Aircraft Intermediate Maintenance Department) maintenance requiring an intermediate level capability to repair the aircraft. Under the OMFTS concept, the sea base is assumed to have the capability to perform all necessary maintenance. In the simulation model, we begin by assuming that 15 percent of the time the MV-22 requires maintenance after the aircraft returns to the sea base from a lift mission. This reliability/maintainability figure probably is an overestimation although no real data is available yet. In the next section, we will show the sensitivity analysis by changing this 15% value. Of these 15% maintenance requirements, with 80% chance, an MV-22 will require minor maintenance action for an average period of 3 hours. Major maintenance occurs 20 % of the time (i.e., 3%, or 20% of the 15%, of all the returning aircraft) and removes the aircraft from service for an average of 25 days. Data from air-capable amphibious ships in the NALDA database (July 2000 to July 2001) was used to estimate the average delay time. While the average was 25 days, there were many extreme values which could be due to the difficulty of obtaining materiel and spares during the deployment. For example, data from the USS Wasp showed a range from five to 257 days of delay. Because of the high variance in the data and the fact that the true distribution for major maintenance for the MV-22 is unknown at this time, an exponential distribution was used. Due to the long AIMD delay for major maintenance, a failed aircraft is most likely removed from rest of the mission. In the next section we conducted sensitivity analysis on the AIMD turnaround time. As data becomes available as the MV-22 is introduced into the fleet, an analysis of the turnaround time should be revisited in order to improve the results of the model.

2.3 Other Assumptions

There are several additional assumptions that affect the simulation model developed for this analysis. First, it is assumed that the enemy air defenses and air assets were neutralized prior to the insertion of the Marines. Thus there is no attrition to the MV-22s flying resupply missions due to enemy action in this simulation model. Support for this assumption can be drawn from recent examples of United States intervention in Kosovo, Afghanistan and the Gulf War.

Secondly, this analysis assumes the entire force has been deployed prior to the start of the resupply missions. Therefore, there is little requirement for aircraft to ferry personnel from the sea base to the shore. This leaves all MV-22s initially available for resupply sorties. Any requirement for minor reinforcement or medical evacuation is assumed to be filled by the UH-1N utility helicopters.

Lastly, it is assumed that the MEU forces that were deployed ashore did not secure any beachhead and are sufficiently far enough away from any usable beaches to preclude the use of any sort of surface transportation (e.g., LCAG or any other lighterage) to deliver the sustainment requirements.

3 SIMULATION RESULTS AND ANALYSIS

Upon completion of the 15 different scenarios over a 15-day mission, the daily delivery percentage was calculated for 30 replications. Table 5 summarizes the average percentage of daily requirements delivered for the last 5 days of the 15-day mission. The final portion of the mission is the most critical, since aircraft maintenance requirements will have the heaviest impact at that time. Undelivered portion would be added to the following day's requirements

Also recorded in the simulation, but not reported in this paper, is the time that the last pallet of each of the four commodities was delivered each day. This is done so that on the days when 100% delivery is achieved a measure of aircraft utilization for that day could be extracted from the model. There are other measures recorded as well: the number of MV-22 sorties, the number of aircraft requiring AIMD maintenance, and the number of aircraft requiring minor maintenance. The detailed results are available in Bryan (2001).

These results indicate that the size of the force, which determines the quantity of sustainment requirements, and the distance between the deployed forces and the sea base are the key that determined whether or not success was achieved for the missions. The pattern of failure begins with the NEO mission (assault rate) at 150 miles. Analysis of the simulation results from this mission indicates that it

Table 5: Mission Delivery Summary (percentage of daily requirements delivered for days 11 to 15)

Mission	Dist.	Mission Days (last 5 days)				
		11	12	13	14	15
HA/DR	50	100	100	100	100	100
	100	100	100	100	100	100
	150	100	100	100	100	100
NEO-sustain	50	100	100	100	100	100
	100	100	100	100	100	100
	150	100	100	100	100	100
NEO-assault	50	100	100	100	100	100
	100	100	100	100	100	100
	150	100	98	96	93	93
EF-sustain	50	100	100	100	99	90
	100	96	91	92	93	87
	150	61	58	48	44	47
EF-assault	50	97	99	95	98	100
	100	93	91	88	81	91
	150	51	40	33	33	29

is the distance and the resulting increase in importance of the aircraft availability that results in mission failure. The largest mission force package, comprised of 1500 Marines, is the Enabling Force – assault rate. Missions with an assault rate of ammunition consumption added an additional 22 pallets of ammunition (a total of 29 pallets versus 7 for the sustainment rate) which require more sorties. Also longer mission radius requires more sorties since less load can be transported in a single sortie as shown in Table 3. The longer flight times imply that fewer sorties can be flown during a give time period. The longer flight times and lesser payload capabilities make the availability of the aviation assets more important. Removal from the mission due to maintenance requirements also takes on greater importance in determining the success of the mission. For these reasons, the number of available aircraft also is a key for success or failure of the various missions.

Failure of each of the Enabling Force missions at all distances indicates that the quantity of sustainment requirements that must be delivered exceeds the sea base's ability to deliver them. Additionally, the incidence of failure occurs earlier as the distance between the forces and the sea base is increased since more sorties are required. In some cases, the delivery percentages of Day 15 are higher than those of earlier days. This is probably due to aircraft reliability and maintenance.

4 SENSITIVITY ANALYSIS

For the sensitivity analyses conducted in this section, only one input parameter was changed at a time while all others were held constant. The AIMD maintenance delay effectively removes the affected aircraft from the rest of the simulation because of the long turnaround time. By increasing the number of initial aircraft, the effects of this delay should be lessened because more aircraft will still be in an operational status. To test the sensitivity of the model, the Enabling Force (assault rate) mission at 150 miles was used as the test scenario. The total number of aircraft was increased incrementally until the Enabling Force (assault rate) mission at 150 miles was successfully completed while all other input parameters were held constant. The minimum number of MV-22s required to successfully complete this mission is 27, i.e., 15 more aircraft. The number of sorties required to complete the mission was 714.

Next we change the maintainability requirement factors. The probability of maintenance requirement after returning to the sea base was steadily decreased until the most rigorous mission (Enabling Force/assault rate/150 miles) was successfully completed, while all other parameters were held constant. We also changed the percentage of AIMD maintenance requirement was reduced until the mission was completed successfully. The results of both analyses indicate that if no more than 1% (vs. 3% for the base scenario) of the aircraft returning from the delivery mission, are sent to the AIMD repair, they can successfully achieve the mission goal.

Another way to increase the operational availability is to reduce cycle time by providing better logistics support. For instance, additional spare parts can be added to the inventory of the units maintaining the aircraft to reduce the turnaround time for the AIMD maintenance. Or the capability of the AIMD can be increased or expanded to improve the AIMD's ability to quickly return aircraft to service. Another way to improve operational availability is to reduce to the turnaround time for AIMD maintenance. The average AIMD maintenance delay was decreased incrementally until the Enabling Force (assault rate) mission at 150 miles was successfully accomplished. The distribution remained the same – exponential distribution. The result indicates that the AIMD turnaround time should be reduced to 2 days from 25 days to accomplish the mission. The two day turnaround time for the deployed AIMD may not be realistically achievable, yet this sensitivity analysis reemphasized the importance of maintenance turnaround time for the higher operational availability of aircraft.

5 CONCLUSIONS

The current LHD-class ship is capable of sustaining forces deployed ashore only under OMFTS concepts for a limited time or a limited distance. The proposed complement of 12 MV-22 aircraft for a LHD-class ship is insufficient to accomplish all required sustainment missions with the given sustainment requirements and maintenance factors assumed in this study. Sensitivity analysis indicated that accomplishing the most extensive mission requirements would require significant changes in 1) the number of aircraft available, 2) reliability of MV-22, and/or 3) the AIMD maintenance delay.

Another way to accomplish the most extensive missions would be to reduce sustainment requirements. Fuel and water requirements are the most difficult requirements to transport, but also provide the most promise for realizing reductions (e.g., more fuel efficient trucks).

Improvement in any of these areas requires major investment. A more comprehensive study must be done before implementation. These situations need to be addressed in order to ensure a LHD-class ship or any future ship designed to accomplish operational missions with OMFTS concepts to ensure the forces deployed ashore can be properly sustained.

ACKNOWLEDGMENTS

This work was partially supported by the Naval Facilities and Engineering Service Center (NNESC), Port Hueneme, CA. We would like to thank LTJG Lopez and LCDR Neuheisel for providing a tour of the *USS Bonnehomme Richard*, LHD-6 for this study.

REFERENCES

Bryan, K. A. 2001. *Simulation of Sea Based Logistics Support of Operational Maneuver from The Sea,* Master's Thesis, Naval Postgraduate School, Monterey, California.

Curtin, M. J. 2001. *Analysis of Inter/Intra Ship Materiel Movement in Sea Based Logistics Using Simulation*, Master's Thesis, Naval Postgraduate School, Monterey, California.

Frey, C. M. 2000. *An Evaluation of Sea-Based Sustainment of Forces*, Master's Thesis, Naval Postgraduate School, Monterey, California.

Hagan, R. M. 1998. *Modeling Sea-Based Sustainment of Marine Expeditionary Unit (Special Operations Capable) (MEU(SOC)) Operations Ashore*, Master's Thesis, Naval Postgraduate School, Monterey, California.

Kelton, W. D., R. P. Sadowski, and D. A. Sadowski. 2002. *Simulation With Arena*, 2nd edition, McGraw-Hill, New York.

Marine Air-Ground Task Force (MAGTF) Data Library (MDL) CD-ROM. 1998. Headquarters Marine Corps, Washington, D.C.

Naval Studies Board, National Research Council. 1999. *Naval Expeditionary Logistics: Enabling Operational*

Maneuver From the Sea, National Academy Press, Washington, D.C.,

Reitter, N. L. 1999. *A Decision Support System for Sea-Based Sustainment Operations*, Master's Thesis, Naval Postgraduate School, Monterey, California.

U.S. Marine Corps. 1996. *Operational Maneuver From the Sea* (Concept Paper), Marine Corps Combat Development Command, Quantico, Virginia.

U.S. Marine Corps. 1997. *Ship-To-Objective Maneuver* (Concept Paper), Marine Corps Combat Development Command,. Quantico, Virginia

U.S. Marine Corps and U.S. Navy. 1998. *Sea-Based Logistics* (Concept Paper), Marine Corps Combat Development Command Quantico, Virginia, and U.S. Naval Doctrine Command.

AUTHOR BIOGRAPHIES

KEEBOM KANG is an Associate Professor of Logistics at the Graduate School of Business and Public Policy, Naval Postgraduate School. He was the Co-Editor of the *Proceedings of the 1995 Winter Simulation Conference*, and the program chair for the 2000 Winter Simulation conference. He received his Ph.D. from Purdue University. His research interests are in the areas of simulation modeling, and logistics applications. His email and web address are <kkang@nps.navy.mil> and <web.nps.navy.mil/~kkang>.

KENNETH H. DOERR is an Associate Professor of Operations Management at the Graduate School of Business and Public Policy, Naval Postgraduate School. He received his Ph.D. from the University of Washington. His interests are in work design, research methods, and information systems for logistics and operations. His email and web address are <khdoerr@nps.navy.mil> and <www.sm.nps.navy.mil/fpages/kdoerr>.

KYLE A. BRYAN is Lieutenant Commander of the United States Navy. He is a Supply Corps Officer currently assigned to U.S. Strategic Command as a Logistics Planner. Previous assignments include tours as Disbursing Officer onboard USS John L. Hall (FFG 32), as an ILS Intern at Space and Naval Warfare Systems Command, and as Supply Officer onboard USS Paul Hamilton (DDG 60). He has earned his M.S. in Management from the Naval Postgraduate School. His email address is <BRYANK@stratcom.mil>

GREGORIO AMEYUGO is Commander of the Spanish Navy. After graduating from the Spanish Naval Academy, he served as a line officer dealing with operations in different fleet ships for 10 years. His last assignment afloat was the Head of the Combat System of a Knox class frigate. He graduated with distinction from the Operations Research curriculum at the Naval Postgraduate School in 1996. He then served at the Naval Operations Research Office in Madrid until his appointment in 2000 as Deputy Head of the NATO Modeling and Simulation Office, part of the NATO Research and Technology Agency, in Paris, France. His email address is <ameyugog@rta.nato.int>.