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SEA BASED LOGISTICS: DISTRIBUTION PROBLEMS FOR FUTURE GLOBAL CONTINGENCIES

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ABSTRACT

Evolving doctrine in the U. S. Marine Corps emphasizes small, highly-mobile forces, supported from the sea rather than from large, land-based supply points. We introduce some emerging problems in *sea based logistics*, and show how simulation might be used to address them. We describe a simulation model of the offload of supplies to support a Marine Air-Ground Task Force, and show how to determine the number and allocation of different material handling devices for such an operation.

1 NEW DOCTRINE

The end of the Cold War and the emergence of third-world regional threats have drastically changed the missions of our military services. For the Naval Services (the Navy and Marine Corps), the new threat environment is perceived to be the *littoral*, meaning the sea and land arenas nearest a coast line. For the Navy, this is a change in the nature of the conflict, away from the open water; for the Marine Corps, it is a change in magnitude—likely conflicts today will involve smaller forces and more rapid response.

Complicating the changes in potential threats has been a rapid rise in information technology capability, which promises to improve many of the processes used for operational support. Today's battlefield increasingly contains handheld communications devices, installed equipment monitoring systems, and complete visibility of assets.

The development of new threats and new technologies has spawned the concept of Operational Maneuver from the Sea (OMFTS), which calls for the use of small, highly-mobile fighting forces operating without strictly established resupply lines, called *lines of communication*. This method of operation presents new challenges to the military logistics community.

1.1 Sea Based Logistics

Logistics support for a nominal contingency operation begins with the dispatch of ships of the Maritime Prepositioned Force (MPF). The MPF consists of 13 Maritime Prepositioned Ships (MPS), divided into three squadrons located in the Pacific, Indian, and Atlantic Oceans. Each MPF squadron is similarly loaded with weapons, equipment, and supplies sufficient to support a Marine Air-Ground Task Force for thirty days of combat. At least one MPF squadron can reach anywhere in the world within 7 days of a global contingency.

The purpose of the MPF offload is to provide initial support and to set the stage for follow-on *sustainment* operations. During the offload, supplies are transported to the beach or pier and sent to a Combat Service Support Area (CSSA), from which they are delivered to the combat forces.

After the initial response, sustainment support is provided with a nominal distribution system illustrated in Figure 1. The heart of the system is the CSSA, which acts like a distribution center in commercial distribution. The CSSA dispatches several Combat Service Support Detachments (CSSDs), each of which holds a cache of supplies for an individual maneuver unit. The CSSA receives replenishments from sea- or land-based assets.

When the maneuver unit needs supplies or repair parts, it radios the needs back to the CSSD, if security conditions allow; otherwise it sends a truck back to the CSSD. The CSSD issues the part, if carried, or radios the request back to the CSSA, where the requisition is filled. Naturally, the further back in the supply chain the requisition is filled, the longer the response time and the greater the potential risk to the maneuver unit.

Complicating this process is a limit on transportation assets, such as trucks, helicopters, and container handling equipment. Further, supply routes can be-

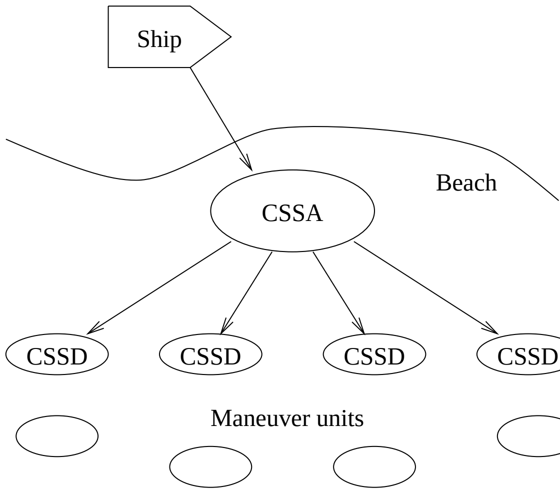

Figure 1: Distribution System for a Combat Service Support Element

come congested, or even close down due to interdiction by opposing forces.

The concepts underlying OMFTS suggest the insertion of smaller, potentially more distributed forces with little or no logistics support in tow. A current and popular military maxim is "Replace mass with information and speed." This is sea based logistics: to support forces on the ground primarily from sea-based assets, using information systems to discern needs and fast transportation assets to deliver supplies.

The principles of sea based logistics and OMFTS suggest that MPF ships may perform a partial offload of supplies to reduce the logistics footprint ashore, rather than a complete offload to outfit the Combat Service Support Element (CSSE). In some cases, they would not offload supplies at all, but rather act as on-scene floating distribution centers.

For the nominal distribution system, sea based logistics means that the CSSA and CSSDs are severely reduced in size, or eliminated altogether, depending on the nature of the conflict. The stock held in these units is "replaced" by responsive transportation and reliable communications systems.

A special concern in sea based logistics is the capacity of the replenishment stream. Traditional logistics operations dump supplies on the land and run the distribution operation from relatively close to the battlefield. In sea based logistics, the source of supply is much farther away (up to 100 miles offshore), and resupply is subject to variables such as weather and sea state.

The primary vehicles that will be used for resupply are the CH-53 helicopter, the V-22 tilt-rotor aircraft, and the Landing Craft Air Cushioned (LCAC, spoken "el-kak"). These are capable vehicles with large capacities, but their ability to meet the replenishment needs depends on, among other things, the number of vehicles available, the distance of the supply ship from shore, and weather and sea conditions.

Another problem concerns the processing of requests from the supplying ship. In sea based logisitics the supply ship becomes a floating warehouse, in which items must be visible and accessible. This is a different role than current operations, which, generally speaking, require only that the ship transport and deliver supplies in a single offload. Operating the ship as a distribution center will require reconfiguration of supplies on the ship and careful management of material handling resources, if not an entirely new ship design.

1.2 Problem Areas

Simulation can be used to address a number of these problems, and seems especially suited to many because of the complexity of the distribution process.

For example, the offload of MPF ships involves many types of transportation and material handling devices. It is an important and difficult operation because of the uncertainty of environmental conditions and the sheer volume of supplies involved. Below we describe a simulation-animation tool to help logistics commanders make operational decisions during an MPF offload.

The battlefield replenishment problem involves many vehicles of different types under changing requirements and environmental conditions. Replenishment requirements depend on the course of the battle, the reliability of components in various weapons systems, the items stocked in the CSSE, and the availability of vehicles. Simulation might be used to examine the availability of aircraft and LCACs when they are used for deliveries between the ship and the CSSE and between the CSSE and individual units.

Increasingly, simulation is being used in inventory modeling for weapons systems support. Such inventory systems seek to maintain a high operational availability A_o of a weapon system, rather than to achieve a target fill rate. This is done using a technique known as Readiness Based Sparing (RBS), in which a reliability block diagram is developed for the system and simulations run to determine which components are most often responsible for the system becoming unavailable. For sea based logistics, RBS models might be developed to determine stocking levels for a CSSE.

Simulation could also be used to determine bottlenecks aboard the supply ship, when it fulfills its distribution center function.

2 IN-STREAM OFFLOAD

Our study of sea based logistics begins with a simulation of the offloading of those ships to support a Marine Air-Ground Task Force. We develop a simulation-animation decision support tool to assist Marine Corps logisitics commanders in optimally allocating scarce resources and material handling equipment for rapid in-stream offload in different offload environments.

Each Maritime Prepositioned Ship is capable of offloading either pierside or *in-stream*, meaning near the beach. The pierside offload is preferred due to its speed and safety. For a pierside offload, containers are lifted off the ship directly to the pier. All rolling stock is driven or is towed off the stern ramp of the ship. The efficiency of the MPF pierside offload during Desert Shield was primarily due to well-trained Marines and Navy personnel and the excellent port facilities in Saudi Arabia.

However, port facilities may not be available as in Desert Shield, or they may be sabotaged or mined to deny access. In such cases, prepositioned equipment must be offloaded directly to the shore. This operation is referred to as an *in-stream offload*.

With the ship at anchor offshore, all vehicles and containers are lifted onto floating vessels which shuttle the gear from ship to shore (see Figure 2). This operation is slower, more dangerous, and sensitive to environmental and terrain factors. Congestion at the beach area must be minimized by the efficient allocation of material handling equipment.

Loaded onboard each MPF ship are vehicles, tanks, fuel, and 300–400 International Standards Organization (ISO) containers of ammunition and supplies. The continuous and concurrent offload of both vehicles and containers is achieved through effective management of the material handling equipment and personnel. Container movement is the most critical part of the operation due to the special handling and limited resources. We consider only the offload of containers, because offloading vehicles are self-powered and do not require material handling resources; and fuel is offloaded with a portable pipeline.

Each ship operates three twin-tandem cargo cranes that service three offload positions. Each ship carries eight $75' \times 21' \times 5'$ causeway sections which are configured into three powered barge ferries, called *lighterage*. The cranes lift containers and vehicles overboard to floating lighterage alongside the ship which then transit to the shore. At this point, all rolling stock drives or is towed to the Combat Support Service Area.

Containers are individually removed from the lighterage by the Rough Terrain Container Handler (RTCH, spoken “ratch”), which is an enormous, rough terrain, 50,000 pound capacity forklift specially designed to handle containerized cargo. It is designed to operate in unimproved beachhead areas and is capable of wading in seawater up to 1.5 meters deep in order to board a causeway ferry and sequentially offload the containers (see *Jane's Military Logistics*, 1991). This capability allows the lighterage to beach anywhere in the vicinity of the RTCH.

The RTCH is able either to load containers directly on Logistics Vehicular System (LVS) platform trucks, or to stack them two-high in a *marshalling area* set up at the beach. The LVS has a flat platform deck with standard container lashing points to carry the ISO container. Its unique design provides off-road capability for transporting individual containers to an inland destination.

After backing off the barge with a container, the RTCH driver checks to see if an LVS is available for loading. If so, he transports the container approximately 200 feet to the LVS from the lighterage. The RTCH then releases the container on the LVS. The LVS departs and the RTCH returns to the lighterage to complete the cycle. Once its containers are offloaded ashore, the lighterage returns to the ship for another load of containers.

If an LVS is not available for loading, the RTCH carries the container to the marshalling area. If additional containers remain on a lighterage, the RTCH returns to complete the offloading, thereby clearing and releasing the lighterage to return to the ship. Usually there are one or more RTCHs tasked with clearing the containers from the marshalling area. These RTCHs are stationed in the marshalling area where they await the arrival of an LVS.

2.1 Model and Analysis

Our model of the in-stream offload is an extension of Sumner and Kang (1992) with the addition of graphics animation using ARENA (1995). It is designed to help a logistics commander to understand the effects of resource allocation on offload times. Our recent experience with Marine officers in the Fleet Marine Force suggests that the graphics animation capability significantly improved the usefulness of the model. The officers found the graphical user-interface easy to use when specifying input parameters to generate different scenarios.

Cowie et al. (1991) also developed an MPF offload simulation model using SIMSCRIPT, but, while their model is comprehensive, it may not be as easy to use in practice.

Our model can simulate a one- or two-ship in-stream offload under various conditions. The following inputs are provided by the user:

- number of containers to be moved,
- number of LVSs,
- number of RTCHs (and the number assigned to the marshalling area),
- distance from the beach to the CSSA,
- lighterage travel time (or the distance) from the ship to the beach, and
- reliability of material handling equipment and repair times.

The most important simulation output is the total offload time. The simulation offload time starts when the first container is lifted from the ship to the lighterage, and ends when the last container is delivered to the CSSA. Figure 2 shows a sample graphics panel of a two-ship offload (USS NPS and USS SM). It is a snapshot taken at simulation time 19 hours, when 14% of the total containers have been delivered to the CSSA (see the boxes % SENT IN and HOURS in Figure 2).

There are three tallies shown on the screen, ARRIVED AT BEACH, ARRIVED AT MARSHALLING, and ARRIVED AT BATTLE. The tally ARRIVED AT BEACH traces the number of containers delivered from the ship to the beach during the simulation run.

The tally ARRIVED AT MARSHALLING indicates the number of containers double-handled at the marshalling area. This occurs when a container is offloaded at the marshalling area before it is later loaded onto an LVS. A high number indicates a shortage of LVSs. If a sufficient number of LVSs are available, the marshalling area will be rarely used.

The tally ARRIVED AT COMBAT shows the number of containers delivered to the final destination, the CSSA. The box at the bottom-left shows the current material handling equipment assignment. In this case, we use 2 RTCHs for lighterage offload, 1 RTCH at the marshalling area, and 18 LVSs. This snapshot also shows that 3 LVSs are waiting to load containers, 12 containers are waiting to be loaded to LVSs by the RTCHs, and 2 containers are being transported by RTCHs. We assume the round-trip distance from the beach to the CSSA is 25 km. (The CSSA is not shown.)

Table 1: Average Offload Times (in hours)

	Number of LVSs		
Dist (km)	10	20	30
15	126 (0.56)	107 (0.39)	107 (0.39)
25	194 (0.78)	108 (0.51)	108 (0.41)
50	375 (0.79)	193 (0.48)	133 (0.32)

2.2 Example

We provide an example to illustrate capability of the model. Table 1 illustrates the effects on offload times of various quantities (10, 20, 30) of LVSs transporting containers over various round-trip distances (15 km, 25 km, 50 km) to the CSSA. We made 20 replications; standard errors are shown in parentheses.

The example requires that 720 containers from two ships (360 for each ship) be offloaded by 3 lighterage. During each trip a lighterage moves 16 containers from the ship to the beach. The results in Table 1 are the average offload times calculated from 20 independent replications for each scenario.

The established goal for an in-stream offload time is 5 days, or 120 hours. For a round-trip distance of 15 km, 10 LVSs nearly achieved the goal. At 25 km, 10 LVSs was insufficient, and approximately 20 LVSs were required. For both distances, the offload time was unaffected by adding LVSs beyond 20. If the distance is 50 km, even 30 LVSs are not sufficient to achieve the goal. Because in practice the number of LVSs is usually constrained, our model could be used by planners to determine the maximum possible distance from the beach to the CSSA while still meeting the 5-day goal for offload time; or conversely, it could be used to determine the required number of LVSs for a given distance.

We also considered the effects of different allocations for the RTCHs. The results shown in Table 1 assume a 2/1 RTCH policy, that is, 2 RTCHs are dedicated to offload lighterage, and 1 RTCH is dedicated to the marshalling area. Table 2 shows results of the 3/0 RTCH policy (at 50 km with 30 LVSs), which simulates shifting the RTCH in the marshalling area to the beach to expedite the lighterage offload. In this case, containers in the marshalling area are serviced only if the RTCHs are not occupied by the lighterage offload. As shown in Table 2, this reassignment may increase the offload time by as much as 7 hours. Assigning one RTCH from the lighterage offload area to the marshalling area (a 1/2 policy) negatively affects the performance, increasing the offload time by 57 hours (from 133 to 190 hours). Adding an extra

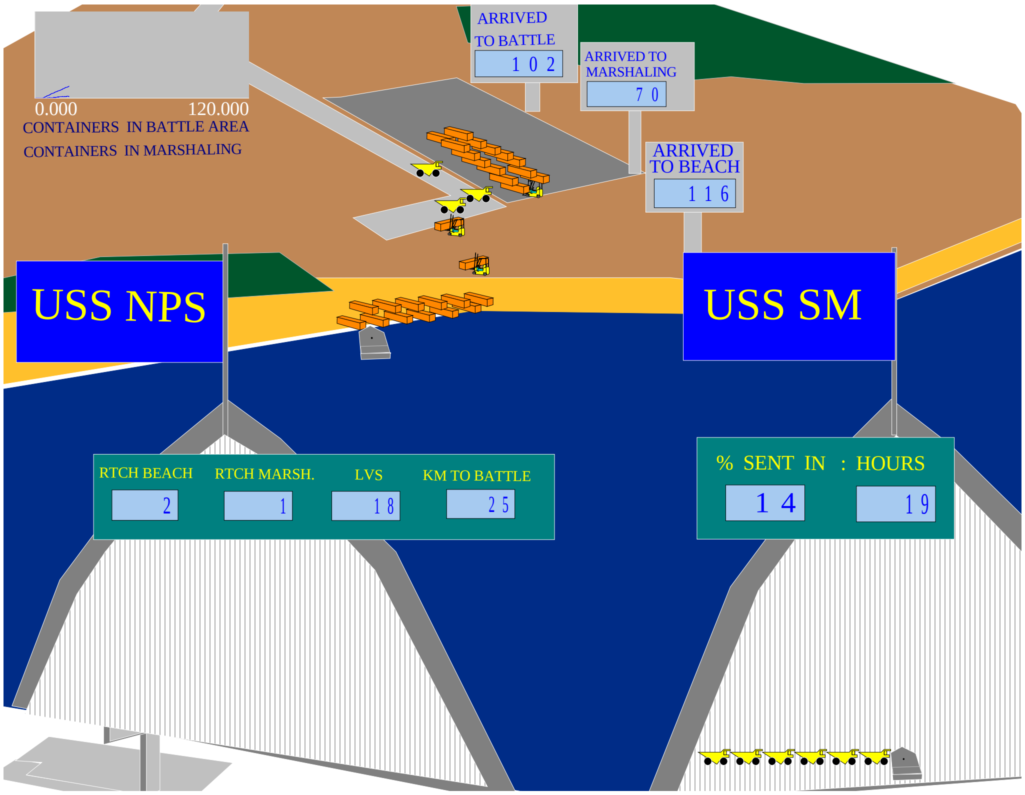

Figure 2: A Screenshot of the Model Implemented in ARENA Animation

Table 2: Offload Time for RTCH Allocation Policies

Policy	*Offload time*
2/1	133 (1.41)
3/0	140 (1.52)
1/2	190 (0.89)
2/2	133 (1.68)
3/1	134 (1.79)

RTCH to the marshalling area (a 2/2 policy), or to the lighterage offload (3/1 policy) does not improve the total offload time. We note that performance is affected by not only the total number of RTCHs, but also the allocation of those RTCHs to the beach and marshalling areas.

3 CONCLUSIONS

We presented the model to the Commanding General of the 1st Force Service Support Group (FSSG) and his staff at Camp Pendleton, CA. The General and his staff indicated that the model had great potential to provide operational and planning support for logisitics commanders involved with MPF operations. We are currently collaborating with the 1st FSSG to collect the offload exercise data for model validation and implementation.

We view our simulation model as a first step in gaining insight into the operational problems of sea based logistics. Future work will focus on defining supply channels to support combat forces with little or no logistics footprint and managing limited transportation assets in a highly uncertain environment.

ACKNOWLEDGMENT

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