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AN ANALYSIS OF ALTERNATIVES FOR RESUPPLYING THE SEA BASE

by

Steven L. Kennedy

March 2002

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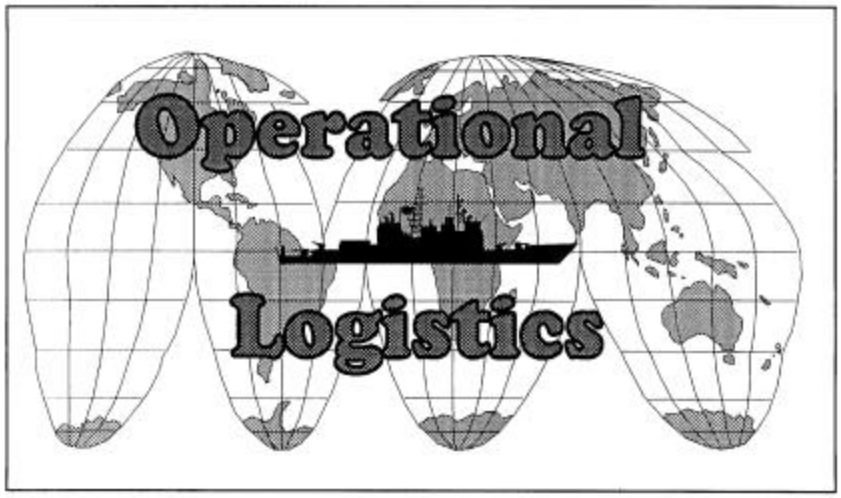

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In the concept papers Operational Maneuver From the Sea, Ship-to-Objective Maneuver, Sea-Based Logistics, and Maritime Prepositioning Force 2010 and Beyond, the Marine Corps laid out its vision of how it will conduct future amphibious warfare. Under OMFTS, combat forces will be deployed from the sea base directly to an objective ashore. This approach drastically reduces logistics infrastructure ashore and retains these capabilities at the sea base. Numerous studies have been conducted to date regarding future STOM requirements of moving forces, equipment, and supplies ashore; however, minimal effort has been exerted thus far in resolving the issue of sustaining the continuously-depleted resources of the sea base.

This thesis compares alternatives for resupplying the sea base. Different scenarios are analyzed for how well each resupply alternative is able to maintain required levels of food, fuel, and ordnance at the sea base with varying distances from the Forward Logistics Site. The scenarios differ by distances between the sea base and FLS, consumption rates at the sea base, and shuttle ship alternatives. Sustainment requirements and safety stock levels are determined and compared for twelve different cases. This analysis provides insight into the type and number of resupply ships needed to maintain sustainment requirements at the sea base.

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AN ANALYSIS OF ALTERNATIVES FOR RESUPPLYING THE SEA BASE

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ABSTRACT

In the concept papers Operational Maneuver From the Sea, (OMFTS), Ship-to-Objective Maneuver (STOM), Sea-Based Logistics (SBL), and Maritime Prepositioning Force (MPF) 2010 and Beyond, the Marine Corps laid out its vision of how it will conduct future amphibious warfare. Under OMFTS, combat forces will be deployed from the sea base directly to an objective ashore. This approach drastically reduces or eliminates logistics infrastructure ashore and retains these capabilities at the sea base. Numerous studies have been conducted to date regarding future STOM requirements of moving forces, equipment, and supplies ashore; however, minimal effort has been exerted thus far in resolving the issue of sustaining the continuously-depleted resources of the sea base.

This thesis compares possible alternatives for resupplying the Expeditionary Maneuver Warfare (EMW) Sea Base (SB). Different scenarios are analyzed for how well each prospective resupply alternative is able to maintain required levels of food, fuel, and ordnance at the sea base with varying distances from the Forward Logistics Site (FLS). The scenarios differ by distances between the sea base and FLS, varying consumption rates at the sea base, and different shuttle ship alternatives. Sustainment requirements and sea base safety stock levels are determined and compared for twelve different scenarios. This analysis provides insight into the type, number, and capacity of resupply ships needed to maintain sustainment requirements at the sea base.

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TABLE OF CONTENTS

I. INTRODUCTION 1
- A. OMFTS CONCEPTUAL OVERVIEW 1
- B. THE NEED FOR RESUPPLY 3
- C. CURRENT RESUPPLY OPTIONS 3
- D. SEA BASE SUSTAINMENT SYSTEM 4

II. BACKGROUND 5
- A. FACTORY-TO-FOXHOLE LOGISTICS NETWORK 5
- B. CONTAINER JUSTIFICATION AND HANDLING 7
- C. FORWARD LOGISTICS SITE (FLS) 9
- D. FOCUS AND METHODOLOGY 9

III. MODEL AND SCENARIO DESCRIPTIONS 11
- A. MODEL DESCRIPTION 11
- B. SCENARIO SPECIFICS 11
- C. SEA BASE REPLENISHMENT REQUIREMENTS 12
- D. SEA BASE INVENTORIES 12
- E. SAFETY STOCK LEVELS 13
- F. RESUPPLY SHUTTLE ALTERNATIVES 14
- G. ASSUMPTIONS 16
  - 1. Sea Base Assumptions 16
  - 2. T-AKE and T-AO Assumptions 17
  - 3. MPF Variant Assumptions 17
  - 4. FLS Assumptions 19
- H. MODEL FORMULATION 20
  - 1. Indices 20
  - 2. Data 20
  - 3. Formulation and Narrative 21

IV. MODEL FINDINGS AND RESULTS 25
- A. MODEL OVERVIEW 25
- B. THE PHILIPPINE ISLANDS SCENARIO 25
- C. THE IRANIAN SCENARIO 32
- D. THE NIGERIAN SCENARIO 37
- E. GENERAL FINDINGS 42
- F. RESUPPLY ALTERNATIVE PERFORMANCE SYNOPSIS 43

V. CONCLUSIONS 45
- A. OVERVIEW 45
- B. RECOMMENDATIONS FOR FURTHER STUDIES 46

LIST OF REFERENCES 49

INITIAL DISTRIBUTION LIST 51

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LIST OF FIGURES

Figure 1. Factory-to-Foxhole Logistics. 6
Figure 2. Philippines, MPF Variant, One Ship, Standard Consumption Rate 26
Figure 3. Philippines, MPF Variant, Two Ships, Standard Consumption Rate 26
Figure 4. Philippines, MPF Variant, One Ship, Surge Consumption Rate 27
Figure 5. Philippines, MPF Variant, Two Ships, Surge Consumption Rate 28
Figure 6. Philippines, One T-AKE & One T-AO, Standard Consumption Rate 29
Figure 7. Philippines, One T-AKE & One T-AO, Surge Consumption Rate 29
Figure 8. Philippines, Two T-AKE & One T-AO, Standard Consumption Rate 30
Figure 9. Philippines, Two T-AKEs & One T-AO, Surge Consumption Rate 31
Figure 10. Philippines, Three T-AKEs & One T-AO, Surge Consumption Rate 32
Figure 11. Iran, MPF Variant, One Ship, Standard Consumption Rate 33
Figure 12. Iran, MPF Variant, One Ship, Surge Consumption Rate 33
Figure 13. Iran, MPF Variant, Two Ships, Standard Consumption Rate 34
Figure 14. Iran, MPF Variant, Two Ships, Surge Consumption Rate 34
Figure 15. Iran, Two T-AKEs & One T-AO, Standard Consumption Rate 35
Figure 16. Iran, Two T-AKEs & One T-AO, Surge Consumption Rate 36
Figure 17. Iran, Three T-AKEs & One T-AO, Surge Consumption Rate 37
Figure 18. Nigeria, MPF Variant, Two Ships, Standard Consumption Rate 38
Figure 19. Nigeria, MPF Variant, Two Ships, Surge Consumption Rate 38
Figure 20. Nigeria, Two T-AKEs & One T-AO, Standard Consumption Rate 39
Figure 21. Nigeria, Two T-AKEs & One T-AO, Surge Consumption Rate 40
Figure 22. Nigeria, Three T-AKEs & Two T-AOs, Surge Consumption Rate 41
Figure 23. Nigeria, One MPF & One T-AKE & One T-AO, Surge Consumption Rate 42

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LIST OF TABLES

Table 1. Sea Base Replenishment Requirement Data. 12
Table 2. Proposed MPF(F) Squadron Commodity Capacities and Days of Sustainment. 12
Table 3. Safety Stock Levels for Standard Consumption Rate. 13
Table 4. Safety Stock Levels for Surge Consumption Rate. 14
Table 5. MPF Container Calculation. 15
Table 6. Increased MPF(F) Commodity Capacities. 16
Table 7. Safety Stock Levels Percentage of Inventory 17
Table 8. MPF TEU Calculations 18
Table 9. Shuttle Ship Alternatives Consumable Capacities after Ref. [20] for T-AKE and after Ref. [21] for T-AO. 19
Table 10. FLS Cargo Transfer Rates. 19
Table 11. Performance of Resupply Alternatives 44

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LIST OF SYMBOLS, ACRONYMS AND/OR ABBREVIATIONS

AAAV	Advanced Amphibious Assault Vehicle
ACE	Aviation Combat Element of a MAGTF
AMSEA	American Overseas Marine Corporation
ARG	Amphibious Readiness Group
ATF	Amphibious Task Force
bbl	Barrels
CNA	Center for Naval Analyses
CONUS	Continental United States
CSSE	Combat Service Support Element
CVBG	Aircraft Carrier Battlegroup
DOS	Days of Supply
EMW	Expeditionary Maneuver Warfare
EXLOG	Expeditionary Logistics
FSS	Fast Sealift Ship
gal	Gallons
JLOTS	Joint Logistics Over-the-Shore
LCAC	Landing craft, air cushion
MAGTF	Marine Air Ground Task Force
MCCDC	Marine Corps Combat Development Command
MEB	Marine Expeditionary Brigade
MEF	Marine Expeditionary Force
MEU	Marine Expeditionary Unit
MPF	Maritime Prepositioning Force
MPF(F)	Maritime Prepositioning Force (Future)
MPSRON	Maritime Prepositioning Ship Squadron
MRE	Meal Ready to Eat
MSC	Military Sealift Command
MTMC	Military Traffic Management Command
NASSCO	National Steel and Shipbuilding Company
NAVCHAPGRU	Navy Cargo Handling and Port Group
nm	Nautical miles
OMFTS	Operational Maneuver From the Sea
OPDS	Offshore Petroleum Distribution System
SBL	Sea-based Logistics
STOM	Ship-to-Objective Maneuver
T-AE	Auxiliary Ammunition Ship
T-AKE	Auxiliary Dry Cargo Replenishment Ship
T-AO	Auxiliary Fleet Oiler
UNREP	Underway Replenishment
USTRANSCOM	United States Transportation Command

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EXECUTIVE SUMMARY

In the concept papers *Operational Maneuver From the Sea* (OMFTS), *Ship-to-Objective Maneuver* (STOM), *Sea-Based Logistics* (SBL), and *Maritime Prepositioning Force* (MPF) *2010 and Beyond*, the Marine Corps laid out its vision of how it will conduct future amphibious warfare. Under OMFTS, combat forces will be deployed from the sea base directly to an objective ashore. This approach drastically reduces or eliminates logistics infrastructure ashore and retains these capabilities at the sea base. Numerous studies have been conducted to date regarding future STOM requirements of moving forces, equipment, and supplies ashore; however, minimal effort has been exerted thus far in resolving the issue of sustaining the continuously-depleted resources of the sea base.

The Marine Corps plans to indefinitely sustain combat forces from the supplies and equipment onboard the ships of an Maritime Prepositioning Ship Squadron (MPSRON) composed of Maritime Prepositioning Force (Future) (MPF(F)) ships. The MPSRON is equipped to logistically support a MEB-sized force for a period of approximately 30 days. Considering this initial level of inventory, 15 days of supply (DOS) safety stock level dictates a maximum of 15 days of operations supported from the sea base prior to going below the reserve inventory level. If operations continue for greater than 15 days, replenishment of the sea base will be required prior to the fifteenth day. The lack of a replenishment system could force the withdrawal of forces prior to mission accomplishment.

In order for the MPSRON to provide indefinite sustainment, ships will either need to rotate off-station for replenishment or be resupplied on-station on a recurring basis. The flow of resupply consumables from the Forward Logistics Site (FLS) to the sea base is a significant challenge. This thesis compares two possible shuttle ship alternatives for resupplying a sea base that is providing logistics support for a MEB-sized force. The alternatives are (1) T-AKE (Auxiliary Dry Cargo Replenishment Ship) and T-AO

(Auxiliary Fleet Oiler) combination, and (2) MPF(F) variants with a capacity based upon current MPF ship capacities.

Twelve cases drawn from three different geographic scenarios are analyzed with respect to each sustainment alternative's ability to maintain required levels of subsistence, fuel, and ordnance at the sea base. The scenarios differ by distances between the sea base and FLS. Additionally, the analysis considers two consumption rates at the sea base and two shuttle ship alternatives. Sustainment requirements and sea base safety stock levels are thus determined and compared for twelve different cases. The scenarios are analyzed to investigate the feasibility of each possible alternative in meeting resupply requirements and the number of each ship required to maintain sea base commodity inventories above safety stock levels. This thesis provides an initial look at the analysis required to compare these or any other future alternatives.

Results of the analysis indicate that, except for the shortest distance between the FLS and the sea base, two MPF variant shuttles or the combination of three T-AKEs and one T-AO are required to keep sea base commodity inventories above inventory safety stock levels. Ordnance stocks are the driving factor.

Even while the resupply system of two MPF variant shuttles is able to maintain long-term sustainment in most cases with minimal difficulty, inventory problems exist primarily after the shuttle ships have offloaded their initial three-day sustainment supply at the sea base and transit to the FLS for the first resupply evolution. In four of the six cases involving the MPF variant, inventories of one or more commodities drop below the 10-DOS level, and one of the remaining two cases drops below 15-DOS.

While the combination of two-T-AKEs and one T-AO is able to sustain food and fuel with minimal difficulty in most scenarios, analysis determines that three T-AKEs and one T-AO are required to maintain ammunition expenditure rates in the most difficult cases.

The large capacity of the MPF shuttle results is a superior cargo handling advantage over the T-AKE/T-AO combination. The ability to receive twenty-foot containers at the FLS coupled with the increased size enable the MPF shuttle to onload

three times the dry cargo of the T-AKE in one-third less time. Considering assumed FLS load rates, the T-AKE will take three days to completely reload with palletized cargo, while the MPF shuttle will depart the FLS fully loaded in only two days.

Subject to the ability to procure MPF shuttle variants of sufficient size and capacity, the MPF shuttle alternative may be the more attractive of the two possibilities considered. Cost factors were not applied, as only operational capabilities were considered in this analysis.

The overall results of this thesis are intended to serve as an entering argument for discussions by Navy and Marine Corps planners regarding resupply of the sea base, as well as providing a tool for any future analysis of other sea base resupply alternatives.

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I. INTRODUCTION

A. OMFTS CONCEPTUAL OVERVIEW

The Marine Corps Combat Development Command (MCCDC) Concepts Division formed its vision for fighting future expeditionary campaigns in its *United States Marine Corps Warfighting Concepts for the 21st Century* [Ref 1]. In the follow-on concept papers *Operational Maneuver From the Sea* (OMFTS), *Ship-to-Objective Maneuver* (STOM), *Sea-Based Logistics* (SBL), and *Maritime Prepositioning Force* (MPF) *2010 and Beyond*, the Marine Corps detailed how it foresaw the conduct of future amphibious operations. Under OMFTS, combat forces of a Marine Air-Ground Task Force (MAGTF) will be deployed from the sea base directly to an objective ashore. By using the sea as a maneuvering space instead of using a single point of assault, Marines will be able to strategically insert combat forces, rapidly collect and process intelligence data, and take decisive action before the enemy can react [Ref 2]. Forces operating ashore will maintain minimal inventory levels, relying instead on frequent support from the sea base.

Ship-to-Objective Maneuver implements OMFTS at the tactical level and provides for the rapid projection of Marine Corps units ashore while maintaining command and control, fire support and logistics support at the sea base. Using Landing Craft, Air Cushion (LCAC), Advanced Amphibious Assault Vehicles (AAAVs), and Vertical Take-Off and Landing (VTOL) aircraft, troops and supporting equipment will be moved and sustained ashore. Landing forces will no longer be required to make a massive assault in landing craft to secure the beach area for follow-on support forces to catch up. Instead, Marine Corps units will generate and maintain a high-tempo operation and overwhelm enemy units with continued power, surprise, and swift maneuvers [Ref 3].

Sea-Based Logistics [Ref 4] is the prime enabling concept that will make STOM possible. SBL uses Amphibious Readiness Group (ARG) and Maritime Prepositioning Force (Future) (MPF(F)) ships to provide a sea base from which combat forces ashore are sustained. Traditionally, amphibious landings have been supported from supply inventories established ashore in the early stages of an assault. Rather than building a

large logistics stockpile ashore, SBL uses over-the-horizon delivery vehicles to provide a more adaptable and secure replenishment option for the landing force. By maintaining essentially all logistics functions and inventory onboard the ships of the sea base, the logistics footprint ashore can be drastically reduced, or even eliminated, while creating a combat service support infrastructure that is much more responsive to the requirements of the landing force commanders. SBL will not be tied to basing rights issues or host nation support. The sea base will essentially serve as a primary distribution center with the capability to transship cargo and distribute ready-for-issue materiel cargo for distribution to forces ashore.

MPF 2010 and Beyond describes the four pillars of future MPF operations: force closure, amphibious task force integration, indefinite sustainment, and reconstitution and redeployment. A key enabler of SBL is the indefinite sustainment requirement of MPF(F). Logistics support will flow from bases and support facilities located in the U.S. or overseas, via the sea base provided by *MPF 2010 and Beyond*, then on to Marine units conducting operations ashore or at sea [Ref 5]. This sea-based logistics effort could include not only MPF and ARG ships, but also aviation logistics support ships, hospital ships, and offshore petroleum distribution system (OPDS) ships.

In addition to the pillars of MPF(F), this concept paper also details the required triad of operational capabilities: fast deployment, reinforcement, and sustained sea-basing. The sustained sea-basing capability will furnish a full range of logistics support, as well as the conduit to strategic bases through which *MPF 2010 and Beyond* will provide indefinite sustainment for a MAGTF [Ref 5]. Unlike current MPF operations where ships will conduct a complete offload of equipment and supplies in a benign environment and then depart the area, ships of the future sea base will remain on station providing on-demand logistics support and selective offload capabilities, extensive medical and intermediate repair facilities, and advanced command and control features. Selective offload, the rapid retrieval and distribution of essential items from sea-based storage onboard MPF(F) ships, will be at the core of Sea-Based Logistics.

B. THE NEED FOR RESUPPLY

The Marine Corps plans to indefinitely sustain combat forces from the supplies and equipment onboard the ships of the Maritime Prepositioning Ship Squadron (MPSRON). The MPSRON is equipped to logistically support a MEB-sized force for a period of approximately 30 days. Considering this initial level of inventory, a 15 DOS safety stock level (safety stock levels will be discussed in detail in Chapter III) dictates a maximum of 15 days of operations supported from the sea base prior to going below the reserve inventory level. If operations continue for greater than 15 days, replenishment of the sea base will be required prior to the fifteenth day. The lack of a replenishment system will possibly force the withdrawal of forces prior to mission accomplishment.

In order for the MPSRON to provide indefinite sustainment, ships will either need to rotate off-station for replenishment or be resupplied on-station on a recurring basis. If ships were required to rotate off station to be resupplied, this would result in fewer ships available at the sea base to support Marines ashore. Ships that are required to depart the sea base take with them much needed equipment, as well as command and control, medical, and intermediate-level repair facilities. This logically leads to the need for a system to resupply the ships of the sea base on-station to prevent the ships from having to rotate off station for sustainment.

C. CURRENT RESUPPLY OPTIONS

As the Navy and Marine Corps embark on the journey towards OMFTS, no current system exists that is able to resupply Marine Corps provisions, fuel and ammunition. The current Navy operational logistics system is not equipped to support the Marine Corps.

The Navy's Combat Logistics Force (CLF) is a very capable asset that enables sustained naval presence and aircraft carrier battle group (CVBG) operations anywhere in the world; however, there are simply not enough available ships or space for Marine Corps sustainment requirements.

Modular Cargo Discharge System (MCDS) ships could be considered a possibility; however, there are some major problems with the current platforms. Ships with the MCDS system currently installed are approximately 40 years old already and will be at least ten years older by the time sea basing becomes a reality. Additionally, the ships are only capable of breakbulk cargo. The term "breakbulk" refers to ships characterized by large open hatches and fitted with boom-and-winch gear or deck cranes [Ref 6]. These ships may retain some usefulness with odd-shaped cargos; however, in direct comparison with container-capable ships, breakbulk ships are no longer commercially viable. Whereas the complete loadout of an auxiliary ammunition ship (T-AE) takes only two days using palletized cargo loads, a breakbulk ship may take up to fourteen days for an equivalent amount of cargo. An additional item of concern for the MCDS ships is the recurring difficulty of manning the nation's Ready Reserve Force (RRF) ships, which MCDS is part of the inventory. RRF ships remain ready to serve within a few days notice; however, they do not retain a permanent crew. As the Baltimore Sun reported in September 2001, the shortage of qualified sailors to man our RRF fleet is a significant issue, and in their words, "a threat to national security" [Ref 7]. The MCDS system may be sufficient for occasional supplementary assistance to the CLF, but its deficiencies in capability and reliability prevent it from being a serious consideration for the sea base resupply system.

D. SEA BASE SUSTAINMENT SYSTEM

Based upon the absence of any current system capable of handling sea base resupply, the Expeditionary Maneuver Warfare (EMW) sea base must have its own sustainment system. The system must be capable of resupplying ships of the sea base on-station and in a timely manner. This thesis presents two possible alternatives for resupplying the sea base and provides an initial look at the analysis required to compare these or any other future alternatives. The alternatives are (1) a T-AKE (Auxiliary Dry Cargo Replenishment Ship) and T-AO (Auxiliary Fleet Oiler) combination, and (2) an MPF(F) variant with a capacity based upon current MPF ship capacities.

II. BACKGROUND

A. FACTORY-TO-FOXHOLE LOGISTICS NETWORK

For any sustained expeditionary operation, there is an immediate requirement to establish a resupply system for Marine Corps fuel, ordnance, and stores. There must be the capability to move sustainment supplies to an MPSRON prior to initial MPF(F) inventories being decremented to the theater safety stock level.

To properly represent the overall process of maintaining the Marines in an expeditionary environment, the sustainment system should be viewed as a network with a required amount of throughput based upon demand at the sea base. The best way to understand this throughput is to define all of the necessary steps in the logistics flow.

MPF ships will be indefinitely sustained from sources outside theater, most likely the continental United States (CONUS). Consumables, including provisions, ammunition, and fuel, as well as other supply requirements, such as spare parts and replacement vehicles, will be delivered to the sea base as part of the logistics flow. As sustainment supplies transit from the factory to the foxhole, there are four natural transitions in the supply network:

(1) From the depot/factory to a CONUS port for shipment overseas onboard commercial ships;

(2) From a CONUS port to a Forward Logistics Site (FLS) in-theater;

(3) From the FLS to the ships of the sea base; and

(4) From the sea base to Marine Corps combat forces operating ashore.

Figure 1 provides an illustrated depiction of the entire factory-to-foxhole logistics network.

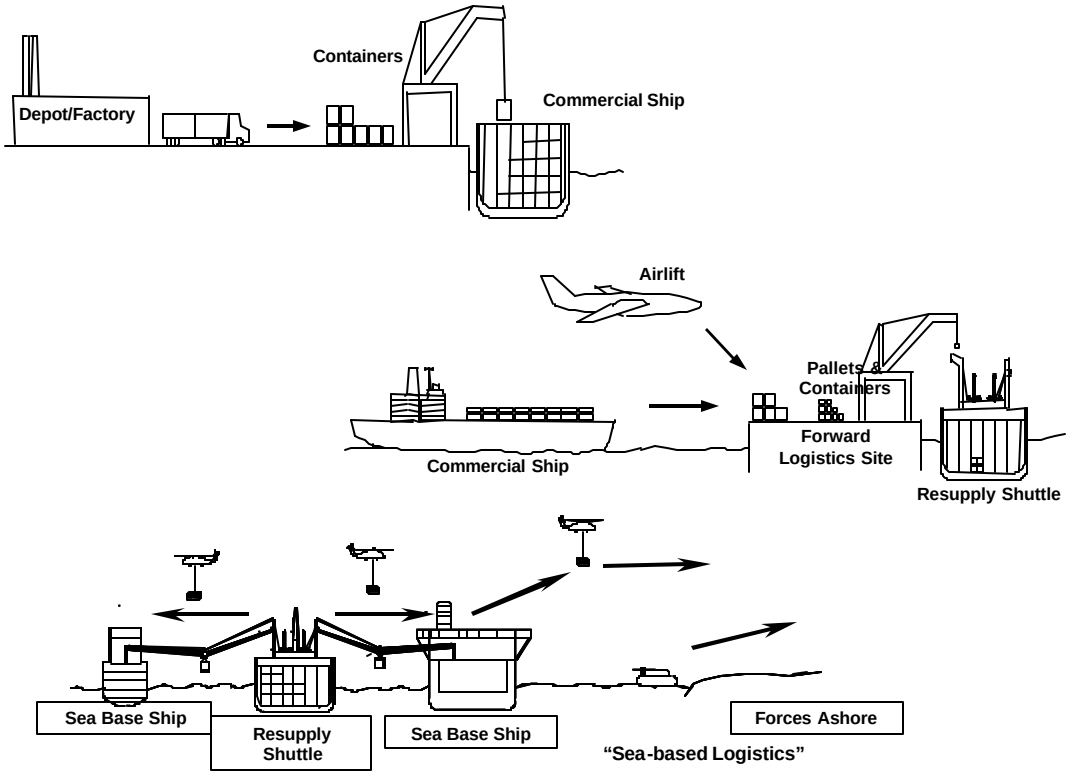

Figure 1. Factory-to-Foxhole Logistics.

Responsibility for the transportation of these supplies differs with the location. The factory to CONUS port and CONUS port to the FLS phases of the network are the responsibility of the U.S. Transportation Command (USTRANSCOM). Marine Corps fuel resupply will arrive in-theater at the FLS by merchant tankers. Marine Corps ordnance and stores resupply will arrive in-theater by commercial container ships.

The FLS to sea base phase of the network, on the other hand, would become the responsibility of the Navy and Marine Corps and would be characterized by a port with the facilities to offload commercial container ships and on-load sea base shuttle ships. Once the commercial ship arrives at the FLS, sustainment cargo will either be offloaded to a holding facility or directly transferred to a sea base resupply shuttle ship. If the shuttle ship cannot receive and handle containers, they will be unstuffed and palletized cargo will be onloaded for sea base resupply.

The last phase of the logistics network, sea base to Marine forces ashore, is the Sea Based Logistics (SBL) concept. Numerous theses and analytical studies have been

completed thus far regarding this phase of OMFTS [Ref 8 through 13]. These studies have determined sustainment requirements, delivery vehicle requirements, and replenishment time requirements for the logistics flow to forces ashore. The overlapping points of interest for this thesis are the overall sea base sustainment requirements that are required to maintain maximum force readiness. These sustainment requirements are the entering argument for the FLS to sea base phase.

B. CONTAINER JUSTIFICATION AND HANDLING

A major aspect of the sea basing system will be the integration of containers into the logistics flow to resupply the sea base. It is assumed that future sustainment ordnance and stores will be transported from the continental United States in twenty-foot intermodal containers or USMC QUADCONs (four connected QUADCONs are handled like a twenty foot container) via commercial container ships of various sizes. In the sea base logistics flow, containers will be loaded at the manufacturers' facilities or a military supply depot, transported to a port of embarkation, and loaded onboard a container ship which will transit directly to the theater of operations. Modern container ships range in capacity from 1500 to 6000 TEUs (twenty-foot equivalent units).

Containerization of cargo in the logistics flow to the sea base would provide significant attributes within the sustainment system. Increased utilization of containers would:

(1) Prevent the numerous occurrences of material re-handling that exist in the current system. Each time that equipment or supplies are unloaded and subsequently reloaded, logistics manpower and resources are expended and material loss or damage can occur;

(2) Provide greater levels of physical security for the equipment being shipped. Materials stored in containers do not require extensive warehouse facilities to provide security and protection from the weather as palletized or bulk cargo does; and

(3) Provide for more efficient loading and offloading evolutions for the resupply ships. This enables the resupply ship, the revenue maker for the logistics system, to return to sea and back to the sea base quicker for an overall faster turnaround time.

An issue to be analyzed is the point in the resupply network to which containers will flow towards Marine Corps forces ashore. Opinions at a recent Sea Base Sustainment Conference with Navy and Marine Corps representatives differ on whether containers should be delivered all the way to the MPF(F) ships of the sea base or delivered to the FLS where the containers would be unstuffed so that palletized cargo can then be delivered to the sea base. Engineers at Naval Surface Warfare Center, Port Hueneme Division, Underway Replenishment (UNREP) Department are currently designing an Expeditionary Logistics (ExLog) Heavy UNREP system which is required under the Future Naval Capabilities (FNC) program. This system, which will be developed and demonstrated by FY 2005, will essentially double the existing UNREP capacity from 5,700 lbs to 12,000 lbs. However, transfer of containers weighing up to 50,000 pounds would represent an eight-fold increase in current UNREP capabilities. The MPF(F) Analysis of Alternatives (AOA) and Concept of Operations (CONOPS) are still under development; thus, it has not been determined if an MPF(F) operational requirement is the ability to receive twenty-foot containers at sea while underway. If so, this would drive technological developments more quickly in that direction.

At the present time, transfer of twenty-foot containers at-sea is not technologically feasible and will not be considered in this thesis. It is assumed that connected cargo transfer at the sea base will be limited to the 12,000 lb Heavy UNREP system.

Despite the fact that at-sea container transfer will not play a part in this analysis, it may be prudent to consider a shuttle ship with container receiving and handling capabilities in the case that container transfer at sea does become a reality for future sea base operations.

C. FORWARD LOGISTICS SITE (FLS)

The Forward Logistics Site (FLS) will serve as a transshipment point between the commercial container and tanker ships and the sea base resupply shuttle. Modern container ships do not have cargo-handling gear and must rely upon ports with container cranes. The FLS would possess the ability to berth and offload commercial shipping and take on whatever capabilities will be required in order to ensure the safe and efficient flow of supplies to the sea base.

Possible alternatives for the FLS could be:

(1) a modern container port;

(2) an unimproved port with pier facilities but no container handling capability; or

(3) a naturally protected bay or harbor where no pier facilities exist.

For alternatives (2) and (3) above, sufficient naval support equipment would need to be brought into the FLS to facilitate container handling and stowage. This may consist of crane ships, barges, tugs and lighterage. The specific FLS location and distance from the sea base would be dependent on various tactical and strategic concerns. Examples of these concerns would be the availability of friendly host nation ports, airfields and the security of the logistic transportation and intermodal assets being employed.

D. FOCUS AND METHODOLOGY

The flow of resupply consumables from the FLS to the sea base is a significant challenge. Without a satisfactory resolution to the problem, OMFTS has no chance of success. This thesis compares two possible shuttle ship alternatives for resupplying a sea base that is providing logistics support for a MEB-sized force. The alternatives are (1) a T-AKE (Auxiliary Dry Cargo Replenishment Ship) and T-AO (Auxiliary Fleet Oiler) combination, and (2) an MPF(F) variant with a capacity based upon current MPF ship capacities.

Three different scenarios are analyzed with respect to each sustainment alternative's ability to maintain required levels of subsistence, fuel, and ordnance at the sea base. The scenarios differ by distances between the sea base and FLS, two

consumption rates at the sea base, and two shuttle ship alternatives. Sustainment requirements and sea base safety stock levels are determined and compared for twelve different cases. The scenarios are analyzed to investigate the feasibility of each possible alternative in meeting resupply requirements and the number of each ship required to maintain sea base commodity inventories above safety stock levels.

III. MODEL AND SCENARIO DESCRIPTIONS

A. MODEL DESCRIPTION

By considering initial MPF ship inventories, consumption rates of supplies, and threshold safety stock limits for a MEB-sized force structure, this model monitors sea base inventories and compares the capabilities of the resupply alternatives to maintain required consumable levels at the sea base. The analysis determines the number of ships of each type that are required to maintain sea base inventory above Marine Corps safety levels.

B. SCENARIO SPECIFICS

In order to fully evaluate the resupply ship alternatives, three different geographic scenarios were developed. The model scenarios were chosen to reflect a realistic range in sea base to FLS distances, but they also reflect a likelihood of future areas of operations. The first scenario is the area of Davao, a city on Mindanao, the southernmost island in the Philippines. Mindanao has recently been recognized as an area of concern for possible terrorist activity in the United States' War on Terrorism. The FLS for the scenario is the U.S. Naval Station on Guam, approximately 1500 nautical miles (nm) due east.

The second scenario simulates a sea base in the northern Gulf of Oman in support of combat operations in southern Iran. This scenario is similar to the one used by Christopher M. Frey in September 2000 for his Operations Research thesis "An Evaluation of Sea-Based Sustainment of Forces" [Ref 9]. The sea base is located southwest of the Iranian city of Gevan. The Forward Logistics Site for this scenario is Diego Garcia, about 2500 nm to the south.

The third hotspot is Lagos, Nigeria where the U.S. has considerable petroleum interests within a very dynamic political environment. The FLS for the scenario is Rota, Spain, located 3500 nm around the western coast of Africa.

C. SEA BASE REPLENISHMENT REQUIREMENTS

The sea base replenishment requirements are computed from a standard rate and a surge rate representing the daily resupply requirements of a MEB-sized operation ashore. The standard consumption rate is based upon Center for Naval Analyses data [Ref 14], with an additional allowance made in the model to provide for a higher surge rate, reflecting the increased level of supplies needed during intense combat operations. This surge rate adds 25% higher ordnance usage and 50% higher fuel usage. The increased fuel rate would be a product of additional troop and rolling stock movements and logistics sorties accompanying the higher intensity operations. Both the standard and surge consumption data are reflected in Table 1.

Commodity	Standard Rate (tons per day)	Surge Rate (tons per day)
Provisions	95	95
Ordnance	550	687.50
Fuel	1063	1595

Table 1. Sea Base Replenishment Requirement Data.

D. SEA BASE INVENTORIES

Extensive research by CNA analysts [Ref 15] has resulted in a proposed loadout of MPF(F) vessels for the future sea base. These ships of the prepositioned squadron arrive in theater with enough equipment and supplies onboard to sustain a MEB-sized force for approximately 30 days [Ref 5]. Table 2 displays the proposed inventory data and the number of sustainment days the MPF(F) (composed of five ships) brings into the operational area based upon the consumption rates contained in Table 1. As is shown, only one of the three commodities meets or exceeds the 30-day estimate for the standard consumption rate and none for the surge rate.

Commodity	Proposed MPF(F) Capacity	Number of Sustainment Days	
		Standard	Surge
Provisions	2,344 tons	25	25
Ordnance	14,850 tons	27	22
Fuel	270,000 bbl/39,690 tons	37	25

Table 2. Proposed MPF(F) Squadron Commodity Capacities and Days of Sustainment.

The CNA-proposed fuel capacity is listed in barrels (bbls); however, since the other commodity inventories and consumption rates are measured in tons, all model calculations and all other tables will account for fuel in tons vice barrels.

E. SAFETY STOCK LEVELS

The shuttle ship alternatives will attempt to maintain sea base inventories above the predetermined amounts of provisions, fuel, and ammunition that constitute the safety stock level, also called the theater safety level. The safety stock level is determined by the Unified Commander and is usually set at 15 days of supply (DOS) [Ref 16]. In the absence of guidance from the Unified Commander, the MAGTF's Logistics Support Concept requires that a 15 DOS safety level be maintained. However, there are occasions when it may be acceptable to go below 15 DOS. If the FLS and a supporting CLF-type system is in place within the theater of operations, the 15 DOS requirement can be spread across the MPF-CLF-FLS, with the MPF/sea base having 10 DOS as a safety level. For the purpose of this model, the 10 and 15 DOS requirements are easily translated into sea base commodity percentages based upon initial inventories and sea base consumption rates as shown in Tables 3 and 4.

	Standard Consumption Rate				
Commodity	**Daily Requirement (tons/day)**	**10 Days of Supply**		**15 Days of Supply**	
		Tons	**Percent of Inventory**	**Tons**	**Percent of Inventory**
Provisions	95	950	40.53%	1,425	60.79%
Ordnance	550	5,500	37.04%	8,250	55.56%
Fuel	1063	10,630	26.79%	15,945	40.18%

Table 3. Safety Stock Levels for Standard Consumption Rate.

	Surge Consumption Rate				
Commodity	**Daily Requirement (tons/day)**	**10 Days of Supply**		**15 Days of Supply**	
		Tons	**Percent of Inventory**	**Tons**	**Percent of Inventory**
Provisions	95	950	40.53%	1,425	60.79%
Ordnance	687.5	6,875	46.30%	10,312.5	69.44%
Fuel	1,595	15,947	40.18%	23,925	60.27%

Table 4. Safety Stock Levels for Surge Consumption Rate.

The commodity percentages tracked at the sea base will be a factor of the initial inventory brought into theater by the MPF ships. The resupply shuttle alternatives will be evaluated as to how effectively each option is able to maintain required safety stock levels.

F. RESUPPLY SHUTTLE ALTERNATIVES

The resupply shuttle variable also consists of two possibilities and the number required of each alternative to maintain required inventory levels. The first possibility is a T-AKE and T-AO combination. The T-AKE is a new two-product class of CLF ship that will replace current T-AFS (fast combat stores ship) and T-AE (ammunition ship) assets. The T-AKE, as designed, will carry stores and ordnance. It will also have a limited cargo fuel capacity. Construction on the first ships of the T-AKE class will begin in 2003 at the National Steel and Shipbuilding Company (NASSCO) in San Diego, CA. Delivery of the first ship is scheduled for 2005. The planned inventory of 12 T-AKEs will be sufficient to service carrier battle groups only. The T-AO (fleet oiler) is an existing, proven fleet asset with many years of service life remaining.

The second possibility for the shuttle variable is an MPF variant. The MPF variant shuttles would actually be ships of the prepositioned squadron, which would assume resupply responsibilities after their initial offload of equipment and supplies. Those ships that are designated as shuttle ships would not contain any of the afloat command and control, medical, or intermediate repair facilities of the sea base. This option would require extra analysis by Marine Corps planners on whether the sea base

can support the loss of potential aircraft landing spots and well decks, if so equipped, for periods when the shuttle ships return to the FLS for resupply.

The proposed MPF variant dry cargo capacity is based upon current MPF ship deck space and design [Ref 17, 18, and 19]. After the ships offload their rolling stock and initial supply of containers, there is a vast abundance of empty deck space. Table 5 provides the container capacity numbers for prepositioning ships STOCKHAM (T-AK 3017), MARTIN (T-AK 3015), and BOBO (T-AK 3008), resulting from the available empty space. By allowing 160 square feet per container (eight feet wide by twenty feet long) with a 50% stow factor within available deck space and a 25% reload factor for initial container storage areas, an average capacity of 848 containers is assumed per MPF shuttle.

	STOCKHAM		**MARTIN**		**BOBO**	
Deck Space Storage Capacity						
Available Space (sqft)	300,826		199,547		181,185	
TEU Capacity	1,880		1,247		1,132	
50% Factor		940		624		566
Organic Container Storage Capacity						
Weather Deck	110		309		120	
25% Factor		28		77		30
Enclosed Cargo	715		426		457	
25% Factor		179		107		114
Total TEU		**1147**		**808**		**710**
				Average TEU Capacity		**848**

Table 5. MPF Container Calculation.

The reduced percentage stow factors mean that approximately half of available deck space will be utilized for container stowage. This leaves large amounts of space for cargo handling and unstuffing containers en route to the sea base in preparation for selective offload of equipment and supplies. These proposed cargo handling evolutions would present a manpower problem for the minimally manned crew of the MPF ships. The current crew size of 25 to 30 government-contracted merchant mariners would need to be increased in size or possibly augmented by MEB Combat Service Support Element (CSSE) or Navy Cargo Handling and Port Group (NAVCHAPGRU) personnel.

G. ASSUMPTIONS

Because of the number of possibilities involved in sustaining the sea base, the following assumptions are made to make the model more manageable:

1. Sea Base Assumptions

- All ships of the sea base are equipped with the Expeditionary Logistics (ExLog) Heavy UNREP system that is currently under development. This system will enable the ships to receive 12,000 lbs by connected replenishment.

- Resupply shuttles will be capable of traveling approximately 500 nautical miles per day, which equates to a sustained speed of 20 to 21 knots.

- In cases involving the MPF variant shuttles, it is assumed that the remaining MPF(F) ships at the sea base will be able to receive amounts of provisions and ordnance greater than the initial inventory levels onboard each ship. This will allow the sea base ships to overcome the loss of one or two ships' worth of commodities. These inventory increases are assumed to be allowable due to excess cargo space that becomes available after the partial offload of rolling stock and supplies. Table 6 provides the revised onboard commodity inventories per ship for a four-ship sea base (one ship as resupply shuttle) and a three-ship sea base (two ships as resupply shuttles). The "Four Ships at the Sea Base" and "Three Ships at the Sea Base" columns reflect approximately 25% and 67% increases in inventory, respectively.

Commodity	Initial Inventory Levels	"Per-Ship" Inventory (tons)		
		Five Ships at Sea Base	Four Ships at Sea Base	Three Ships at Sea Base
Provisions	2,344	470	586	780
Ordnance	14,850	2,970	3,713	4950

Table 6. Increased MPF(F) Commodity Capacities.

- Without the increased storage capacity on non-shuttle MPF ships, the percentage of onboard stock that equates to the safety stock requirements

greatly increase as the number of MPF shuttle ships increases. Considering the 15- and 10-DOS data from Table 3 and the "Five Ships at the Sea Base" initial shipboard inventory levels from Table 6, inventory percentages are listed in Table 7 that reflect safety stock levels with a reduced number of sea base ships.

Commodity	**Safety Stock Levels Percent of Inventory**					
	Five Ships at Sea Base		**Four Ships at Sea Base**		**Three Ships at Sea Base**	
	15-DOS	**10-DOS**	**15-DOS**	**10-DOS**	**15-DOS**	**10-DOS**
Provisions	60.79%	40.53%	75.99%	50.66%	101.32%	67.55%
Ordnance	55.56%	37.04%	69.44%	46.30%	92.59%	61.73%

Table 7. Safety Stock Levels Percentage of Inventory

- Due to initial excess inventory of fuel within the MPF(F) ships, there is no need to attempt to increase onboard storage capacity.

2. T-AKE and T-AO Assumptions

- Both T-AKE and T-AO ships will be at the sea base and available for resupply evolutions upon commencement of operations.
- Based upon the CNA-proposed MPF(F) loadout contained in Table 2, it is assumed that 14% of the dry cargo at the sea base will be provisions, and 86% will be ammunition. Correspondingly, the T-AKE dry cargo loadout will reflect these same percentages. With a total dry cargo capacity of 5,910 tons, 830 tons will be allocated for provisions and 5,080 tons for ammunition.
- The T-AO fuel capacity is 26,166 tons (178,000 bbls). The T-AKE cargo fuel capacity is 2,646 tons (18,000 bbls).

3. MPF Variant Assumptions

- MPF variant shuttle ships will be sized and configured to receive, handle, and unstuff twenty-foot containers.

- The dry cargo relationship between provisions and ordnance onboard the MPF shuttle will be the same as the T-AKE loadout, 14% provisions and 86% ordnance. This results in 2,500 tons of provisions and 15,360 tons of ordnance when the MPF shuttle is completely loaded with 848 containers. Table 8 containers the container and tonnage calculations.

Commodity	Tons	Tons per TEU	Number of TEUs
Provisions	2,500	12	208
Ordnance	15,360	24	640
Totals	17,860		848

Table 8. MPF TEU Calculations

- In order to provide a more effective shuttle capability for refueling operations, the proposed MPF(F) onboard supply of approximately 7,940 tons of fuel will be increased to 12,500 tons for the designated MPF shuttles. This capacity of cargo fuel will enable the MPF variant shuttles to provide a complete refueling to the non-shuttle MPF ships following a resupply transit to the furthermost FLS.

- The 848-container capacity for the MPF variant is based strictly on available deck space without regard to tonnage restrictions. The Fast Sealift Ship (FSS) of the Military Sealift Command is 950 feet long and can carry approximately 25,500 tons of cargo. With a combined cargo and fuel capacity of approximately 30,500 tons, the MPF shuttle variant may result in a ship too large to be feasible for naval planners.

- Those ships of the MPF squadron that are designated as the shuttle ships will be optimally configured to offload first. It is estimated that the MPF shuttle ships would initially contain three days worth of sustainment. Following the offload of equipment and supplies at the sea base, the shuttle ship will convert to its resupply role. For cases involving two shuttle ships, the second ship will provide sustainment for the second three-day period and then depart for the FLS in its resupply role.

Cargo capacity assumptions for all three resupply ships are listed in Table 9.

Commodity	T-AKE	T-AO	MPF Variant
Provisions	830 tons	N/A	2,500 tons
Ordnance	5,080 tons	N/A	15,360 tons
Fuel	2,646 tons	26,166 tons	12,500 tons

Table 9. Shuttle Ship Alternatives Consumable Capacities after Ref. [20] for T-AKE and after Ref. [21] for T-AO.

4. FLS Assumptions

- The flow of cargo towards the sea base will be routed through a forward logistics site for transfer to one of the resupply alternatives. For the cases involving the T-AKE alternative, containers will be unstuffed at the FLS with palletized cargo loaded onboard the shuttle ship. For the MPF variant, containers will probably be offloaded from the commercial container ship to a holding area and then transferred to the shuttle ship.
- There is no disruption or delay in the flow of cargo to the FLS. Whenever a resupply shuttle arrives for onload, the required amounts of all commodities are available.
- Cargo transfer rates for the FLS are listed in Table 10.

T-AKE & TAO Combination		MPF Variant	
Pallets	20 pallets per hour per station	Containers	15 containers per hour per crane
Fuel	440 tons per hour per hose	Fuel	440 tons per hour per hose

Table 10. FLS Cargo Transfer Rates.

- Two pallet-receiving stations on the T-AKE will result in 40 pallets per hour total [Ref 22].
- Two fuel-receiving hoses on the T-AO and MPF shuttles provide a total refuel rate of 880 tons per hour [Ref 22]. T-AKE cargo fuel evolutions will use a single hose, which will result in a refuel rate of 440 tons per hour.

- An MPF container rate of 15 containers per hour at the FLS is based upon a transfer of 30 containers per hour under ideal circumstances in an improved container transfer facility [Ref 23]. The model assumes that the average container weight for provisions and ammunition are 12 tons and 24 tons, respectively.
- Based upon the ships' cargo capacities listed in Table 6 and the cargo transfer rates listed in Table 7, the maximum load time per vessel at the FLS is:
    - T-AKE: 74 hours
    - T-AO: 30 hours
    - MPF: 49 hours

H. MODEL FORMULATION

The Sea Base Inventory and Resupply Model is stated mathematically as follows:

1. Indices

t	Sea base day (0,1,2,…90)
k	Commodity (Provisions, Ammo, Fuel)
r	Commodity Consumption Rate (Standard, Surge)
s	Shuttle alternative (T-AKE, T-AO, MPF)
n	Number of MPF resupply shuttles (1,2)
m	MPF ships in MPSRON (1,2,3,4,5)
d	FLS-to-sea base distance (1500, 2500, 3500)

2. Data

spdShuttle	Speed of resupply shuttle (nm/day)
totalMPF	Total number of MPF ships in MPSRON
$capSB_k$	Sea base capacity of commodity k (tons)
$invSB_{t,k}$	Sea base inventory of commodity k on day t (tons)

$capMPF_{k,m}$	Capacity of commodity k on MPF ship m (tons)
$15DOS_{k,m}$	Percentage of onboard stocks that equate to 15-DOS level (%)
$daily_{k,r}$	Daily requirement of commodity k for rate r (tons)
$capShuttle_{s,k}$	Capacity of commodity k on shuttle s (tons)
$invShuttle_{s,k,t}$	Amount of commodity k on shuttle s on day t (tons)
$numShuttle_{n}$	Number of MPF variant shuttles
$resupSB_{k,s,t}$	Amount of resupply to the sea base of commodity k from shuttle s on day t (tons)
$resupFLS_{k,s,t}$	Amount of resupply onloaded on shuttle s at the FLS of commodity k on day t (tons)
$transitFLS_{s,d}$	Transit time for shuttle s with scenario distance d to replenish and return to sea base (hours)
$distFLS_{d}$	Distance from the sea base to the FLS (nm)
$flsOnldRate_{k}$	Shuttle onload rate of commodity k at the FLS (tons/hour)

3. Formulation and Narrative

The Sea Base Inventory and Resupply Model starts with an MPSRON at maximum capacity of provisions, ammunition, and fuel, as listed in Table 2. As operations commence, inventory for the three commodities are decremented daily in accordance with the consumption rate that is in effect (Table 1) to represent the flow of supplies to Marines ashore. The inventories continue to decrease until resources are expended or until a resupply of commodities is delivered to the sea base ships.

Sea Base Commodity Inventory (tons)

$$invSB_{t+1,k} = invSB_{t,k} - daily_{k,r} + resup_{k,s,t} \qquad \forall t, k, s, r$$

The goal of the assigned resupply ships in each case is to provide replenishment to the sea base ships prior to the commodities inventories decreasing to the 15-DOS level. Safety stock level inventories are listed in Table 3 for standard consumption and Table 4 for surge consumption.

Sea Base Inventory Constraint (tons)

$invSB_{t,k} \geq 15 * daily_{k,r} \qquad \forall t,k,r$

Resupply ship inventories are monitored in order to determine when return trips to the FLS are required. Shuttle ship capacities are listed in Table 9.

Shuttle Ship Inventory (tons)

$invShuttle_{k,s,t} = invShuttle_{k,s,t} - resup_{k,s,t} + resupFLS_{k,s,t} \qquad \forall k,s,t$

When it is time for the resupply shuttle to transit to the FLS for replenishment, total time away from the sea base is a function of sea base-to-FLS distance and the time required for onload at the FLS. Commodity onload rates are listed in Table 10.

Shuttle FLS Transit Time (hours)

$transitFLS_{s,d} = 2 * (distFLS_d / spdShuttle) + ((capShuttle_{s,k} - invShuttle_{t,k}) / onloadRate_k) \qquad \forall k,s,t,d$

In cases involving the MPF variant shuttles, the remaining MPF(F) ships at the sea base must be able to receive amounts of provisions and ordnance greater than the initial inventory levels onboard each ship to account for the n ships' worth of commodities, where *n* is the number of MPF resupply shuttles. These inventory increases are assumed to be allowable due to excess cargo space that becomes available after the partial offload of rolling stock and supplies. The data in Table 6 refers.

MPF Ship Increased Inventory (tons)

$capMPF_{k,m} = (capSB_k / (totMPF - numShuttle_n)) - (capSBk / totMPF) \qquad \forall k,m,n$

Without the increased storage capacity on non-shuttle MPF ships, the percentage of onboard stock that equates to the safety stock requirements greatly increase as the number of MPF shuttle ships increases. Table 7 displays the commodity percentages required to maintain 15-DOS at the sea base.

Increased Inventory Equivalent to 15-DOS (%)

$15DOS_{k,m} = (daily_{k,r} * 15) / capSB_k / (totMPF - numShuttle_n) \qquad \forall k, r, m, n$

The equations contained in this section are used to produce the inventory level profiles shown in Chapter IV.

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IV. MODEL FINDINGS AND RESULTS

A. MODEL OVERVIEW

This chapter provides a synopsis of model results for the Sea Base Inventory and Resupply Model. This model evaluated twelve different cases from the three geographic sea base scenarios. The sea base in each scenario consists of one five-ship MPSRON, which is logistically supporting a MEB-sized operation ashore. The variables that produced the twelve cases were: (1) three sea base-to-FLS distances, (2) two sea base commodity consumption rates, and the (3) two types of shuttle ship alternatives. Each case was analyzed as to the number of shuttle ship alternatives were able to maintain the sea base inventories of provisions, ordnance, and fuel within Marine Corps theater safety stock levels.

The theater safety stock level is typically set at 15 days of supply (DOS) required to be maintained at the sea base; however, there is a provision for easing this requirement to 10 days of supply if the FLS and a supporting CLF-type system is in place within the theater of operations. Since there is relevance in tracking both safety stock levels, the model monitors how well the resupply alternatives perform with regards to both 15-DOS and 10-DOS requirements.

B. THE PHILIPPINE ISLANDS SCENARIO

The Philippines scenario, with the shortest transit distance to the FLS, presents the least challenging situation for the two resupply alternatives. However, even at this elementary stage of the model, significant differences are apparent between the T-AKE and T-AO combination and the MPF variant.

As Figures 2 and 3 display, there is no considerable advantage to having two MPF variant shuttles with a standard consumption rate at this short distance. Both of these cases encounter one day when the provisions inventory drops to the 15-DOS requirement, but all other inventories remain above safety stock levels.

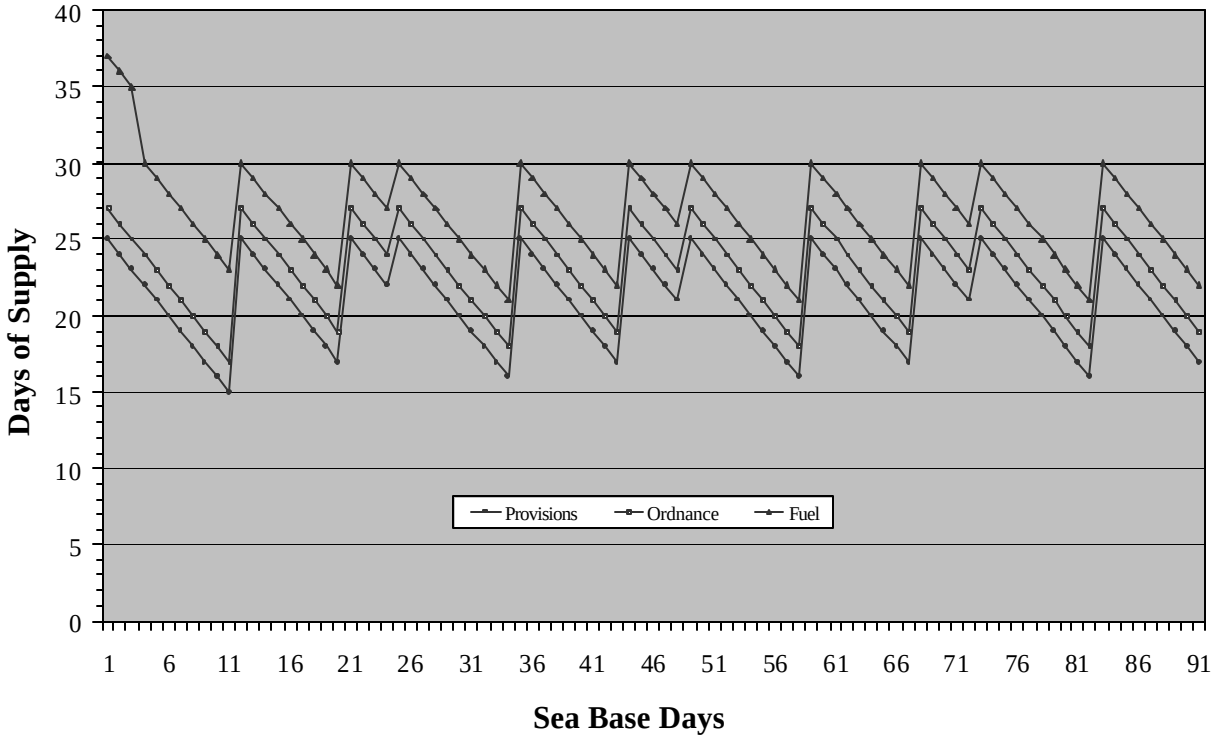

Figure 2. Philippines, MPF Variant, One Ship, Standard Consumption Rate

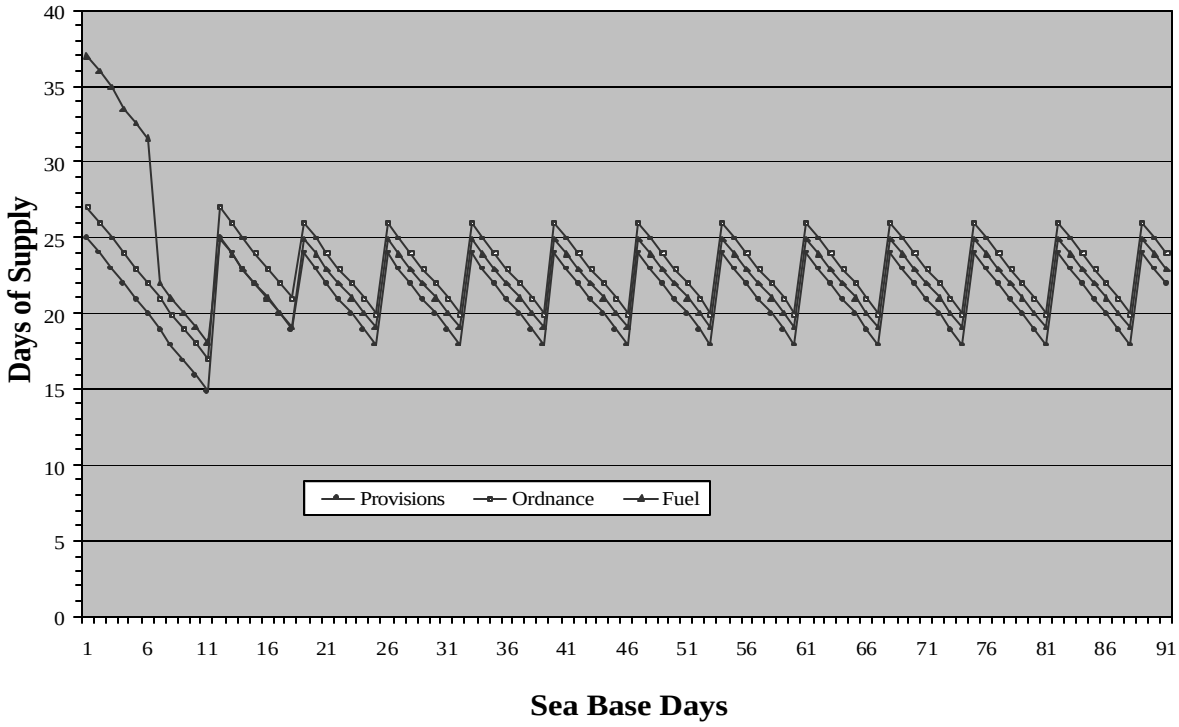

Figure 3. Philippines, MPF Variant, Two Ships, Standard Consumption Rate

Figures 2 and 3 also display how the sea base fuel inventory is affected by the initial departure of the MPF shuttle ships. The first three days of the one-shuttle ship scenarios and the first six days of the two-shuttle ship scenarios include the initial fuel stocks of the MPF shuttle ships in the sea base inventories. However, after the shuttle ships convert to their resupply responsibilities, those stocks are no longer counted as part of the sea base. This results in the inability of the sea base to return to its complete, initial capacity. This affect does not apply to provision and ammunition stocks due to the assumption of increased storage space onboard the non-shuttle MPF ships following equipment offload. This assumption is explained in Chapter III, Section G.

The advantage of a second shuttle is demonstrated under the surge consumption rate variable. The single MPF shuttle results in considerable time during which the inventory is below the 15-DOS level. Ordnance and fuel percentages provide the most glaring deficiency with 32 days and 41 days of the 90-day period, respectively, with supplies less than 15-DOS (Figure 4).

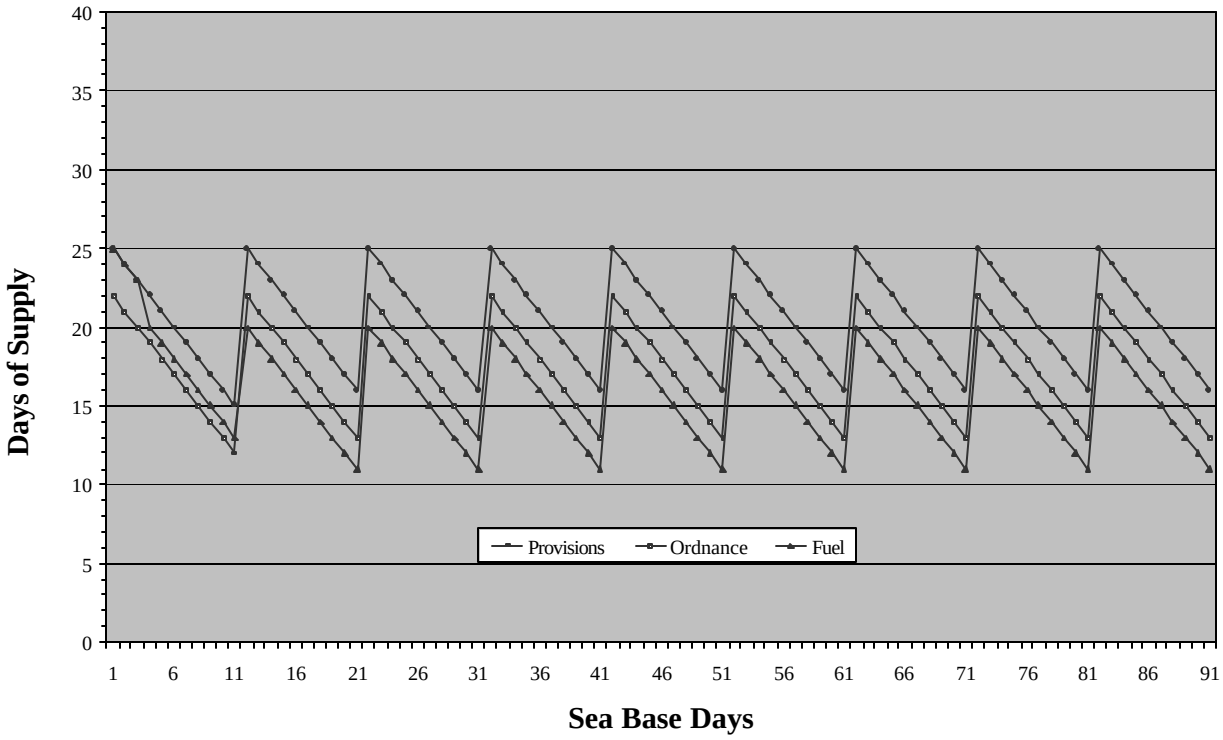

Figure 4. Philippines, MPF Variant, One Ship, Surge Consumption Rate

When two MPF shuttles are applied to the case, a single four-day period is noted with ordnance supplies less than the 15-DOS level (Figure 5). The fuel stocks presents a much worse situation with sea base supplies never climbing above 15-DOS following the initial inventories; however, stocks do not drops below 10-DOS. The loss of two ships' worth of fuel inventory at the sea base is too much for the shuttle ships to overcome. If the 10-DOS level is not acceptable to Marine Corps planners, this alternative is infeasible.

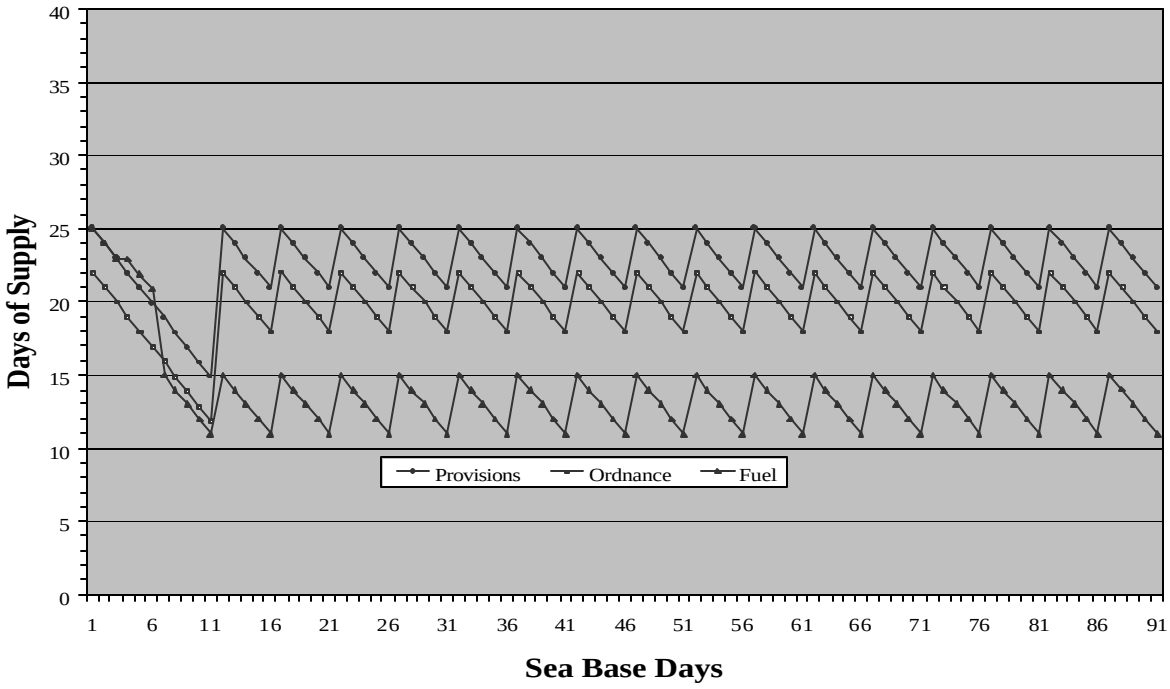

Figure 5. Philippines, MPF Variant, Two Ships, Surge Consumption Rate

Figures 6 and 7 reveal serious provisioning and ordnance problems with a single T-AKE supporting the sea base. Under standard consumption rates, ordnance is below the 15-DOS level for 45 days of the model period. Additionally, ordnance levels are below 15-DOS for 80 days of the evaluation period when surge consumption rates are implemented. The T-AO is generally able to maintain fuel percentages (except for a single three-day period of inventory less than 10-DOS); however the T-AKE is unable to overcome a downward trend in both provision and ordnance inventories.

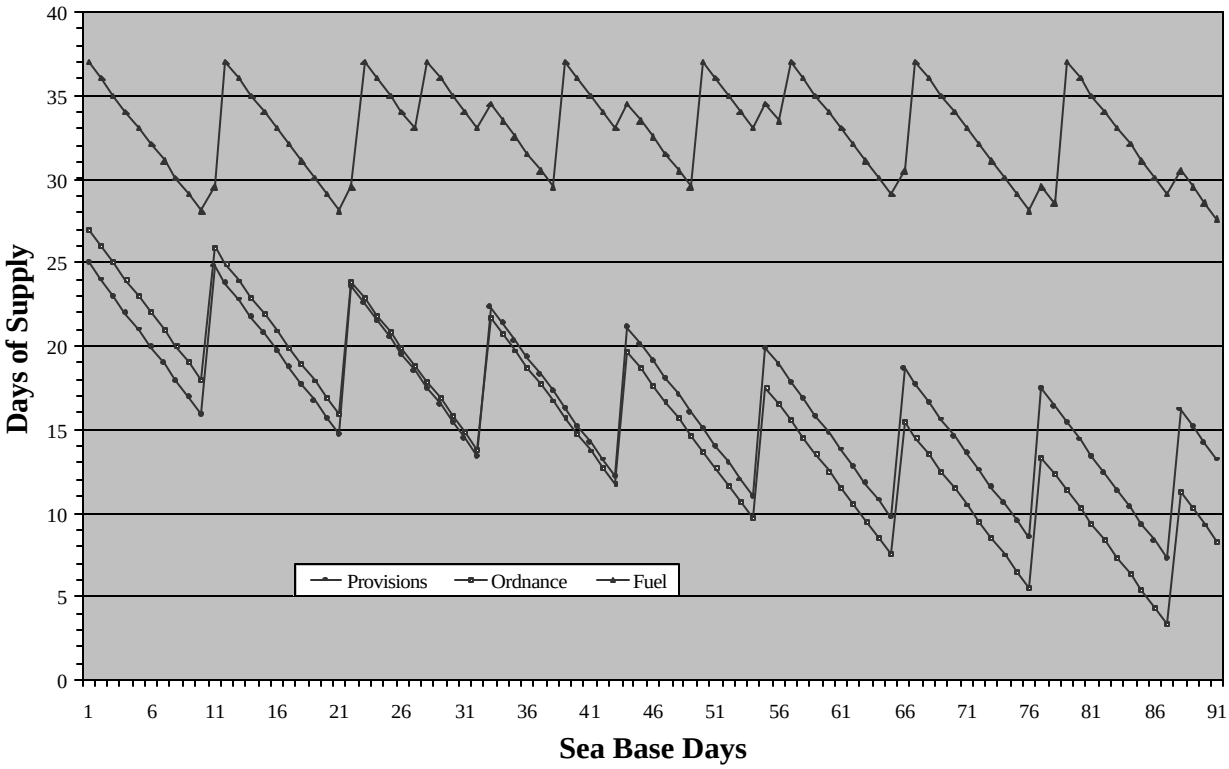

Figure 6. Philippines, One T-AKE & One T-AO, Standard Consumption Rate

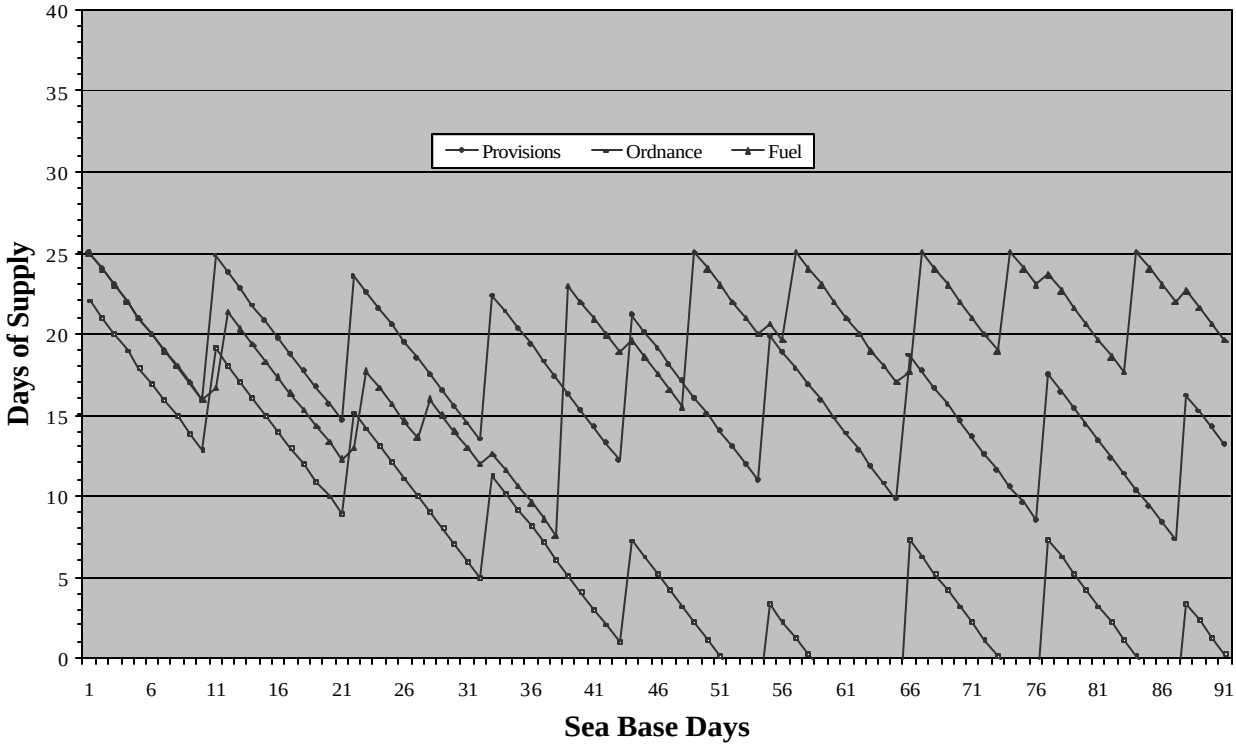

Figure 7. Philippines, One T-AKE & One T-AO, Surge Consumption Rate

In the two T-AKE case, the resupply ships are able to maintain commodity levels with standard consumption (Figure 8) with no drops in inventory below theater stock levels, but surge-rate levels are again a problem with several occasions of ordnance and fuel inventories falling below 15-DOS (Figure 9), although the occasions are only one-third as severe as in the single T-AKE case. There are no inventory observations below the 10-DOS level.

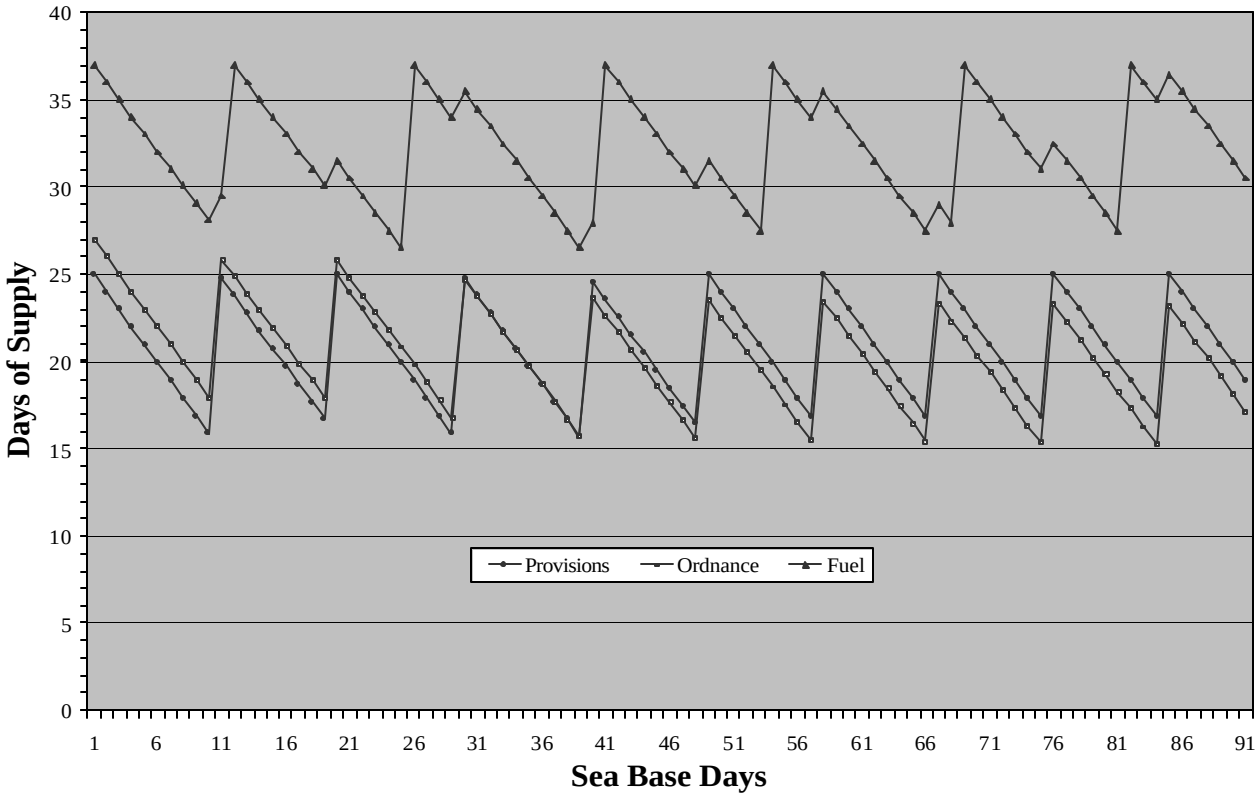

Figure 8. Philippines, Two T-AKE & One T-AO, Standard Consumption Rate

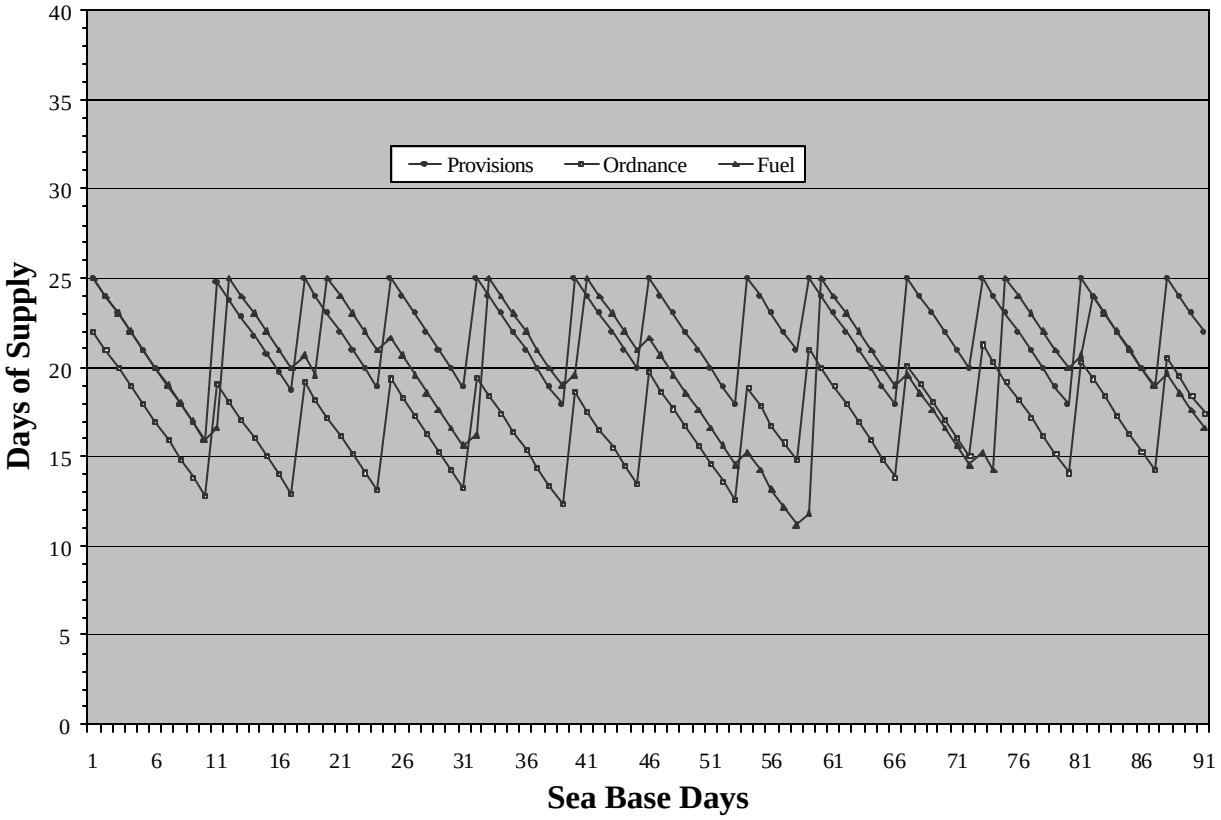

Figure 9. Philippines, Two T-AKEs & One T-AO, Surge Consumption Rate

For the Philippine Islands scenario, it becomes apparent that a single MPF variant shuttle or two T-AKEs combined with a T-AO are very capable of maintaining commodity levels under standard consumption rates; however, in order to maintain surge-rate levels for this easiest scenario, two MPF shuttles or three T-AKEs (Figure 10) are required to sustain provision and ordnance stocks.

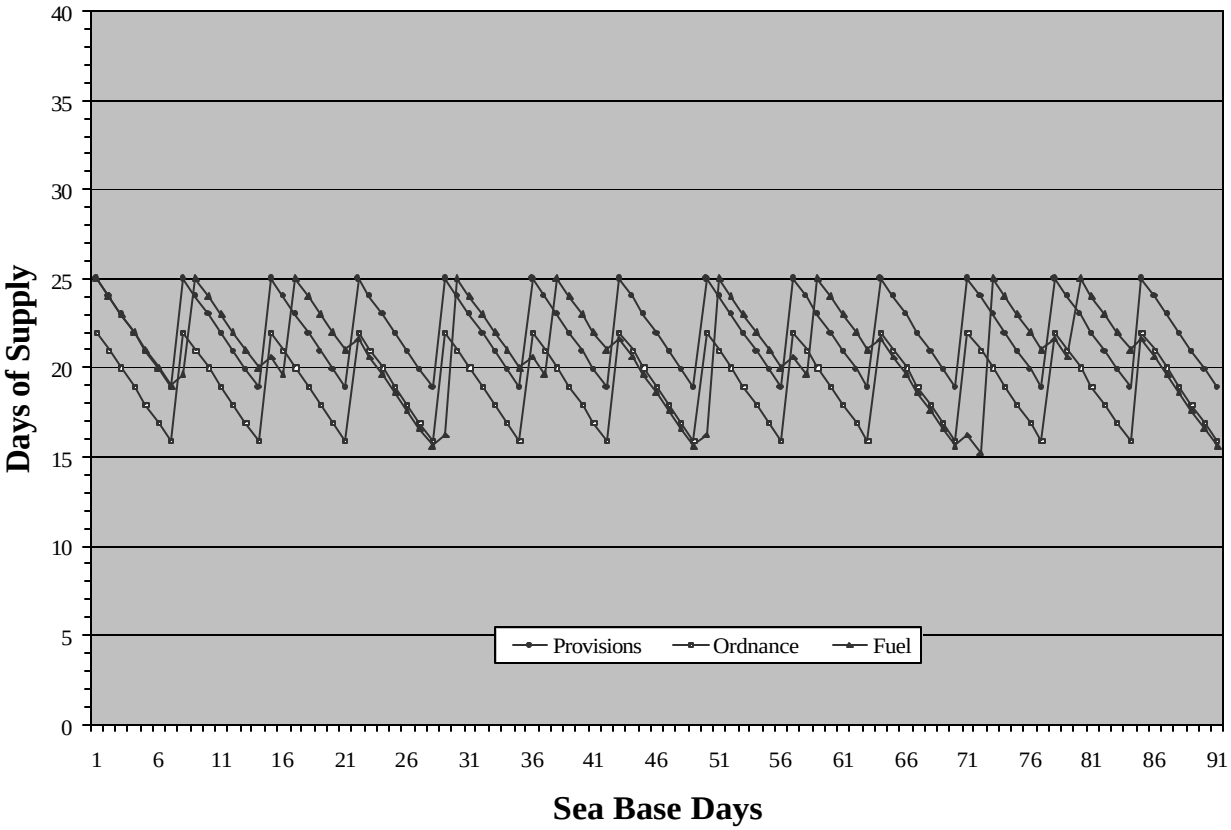

Figure 10. Philippines, Three T-AKEs & One T-AO, Surge Consumption Rate

C. THE IRANIAN SCENARIO

While a single MPF shuttle was able to satisfactorily sustain the Philippine standard- consumption sea base, significant 15-DOS provision and ordnance deficiencies are observed for the Iranian sea base using the same resupply configuration (Figure 11). Provision supplies decrease below the 10-DOS level for one day in this case, while both provisions and ordnance have several instances of stock levels below 15-DOS.

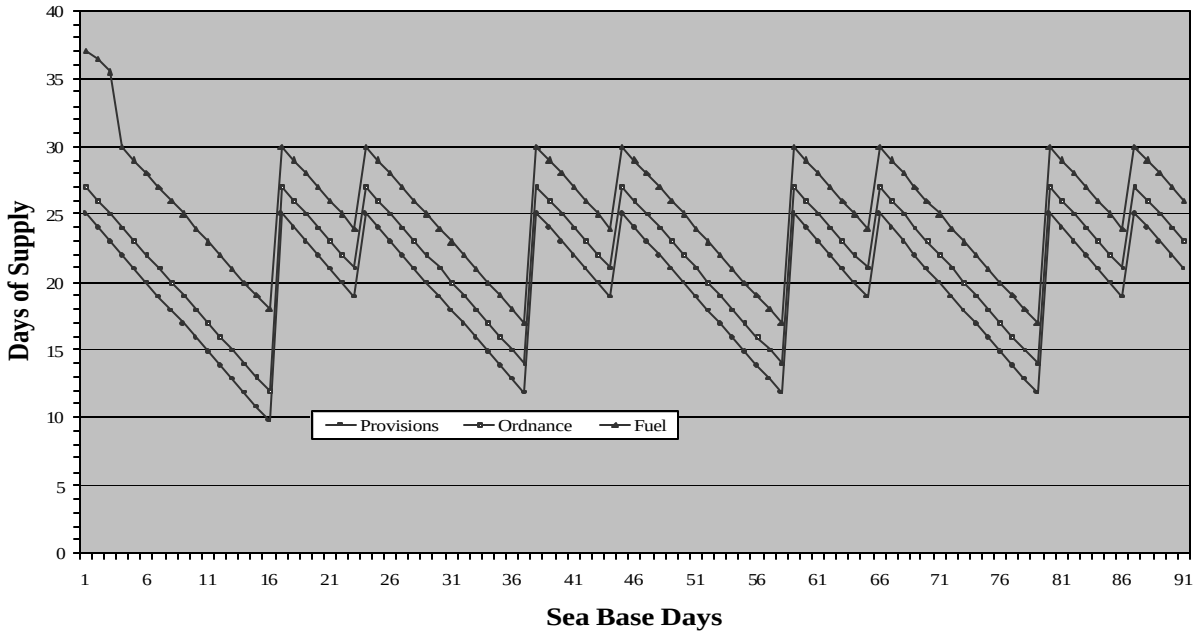

Figure 11. Iran, MPF Variant, One Ship, Standard Consumption Rate

In the case of surge consumption (Figure 12), all three commodity stocks spend long periods of time below 15-DOS. Additionally, fuel levels exhibit an unrecoverable , decreasing trend during the 90-day period, resulting in an infeasible solution.

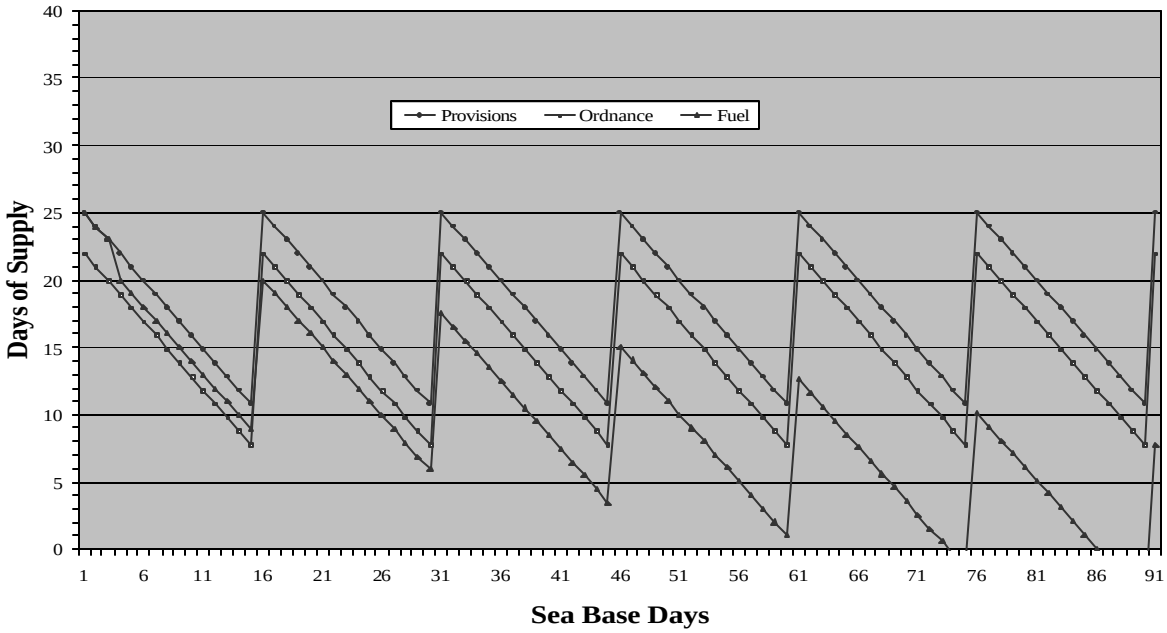

Figure 12. Iran, MPF Variant, One Ship, Surge Consumption Rate

Two MPF ships drastically decrease the number of deficient days for standard consumption provisions and ordnance (Figure 13). The surge consumption rate (Figure

14) still results in sustained fuel inventory at or below the 15-DOS level, including 12 days below 10-DOS, again resulting in an infeasible solution.

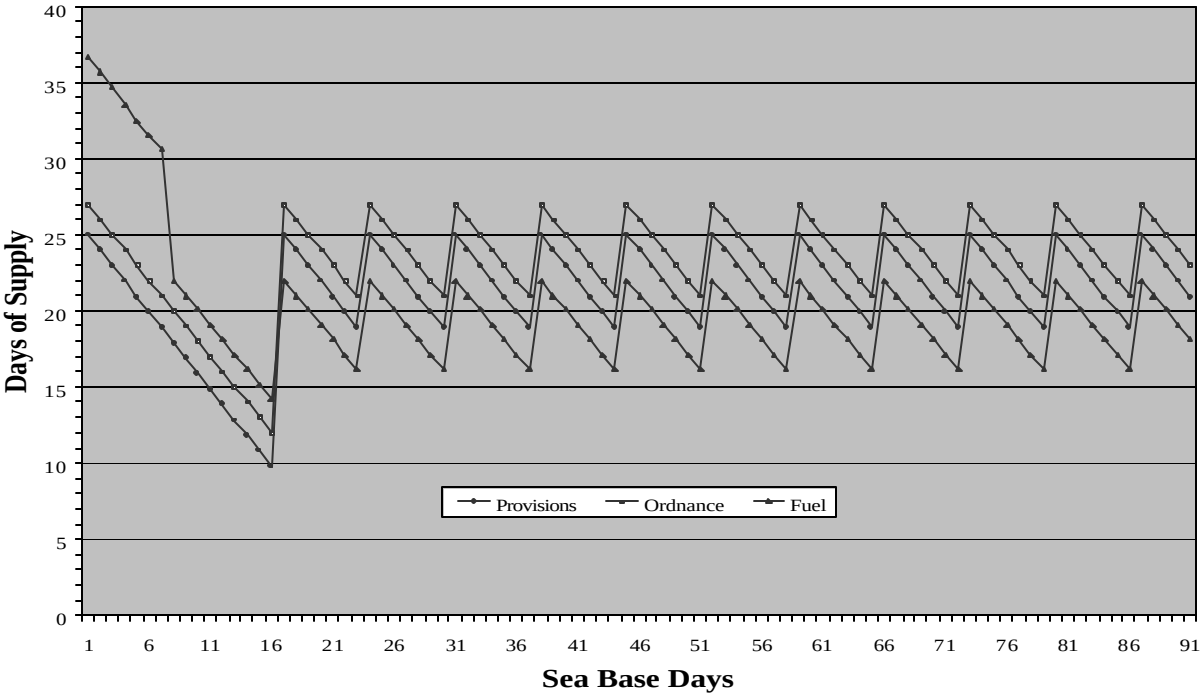

Figure 13. Iran, MPF Variant, Two Ships, Standard Consumption Rate

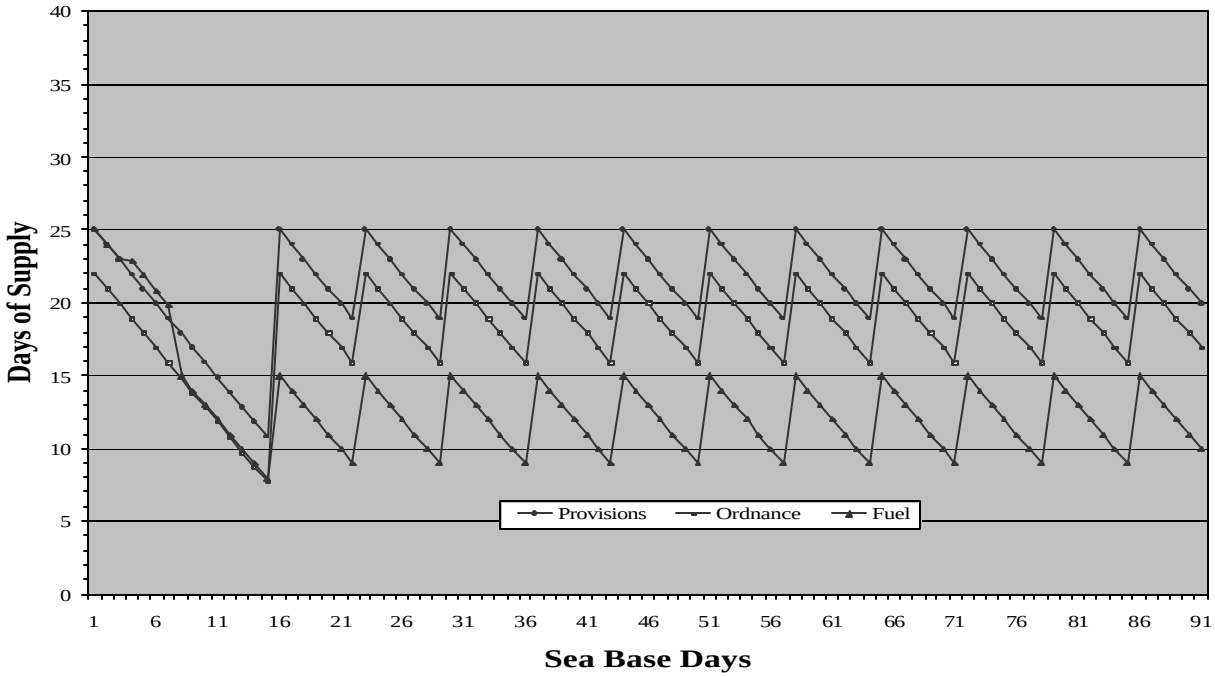

Figure 14. Iran, MPF Variant, Two Ships, Surge Consumption Rate

Based upon the difficulty of one T-AKE in maintaining inventories at the 1500 nm distance, this case was not evaluated for the longer FLS distances, as its further deficiencies are obvious.

The combination of two T-AKEs and one T-AO satisfactorily meets standard consumption requirements (Figure 15), but it is gravely deficient in surge ordnance at the 15-DOS level (Figure 16). Two separate two-day periods were observed where ordnance also falls below the 10-DOS level.

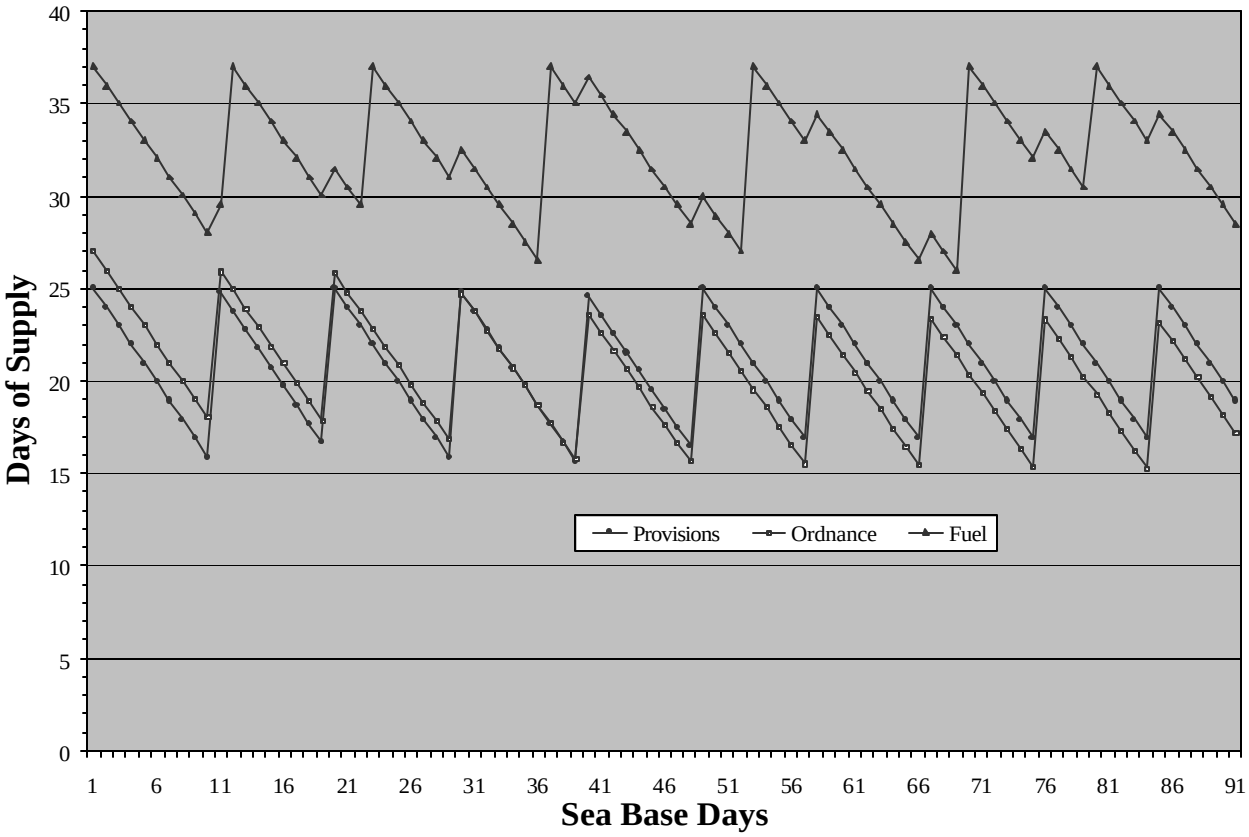

Figure 15. Iran, Two T-AKEs & One T-AO, Standard Consumption Rate

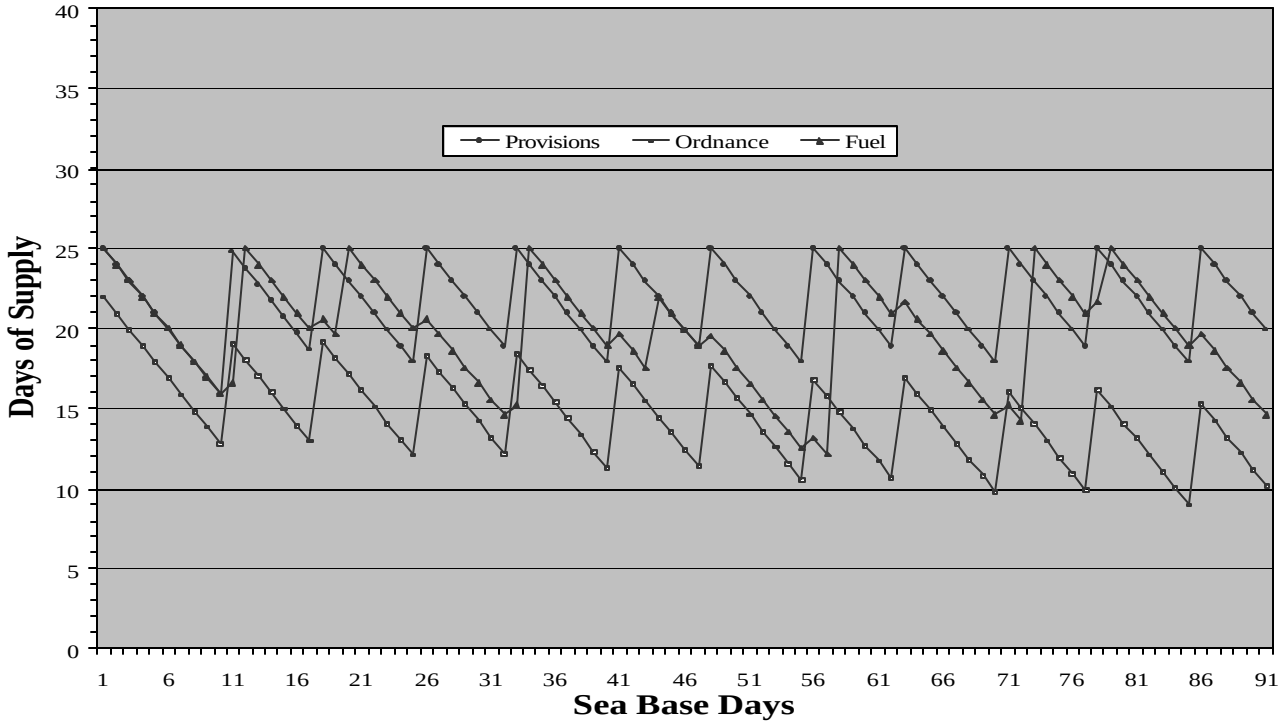

Figure 16. Iran, Two T-AKEs & One T-AO, Surge Consumption Rate

As displayed in the graphs for the Iranian scenario, two MPF variant shuttles are unable to maintain surge requirements above 15-DOS levels, exhibiting significant inventory deficiencies in fuel. Regarding the T-AKE cargo alternative, two ships are able to maintain standard consumption levels; however, similar to the Philippine Islands scenario, three T-AKEs are required to fully maintain commodity levels above 15-DOS with surge rates (Figure 17).

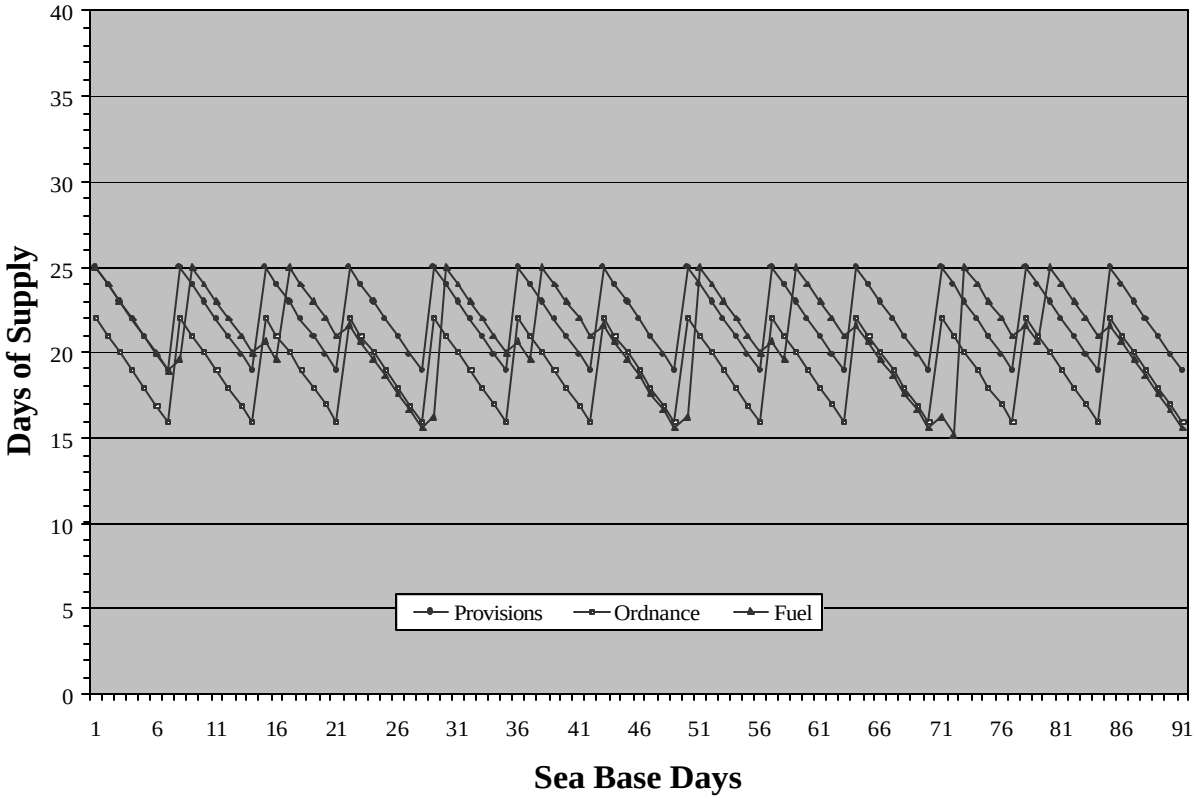

Figure 17. Iran, Three T-AKEs & One T-AO, Surge Consumption Rate

D. THE NIGERIAN SCENARIO

The Nigerian sea base scenario presents the most challenging cases for the resupply shuttles. The FLS distance of 3,500 nm results in shuttle ships being away from the sea base for 16 to 17 days for resupply. This is far too much for a single MPF shuttle to overcome for even the lower standard consumption rate. For the two MPF shuttle case using both standard and surge rates (Figures 18 and 19), all three commodities drop significantly below the 10-DOS requirement during the shuttles' transition to resupply duties. The extreme amount of decrease, in addition to the follow-on fuel difficulties, make this an infeasible alternative.

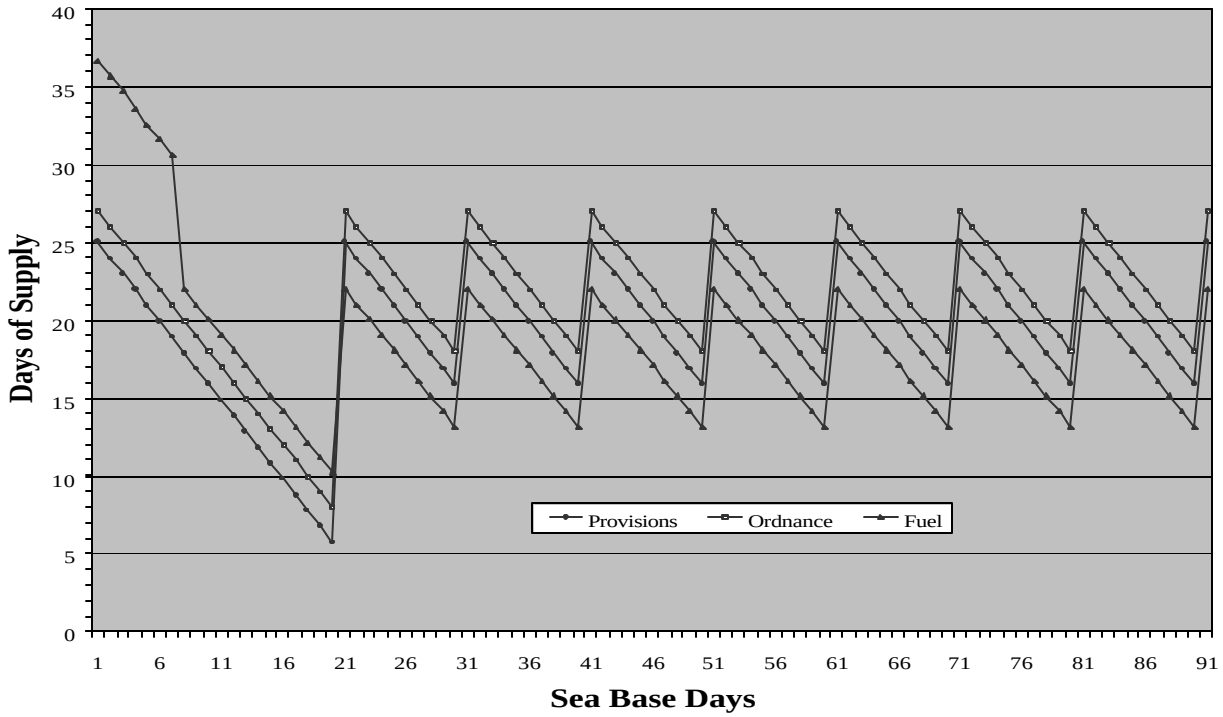

Figure 18. Nigeria, MPF Variant, Two Ships, Standard Consumption Rate

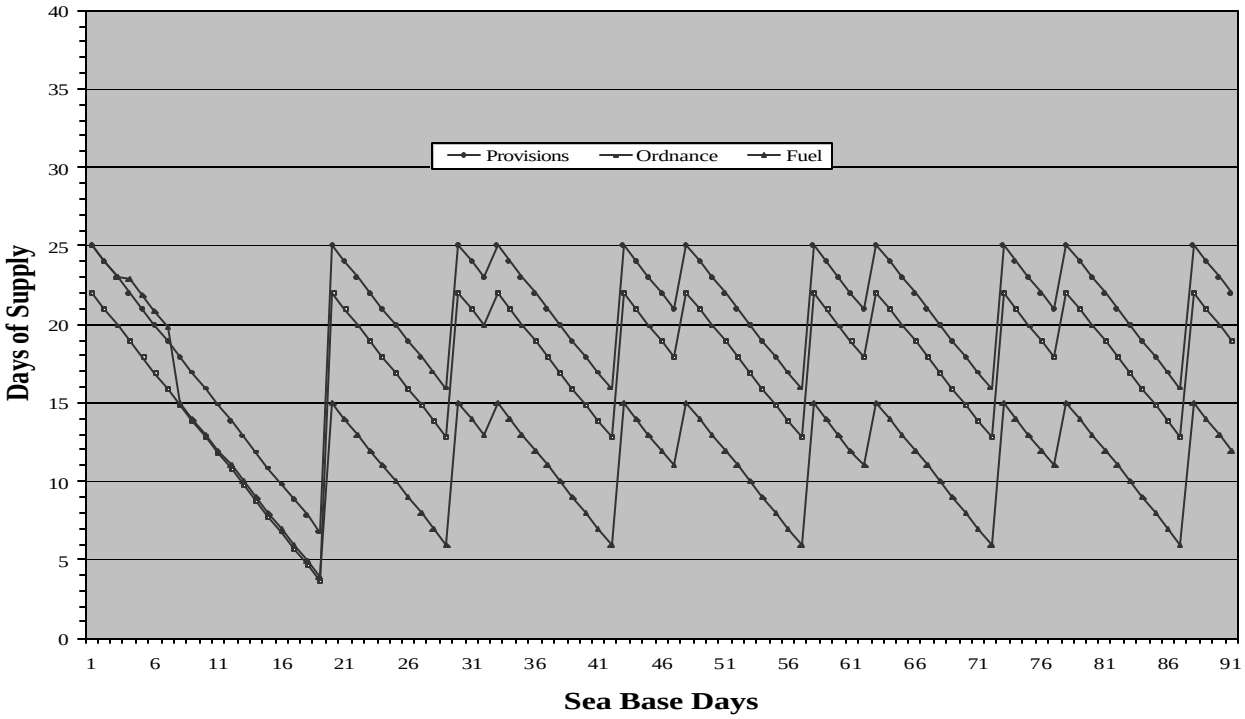

Figure 19. Nigeria, MPF Variant, Two Ships, Surge Consumption Rate

Except for two separate two-day periods, two T-AKEs and one T-AO are able to maintain all standard-rate commodities for the 90-day period; however, the T-AKEs cannot overcome a downward trend in ordnance stocks (Figure 20).

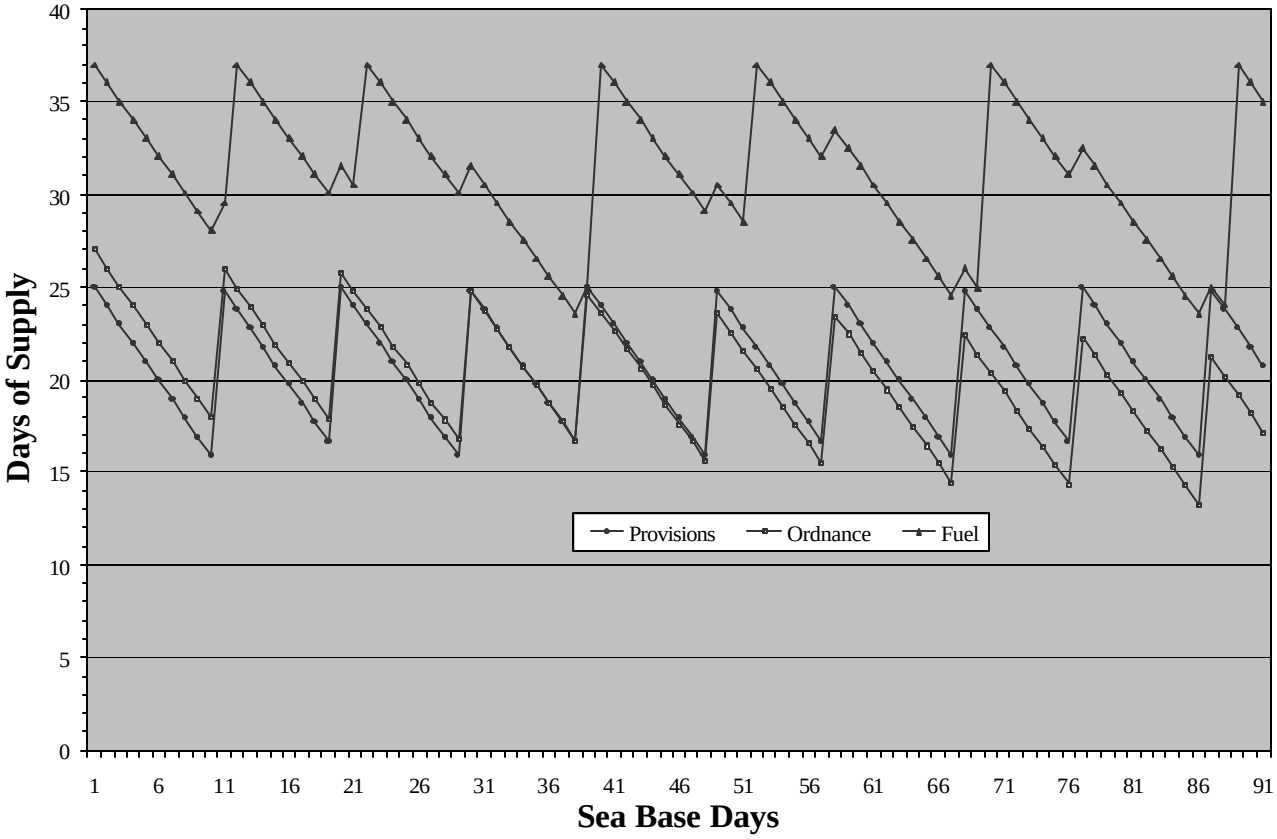

Figure 20. Nigeria, Two T-AKEs & One T-AO, Standard Consumption Rate

Figure 21 demonstrates the surge-rate ordnance shortcomings of two T-AKEs and one T-AO in this difficult scenario. The limited cargo capacity of the T-AKEs, as compared to the MPF variant, is not able to overcome the extreme transit distances to the FLS. Additionally, fuel levels routinely fall below the 15- and 10-DOS levels.

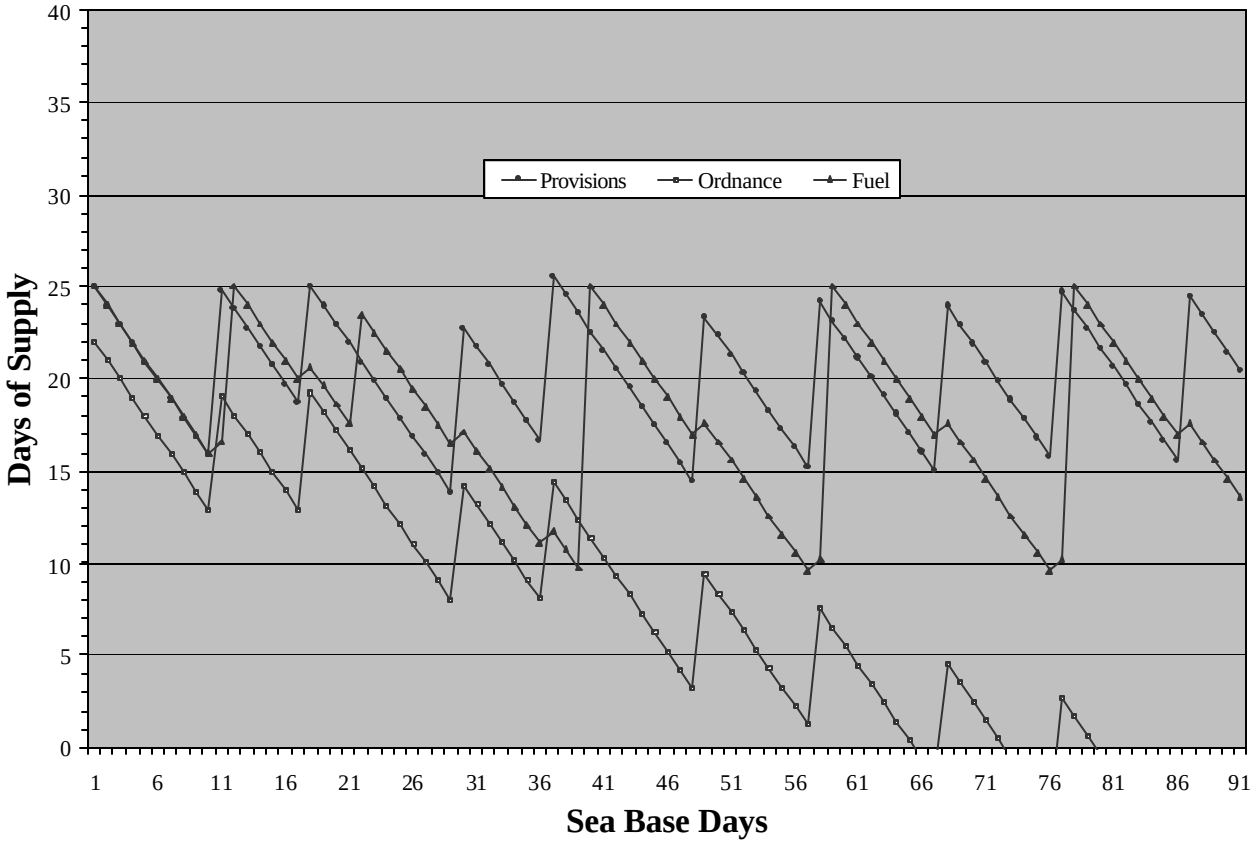

Figure 21. Nigeria, Two T-AKEs & One T-AO, Surge Consumption Rate

Adding a third T-AKE and a second T-AO to the scenario drastically improve the surge-rate commodity levels. As shown in Figure 22, provisions, ordnance and fuel stock levels are maintained above the 15-DOS level throughout the entire analysis period.

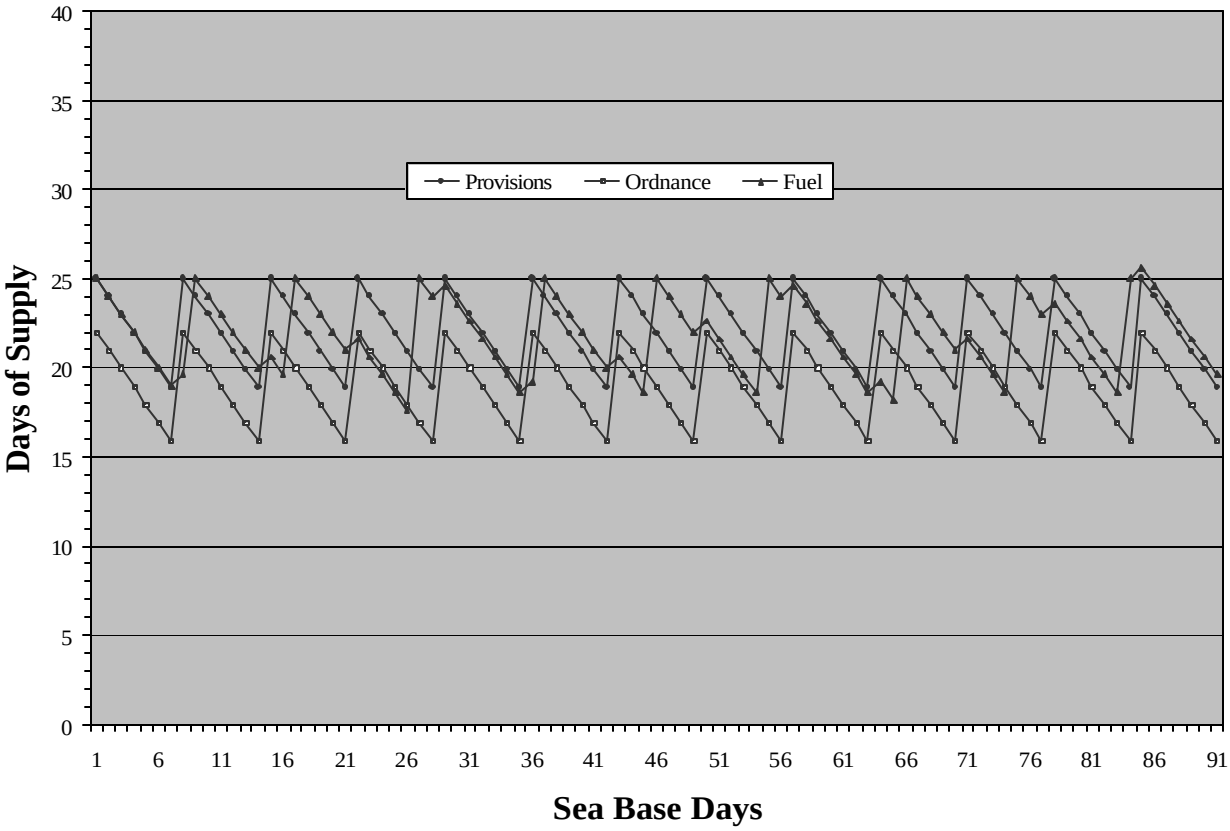

Figure 22. Nigeria, Three T-AKEs & Two T-AOs, Surge Consumption Rate

A resupply system combining the two shuttle alternatives was analyzed. Figure 23 displays the commodity levels that are sustained by a combination of one MPF variant, one T-AKE, and one T-AO while expending supplies at the surge consumption rate.

The MPF variant adds approximately one-half of a T-AO-equivalent of fuel to the resupply system, in addition to the equivalent of three T-AKE's worth of provisions and ordnance. As is seen in Figure 23, fuel levels are no longer an issue, but the MPF and T-AKE combination does not perform as well as three T-AKEs for provisions and ammunition sustainment. This is due to the gaps in resupply ship presence at the sea base because of the 3500 nm transit distance. Three resupply ships provide more consistent presence at the sea base than two ships, even though one of the two ships is the much larger MPF variant.

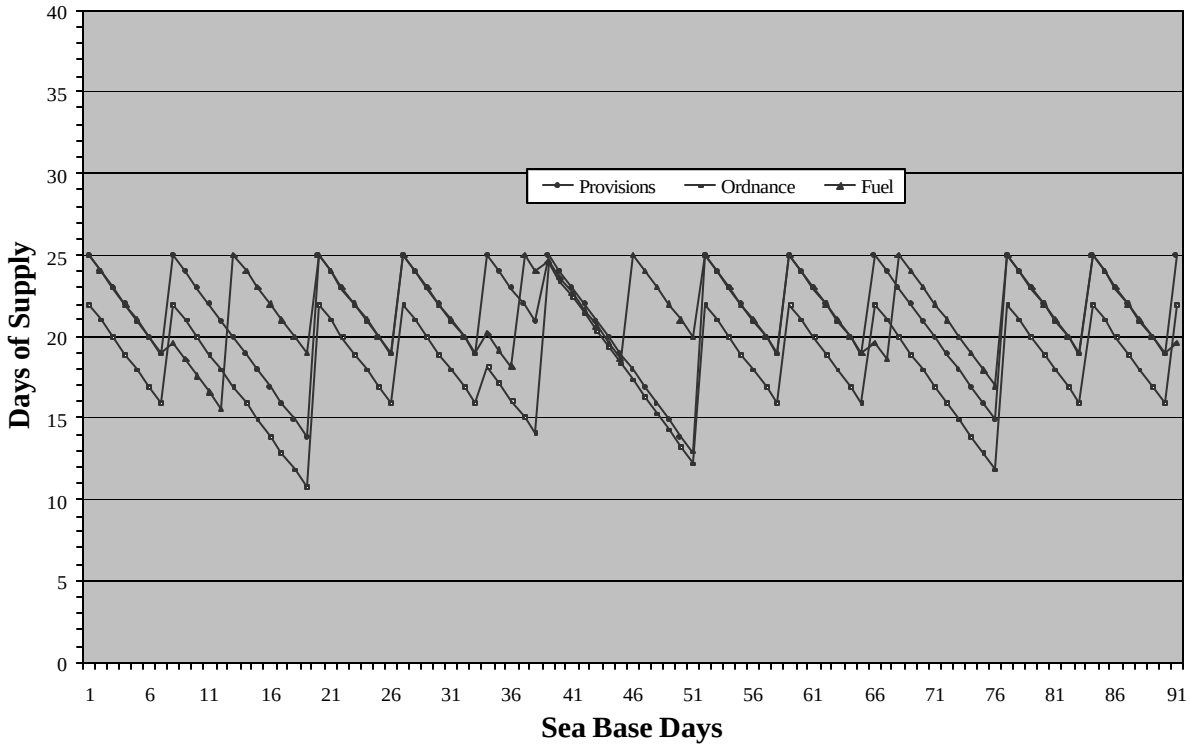

Figure 23. Nigeria, One MPF & One T-AKE & One T-AO, Surge Consumption Rate

E. GENERAL FINDINGS

While the resupply system of two MPF variant shuttles is able to maintain long-term standard-consumption sustainment in most cases with minimal difficulty, inventory problems exist in most cases involving surge consumption requirements. Additionally, recurring deficiencies of all three commodities are observed after the shuttle ships have offloaded their initial three-day sustainment supply at the sea base and transit to the FLS for the first resupply evolution.

The large capacity of the MPF shuttle results in a superior cargo handling advantage over the T-AKE/T-AO combination. The ability to receive twenty-foot containers at the FLS coupled with the increased size enable the MPF shuttle to onload three times the dry cargo of the T-AKE in one-third less time. Considering the FLS load rates stated in Chapter III, the T-AKE will take three days to completely reload with palletized cargo, while the MPF shuttle will depart the FLS fully loaded in only two days.

Beginning with the 2500 nm scenario, two T-AKEs experience great difficulty maintaining ammunition levels. While the two-T-AKE/T-AO combination is able to sustain food and fuel with some difficulty, three T-AKEs are required to keep up with surge ammunition expenditure rates.

F. RESUPPLY ALTERNATIVE PERFORMANCE SYNOPSIS

In order to evaluate one resupply alternative against another, Table 11 provides a synopsis of how each shuttle performed within each scenario. As a standardized scoring convention, categorical grades of "Good", "Fair", and "Poor" are be assigned for performance in sustaining each commodity based upon the following criteria:

- A score of "Good" will be assigned if the resupply alternative is able to fully maintain sea base commodities above all theater safety stock levels, or any occasional decreases in inventory below 15-DOS for no more than four days.
- A system will be graded as "Fair" if it is able to adequately maintain levels with occasional periods of inventory below 15-DOS for no more than 6 days or below 10-DOS for no more than 2 days.
- "Poor" systems will be those that consistently maintain inventories within the 15- or 10-DOS levels, or those that reflect an overall downward trend in commodity inventory.
- A grade of "Fair/Good" or "Poor/Good" may apply for MPF variant cases reflecting a score for the initial decrease in inventory while the ship reverts to its shuttle responsibilities and a separate score to reflect the shuttles ability to sustain long-term inventories.
- A system with an entry of "NA" was not analyzed due to obvious, intuitive shortcomings.

Scenario	Resupply Alternative		Commodities		
			Provisions	Ordnance	Fuel
Philippines	One MPF Variant	Standard	Good	Good	Good
		Surge	Good	Fair	Poor
	Two MPF Variant	Standard	Good	Good	Good
		Surge	Good	Good	Poor
	One T-AKE & One T-AO	Standard	Poor	Poor	Good
		Surge	Poor	Poor	Fair
	Two T-AKE & One T-AO	Standard	Good	Good	Good
		Surge	Good	Fair	Good
	Three T-AKE & One T-AO	Standard	Good	Good	Good
		Surge	Good	Good	Good
Iran	One MPF Variant	Standard	Fair	Good	Good
		Surge	Poor	Poor	Poor
	Two MPF Variant	Standard	Fair/Good	Fair/Good	Good
		Surge	Fair/Good	Poor/Good	Poor
	One T-AKE & One T-AO	Standard	NA	NA	NA
		Surge	NA	NA	NA
	Two T-AKE & One T-AO	Standard	Good	Good	Good
		Surge	Good	Poor	Good
	Three T-AKE & One T-AO	Standard	Good	Good	Good
		Surge	Good	Good	Good
Nigeria	One MPF Variant	Standard	Poor	Fair	Good
		Surge	Poor	Poor	Poor
	Two MPF Variant	Standard	Fair/Good	Poor/Good	Fair
		Surge	Fair/Good	Poor/Fair	Poor
	One T-AKE & One T-AO	Standard	NA	NA	NA
		Surge	NA	NA	NA
	Two T-AKE & One T-AO	Standard	Good	Poor	Good
		Surge	Good	Poor	Poor
	Three T-AKE & One T-AO	Standard	Good	Good	Good
		Surge	Good	Good	Good
	One MPF, One T-AKE, & One T-AO	Standard	Good	Good	Good
		Surge	Good	Good	Good

Table 11. Performance of Resupply Alternatives

V. CONCLUSIONS

A. OVERVIEW

This thesis has established the need for replenishment to occur at the sea base to prevent commodities inventories from being reduced below theater safety stock levels; furthermore, it was established that no existing system is capable of fulfilling this requirement. Two possible alternatives to meet the resupply requirement were introduced and analyzed.

In order to analyze alternative resupply shuttles that will be used to deliver sustainment supplies from the FLS to the sea base in future OMFTS-style amphibious operations, this thesis has developed the Sea Base Inventory and Resupply Model. This analysis is built upon three different geographic scenarios and incorporates proposed MPF(F) cargo inventories, expected rates of commodity consumption, and different resupply ship possibilities. This comparison and evaluation of the two alternatives provides an indication of how an analysis could be conducted for any further resupply possibilities that should arise.

Table 11 in Chapter IV is a compilation of how each resupply alternative performed with regards to maintaining safety stock levels. From the model analysis, several enlightening observations may be made regarding the type of logistics support and resupply system that will be required to sustain sea-based Marine Corps forces.

- Significant design factors and overall sea base inventory issues could adversely impact the ability of MPF(F) ships to serve as resupply shuttles. While their size is definitely a benefit, the sea base may not be able to handle the loss of warehouse space and on-station inventory.

- Assuming that the design issues can be overcome, two pre-designated and pre-configured MPF ships can effectively serve as shuttle ships; however, the major logistics hurdle within this option is the initial drop in sea base commodity inventories while the MPF ship converts to its shuttle mission and makes its first resupply run back to the FLS. This may be overcome by increased initial MPF(F) inventories, or by possibly teaming one T-

AKE with each MPSRON, similar to the case depicted by Figure 23 in Chapter IV.

- Based upon the current T-AKE design, three T-AKE ships would be required to sustain the provision and ammunition requirements of the sea base. Subject to the ability to procure sufficient numbers of T-AKE ships to support future MPF force requirements, the T-AKE/T-AO alternative may be the more attractive of the two possibilities considered.
- Logistics throughput time savings are realized by the containerization of supplies if the shuttle ships have the manning required to unstuff the containers and palletize the cargo.

B. RECOMMENDATIONS FOR FURTHER STUDIES

The Sea Base Inventory and Resupply Model used in this thesis is deterministic in nature. In order to provide more realism to the scenarios, some amount of randomness could be introduced into several of the model's variables (e.g. consumption rates, reload times at the FLS, and transit times). Additionally, the model could be expanded to include other logistics support items which would likely flow into theater as part of indefinite sustainment, such as spare parts and replacement rolling stock. These modifications to the current model may provide a more detailed and robust analysis of the FLS-to-sea base phase of the factory-to-foxhole network, which was described in Chapter II.

A joint aspect can be introduced with the addition of U.S. Army logistics requirements. This would lend itself to longer operations ashore, which may or may not be supported from a sea base.

In addition to this and any future FLS-to-Sea Base studies, the first two phases of the resupply network will require analysis as to how USTRANSCOM will support sea base operations from CONUS. Containerization, in-transit visibility, and the ability to rapidly activate the sea base logistics support network will be necessary hurdles to

overcome prior to the full operational implementation of Operational Maneuver From the Sea and Sea-Based Logistics.

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