XIX. EFFECT OF SPEED OF PLATFORMS ON LOGISTICS AND WARFIGHTING (AN EXPLORATION OF HIGH SPEED VESSEL FEASIBILITY IN THE LOGISTICS ROLE)

A. INTRODUCTION

Among the excursions addressed by the OPNAV Tasker are two key concerns on the effects of speed of platforms on both logistics and war fighting. Particularly, there is an interest in the exploration of High Speed Vessel (HSV) types of high-speed platforms in the context of emerging operational concepts as reflected in the Maritime Vision, the Naval Operational Concept, and various supporting CONOPS. This chapter aims to address the effect of speed within the framework of the ExWar studies, by firstly, identifying and prioritizing the criticality of speed at various phases of the expeditionary operations, followed by an investigation on the limitations of current platforms, based on capability perspective. The HSV will then be used for comparison and feasibility studies to address these limitations. The studies will be both qualitative and quantitative; qualitatively based on researched data matching against definitions of ExWar system architectures, and quantitatively through the examination of Architectural, Operational and Environmental factors. Architecturally, to appraise the issues of payload, cost and speed of platforms; Operationally, to address the need of speed within the framework of specific scenarios; and Environmentally, identifying the any possible external factors affecting the studies. Collectively, Operational Analysis techniques and Modeling Analysis will be employed to analyze and provide appropriate findings and recommendations for the study.

B. SPEED-CRITICAL AREAS IN EXPEDITIONARY WARFARE

Possessing speed as an ability to respond promptly to any arising crisis is a value-added capability in the conduct of ExWar. There are several areas in ExWar where speed is critical to the success of the expeditionary operations. By examining the various distinctive phases of the expeditionary operations, several key areas of prominence have been identified to be speed-critical. Below are the 4 key speed-critical areas identified:

1. Equipment / Logistics Transfer
2. Mine Warfare
3. Special Operations
4. Other operations

1. Equipment / Logistics Transfer

In the Current architecture, 6 Maritime Prepositioning Ships (MPS) of the MPF transfer the initial load of equipment and supplies from the Offshore Base to the Sea Base. This load is capable of sustaining the Marines for 30 days of operation. Subsequent re-supplies from CONUS to the Sea Base are ferried by either the Fast Sealift Ships (FSS) or other commercial carriers. In the Planned architecture, the initial transfer from the offshore base to the location of the planned Sea Base is executed by the MPF(F) ships, which may then form the Sea Base. FSS transfer subsequent re-supplies from CONUS to the Sea Base formed. The logistics transfer concept for the Conceptual architecture is similar to that for the planned architecture except that 3 ExWar Logistics Ships (XLS) will replace the 6 MPS. The MPS and XLS all travel at an average speed of 15 knots while the FSS travels at an average speed of 27 knots. Apparently, in this particular aspect of the expeditionary operations, speed plays a key role in the success of the over logistical supply cycle and hence the overall operations.

2. Mine Warfare

Mine Warfare is an essential warfare capability integral to the ability of naval forces to open and maintain sea-lanes of communication and to dominate the littoral battle space. The Navy plans to deploy its new semi-submersible mine hunter, the Remote Mine hunting System (RMS) onboard destroyers in the near future to provide battle groups with organic MCM capabilities (National Defense Magazine 2002). However the mine-hunting equipment takes up too much space and labor, draining resources from combat functions. It is also too cumbersome and expensive to take equipment and people that may not be needed. In addition, dedicated ships have traditionally conducted the minesweeping and hunting missions. In the pursuit for a new independent sea platform to conduct such mine hunting/ sweeping operations with higher mobility and less dependence on other war fighting ships, the element of speed plays a key role in achieving the goal of higher mobility and operational success.

3. Special Operations

Special Operations (SO) is a form of warfare characterized by a unique set of objectives, weapons, and forces. A mission, under a certain set of environmental constraints, may require the application of Special Operations skills and techniques. The five principal missions for Special Operations are unconventional warfare, direct action, special reconnaissance, foreign internal defense, and counterterrorism (JP 3-05 Doctrine for Joint Special Operations). Specifically, the Navy utilizes SEAL teams, SEAL Delivery Vehicle (SDV) teams, Advanced SEAL Delivery Systems (ASDS) teams, and Special Boat Units (SBU) to conduct some or all of the above operations. Invariably, the conduct of any special operations will require the covert insertion and subsequent extraction of special operation forces into and out of a hostile environment. Speed in this case is inevitably a force multiplier to achieving operational success as well.

4. Other Operations

Other operations including Intra-theater troop lift and Casualty Evacuation are critical areas that can be examined for evaluation on the effect of speed over relatively shorter distances. Understandably, the effect of speed has a significant impact on the rate of transfer of troops within theater of operations for strategic/tactical maneuvers. The evacuation of casualty with speed within theater to Sea Based hospital ship may also be a viable alternative, relieving the aircrafts for other combat missions.

C. POSSIBLE ROLES FOR HIGH SPEED VESSEL (HSV)

1. Equipment/Logistics Transfer Role

In the process of logistics supply/ re-supply for expeditionary operations though critical to the success of the operation, the initial deployment of the MPS or XLS to the Sea Base is not speed-critical as the Marines have 15 days of supplies with them when employed as part of Naval Expeditionary Strike Group (NESG) and normally these deployment are planned and executed prior to start of operations. The slower but larger MPS and MPF(F) ships will be able to transport much more than a smaller HSV. On the other hand, it is critical for subsequent re-supplies to the Sea Base to be expeditious in order to sustain the forces ashore beyond 30 days and up to 90 days of operation. This is where the high-speed characteristics of the HSV are investigated to be useful in the operation as a force multiplier.

An adequate number of HSV will provide a faster rate of transfer than the FSS. The fighting force ashore will then be able to receive any necessary supplies in the shortest possible time, eliminating any compromise or delay to the operation. If a faster rate of transfer is not required, the HSV, having accomplished the re-supply mission in a shorter time, will have more time to turnaround between missions. Subjectively, these extra times can be utilized for crew turnover, maintenance, servicing, and repair of the vessel, which will in turn enhance crew performance, higher availability, and hence operational readiness.

Although the HSV is structurally composed of lightweight metallic alloys like aluminum compared to steel for larger, heavy duty ships, its smaller size (harder to acquire) and higher agility may render it more survivable against targeting from threat aircraft and ships. However, instinctively, it will be less survivable against sea mines and close range, line of sight direct fires.

Logically, utilizing HSV implies the distribution of supplies from a larger ship to numerous smaller vessels. The destruction of a HSV will contribute loss in terms of supplies to only a small percentage as compared to the amount of supplies on one larger ship.

2. Mine Warfare Role

Another possible role for the HSV is in the conduct of mine warfare. The HSV can be employed as a surrogate command-and-control ship equipped with mine warfare systems. One would be assigned to each Navy battle group for countermine duties. The speed of the HSV allows it to be deployed to the Area of Operation in minimum time, ahead of the battle group it is supporting. At the Area of Operation, the MCM HSV will launch the UUV for mine hunting and neutralization, facilitating safe and uninterrupted operations for the arriving battle group. The higher payload capability of the HSV allows it to carry more UUV as compared to a similar speed mine-hunting helicopter. With its speed, maneuverability, and self-protection capabilities, the MCM HSV will be capable of ensuring its own survivability in the Area of Operation without dedicated protection assigned. After the MCM operations, the HSV will retrieve its UUVs and return to join up with the battle group, ready for subsequent operations. However, this aspect of the expeditionary operations will not be examined in details in this study.

3. Special Operations role

A HSV can be employed as a fast deployment platform used to launch and recover the various types of Special Operations crafts. The HSV will swiftly transport a number of Special Operations teams to their respective launch areas for insertion of the Special Operation Forces and their equipment into the Area of Operation. It will then return to safe waters and await orders to recovery the Special Operations crafts. A possible enhancement to operations is for the HSV to be built with stealth capability. Together with its high speed and maneuverability, this will enhance the survivability of the HSV. As an added advantage, utilizing the HSV as a common platform for multiple roles effectively simplifies the maintenance, spares and other logistics support requirements for the service support group. However, it must be noted that the HSV cannot be used to conduct submarine launched operations.

D. HIGH SPEED VESSEL (HSV) SPECIFICATIONS AND ASSUMPTIONS

The possibilities of high-speed sealift have been technologically challenged with the evolutions of high-speed ferries and sea crafts. However, the applications of these high-speed sea crafts are mostly for commercial purposes, with limited military operational applications thus far. For the purpose of the ExWar studies, the technical and operational specifications of a HSV; HSV-X1, designed by the Navy Warfare Development Command for concept development and experimentation purposes has been adopted. Modifying assumptions has been included to use it as baseline definitions for a typical High Speed Vessel. (For details, see http://www.nwdc.navy.mil/HSV/ConceptHSV.asp)

1. Technical Specifications

The Technical Specifications (Lumsden, 2002) of the HSV addressed in this report is obtained mainly from the specifications of the HSV-X1 prototype from Navy Warfare Development Command concept development effort. These adopted specifications are used to act as baseline identifications of a HSV in terms of physical characteristics and capabilities, especially in the areas of speed and payload.

a. Length Overall – 313.22 ft, beam – 87.27 ft
b. Full Load Displacement – 1872 ST (1700 LT), max draft – 13 ft
c. Deadweight Loaded Speed – 38 knots (full load),
    - Lightship Speed – 48 knots
d. Ramp: 35 tons
e. Helicopter capable: CH-46, MH/CH/SH-60
f. Small boat launch and recovery – 11m RHIB, HSAC
g. Aluminum construction, wave-piercing catamaran
h. Manning: 30
i. Cargo Deck: 28,740 sq. feet
j. Passenger capability Seating for 300 troops
k. Main Engines: 4 x Ruston 20RK280 diesel engines
l. Loading/Unloading time (Average): 2 hours.

m. Payload: 308 ST (275 LT)
n. Fuel Capacity: 532 ST (475 LT) or Approximately 156470 gal
o. Fuel Consumption: 52 gal/NM
p. Endurance Range: 600 NM (Full load) – 2 ways
1200 NM (Full load) – 1 way
3000 NM (Empty load) – 1 way

2. Operational Assumptions

a. The effective cruising speed of HSV is assumed to be operating at a sea state-3 for all references based on realistic operational environment.

b. The speed versus payload relationship is assumed to be linear, thus yielding an intermediate cruising speed of 43 knots for half-loaded HSV.

c. The HSV is able to carry all variety of loads and vehicles including M1A1 tanks limited only by the weight of the item to be transported.

d. The refueling of HSV is assumed to be conducted at 1000 NM interval by Strategic Refueler tankers at sea.

e. Refueling at sea for HSV is calculated to be 2 hours per refueling effort, includes timings for approach, set-up, refuel, disengage and pull off.

E. SETUP OF ANALYSIS ENVIRONMENT

The HSV defined above was equated in terms of its physical capabilities against a FSS and using an analysis methodology with certain simplifying assumptions.

There were two lines of re-supply in this study; one for re-supply from CONUS to the Sea Base, and the other for re-supply from the offshore base to the Sea Base. Two different ships were investigated – the FSS, T- AKR and the HSV, HSV-X1 Joint Venture. The study utilized two distinctive re-supply practices, and additionally, a variation of the second practice. The study determined the type and number of ships to be used in each re-supply line investigated, the maximum distance at which the HSV is effective, and recommends increases in speed and payload, and reduction in cost for the HSV to be cost effective. The 12 different runs arising are summarized below:

Factor	Level	Description
Re-Supply Line Distance	CONUS to Sea Base	7,037 NM
	Offshore Base to Sea Base	1,765 NM
Ship Type/ Payload (Full)	T-AKR	27 knots, 32,295 tons deadweight
	HSV	38 knots, 740 LT deadweight
Re-supply Practices	Min Dev Minimum deviation from initial inventory level	Re-supply a certain number of days of supply once that number of days of supplies are utilized at the Sea Base so that there is minimum deviation at the Sea Base; if there are 45 days of supplies at the onset, then there will be approximately 45 days of supply throughout the operation

	Min Reqt 30 At least 15 days of supplies at the end of the 90-day operation (with initial supply set at 30 days)	Re-supply schedule is set such that there will be at least 15 days of supply at the Sea Base at the end of the 90-day operation, with Sea Base having an initial supply of 30 days
	Min Reqt 45 At least 15 days of supplies at the end of the 90-day operation (with initial supply set at 45 days)	As above, except that Sea Base has an initial supply of 45 days

Table XIX-1: Summary of Analysis Environment Setup

Outputs from runs are the number of ships required to sustain the Marines utilizing the respective re-supply line and re-supply practice, and graphs of Days of Supply (DOS) versus days of operation.

F. UNDERLYING ASSUMPTIONS FOR SPREADSHEET MODEL AND ANALYSIS

The assumptions used in this analysis are stated below:

1. The specifications and assumptions of the HSV stated above are key and were adopted for the purpose of this study.

2. The assumptions for the FSS were focused on following relevant attributes that were obtained from the technical specifications of the T-AKR, i.e. the Operational Speed, Payload capacity, loading/unloading time etc.

a. Deadweight Loaded Speed – 27 knots (full load)

b. Deadweight - 32,295 short tons

c. Loading/Unloading Time –2 days/ 3 days.

d. Refueling Time – 1 day (can be refueled concurrently during loading/unloading process).

e. Endurance Range – able to sustain without refueling for single way trip for the particular scenario investigated.

3. Deadweight is the difference between the Full Displacement and the Light Displacement, which represents the carry capacity of the ship. In this study, deadweight is comprehended to be parallel to actual Payload, and is applied consistently for effective Payload Transferred comparison; ships and vessels of various sizes and displacements are assumed to maintain a constant proportionality in term of Deadweight to Full Displacement ratio for effective ship hull designs.

4. The HSV and FSS were assumed to be always operating at Full Payload capacity in order to allow the study to investigate the maximum through put of the entire re-supply cycle.

5. The unit of measurement for Payload Transferred is defined as the DOS, amalgamating all different types of logistics supplies including food, water, fuel and equipments etc. that are required for sustaining the expeditionary operations.

6. The quantity of DOS transported by the ships investigated in this study was computed from the DOS load transported by the 6 MPF ships (assuming the payload is equally distributed among 6 MPF ships of similar or same specifications) and the deadweight of a MPF ship were compared in proportion to the FSS and HSV to derive at the following payload capacity assumptions:

a. Payload of 6 MPF ship = 30 DOS,

b. Payload of 1 MPF ship = 5 DOS,

c. Deadweight of 1 MPF ship = 21,411 ST,

d. Deadweight of 1 FSS = 32,295 ST,

e. Proportionally, 1 FSS carries = 32,295/ 21,411 x 5 DOS

˜ 7.5 DOS

f. Deadweight of 1 HSV = 815 ST

g. Proportionally, 1 HSV carries = 815/ 21,411 x 5 DOS

˜ 0.19 DOS

7. There are two points where the re-supply cycle originates and continues in this study, i.e. CONUS and Offshore Base. The respective distances between these two points and the Sea Base allowed an investigation on the effect of speed of the different ships for both long and shorter distances. In the scenario adopted, the distance between CONUS and Sea Base was computed to be 7037 NM, while the distance between Offshore Base and Sea Base was 1765 NM.

8. The life cycle cost of a FSS (T-AKR) is estimated by analogy to be 1.5 times that of a similar ship class of T-AKE for which information is readily available. The life cycle cost of the FSS (T-AKR) is essentially, 1.5 x (336 + 361)/2 = $525 million (FY02$).

9. The life cycle cost of the HSV-X1 is not available at the point of study, however, an estimation based on the development and acquisition costs for a militarized vessel published by Navy Warfare Development Command derive an approximate cost of $ 85 million (FY02$) per HSV. Essentially, the cost ratio of HSV to FSS is 6:1.

10. The loading/unloading and at-sea refueling of a HSV was aggregated to a total of a one day period during each re-supply cycle for a more consolidated accounting of time lapsed. The FSS loading/unloading/refueling time was stated in the assumptions made earlier.

11. The total storage capacity of the Sea Base was capped at what it initially came with, i.e. either 30 days or 45 days depending on the factor investigated. This

limitation in storage space constrainted the re-supply ships to re-supply the Sea Base up to a certain maximum level before next replenishment was called for.

12. The period of operations for investigation in this study was assumed to be 90 days. This was to allow the initial supply available to be re-supplied at least one cycle for initial 45 days supply and two cycles for initial 30 days supply scenarios. The Follow-On Forces are also expected to move in after 90 days.

13. The study assumed a constant threat level common to all ship types, thus no attrition is modeled in the study for the effect of speed, but was addressed subsequently by the Survivability studies discussed separately.

G. METHODOLOGY OF ANALYSIS

The methodology adopted to evaluate the effects of speed on FSS and HSV for equipment and logistics transfer, was largely based on the set up of the analysis environment mentioned above. This methodology aimed to answer the inter-relationship between Speed with Payload, Speed with Cost, and Speed with types of Re-supply practices. The entire analysis anchors on a scheduling model emulating the ships activities in the re-supply cycle against a running timeline with varying ship types carrying respective payload capacity, with different distances and re-supply practices. The three re-supply practices are as mentioned in the set up for analysis environment, firstly, the Minimum Deviation (Min Dev) practice, where the inventory level of the Sea Base is to be maintained at minimum deviation from the initial supplied level to maintain an extremely high level of logistics readiness. Secondly, the Minimum Requirement from 30 days of initial supply (Min Reqt 30), where the Sea Base are to maintain minimum stockpile or safe inventory level of 15 days throughout the said period of operations from a 30 days of initial logistics supply. Thirdly, the Minimum requirement from 45 days of initial supply (Min Reqt 45) is similar to the former except that it has 45 days of initial logistics supply.

Quantitative findings in terms of number of ships required to complete the mission, and effective operational speed required were generated from the interactions of the factors accounted for. A spreadsheet model integrating the findings from the time line analysis was designed to determine the optimal number of HSVs required, and the optimal period between re-supply runs, to derive the interactions between number of HSV versus time, distance and payload transferred.

Essentially, the two salient methodological approaches towards analyzing the outcome of the replenishment model, were firstly, Equal Payload Transferred, and secondly, Equal Cost Comparison methods.

1. Equal Payload Transferred

The Equal Payload Transferred methodology here examines the characteristics of two different types of ships by the equivalent load of equipment and supplies transferred over same distance. The FSS equivalent was compared to that of the HSV in order to determine the number of HSVs required to transfer an equivalent load of equipment and supplies over designated distances. The scheduling model based on a timeline analysis were used to determine the number of FSS or HSV required for an indefinite re-supply run or to meet a specific safe inventory requirement at the destination within the stipulated timeframe for an operation. The high-speed and versatile features of the HSV versus the high capacity of the FSS were the point of investigation. This methodology aimed to evaluate and propose the optimal operational speed, payload and distance for the HSV and the trade-offs when compared with the FSS. Specifically, this methodology attempted to address the following issues:

a. Computation of the number of vessels for each ship type to complete the re-supply mission within the 90-day period and a proposed ratio between the numbers of two types of ships to complete the same mission with equal payload transferred.

b. Recommendation on the ratio for numbers of operating HSV/FSS at various distances.

2. Equal Cost Comparison

The Equal Cost Comparison methodology compared the cost of the number of HSVs required to transfer an equivalent load transferred by a FSS. This methodology aimed to examine the relationship between the costs of total number of HSVs required to achieve the same payload capacity required of a FSS against factors like distance, payload and speed. Specifically, this methodology addressed the following issues:

a. Recommendation on the maximum distance that a HSV should operate to be cost effective based on comparison with operating a FSS.

b. Proposal on the speed required of a HSV to meet the initial equal cost ratio of 6:1, based on current costs and recommended distances.

c. Proposal on the payload capacity required of a HSV to meet the initial equal cost ratio of 6:1 based on current costs and recommended distances.

H. RESULTS FROM ANALYSIS

The results from the 12 runs are presented in this section, together with the associated analysis and recommendations.

1. From Offshore Base to Sea Base

a. T-AKR/Fast Sealift Ship (FSS)

Each FSS is capable of carrying 7.5 DOS. All three re-supply practices (Min Dev, Min Reqt 30, and Min Reqt 45) require two FSSs to sustain the Sea Base for 90 days. However, the FSS in Min Reqt 45 is required to make the smallest number of runs and have the largest number of rest days between runs. On the contrary, the FSSs in Min Dev make the most runs and have the fewest rest days between runs. The plots of DOS versus Time for FSS are shown in the figures below.

Figure XIX-1 shows the plot when the Min Dev re-supply practice is used, and supplies are kept as close to, but not exceeding, 45 days as possible during the 90-day period. This is achieved by re-supplying the Sea Base with one FSS (7.5 DOS) on every 7th or 8th day. Figures XIX-2 and XIX-3 show the plot when the Min Reqt 30 and Min Reqt 45 re-supply practices are used respectively. In these two cases, the supply level starts at an initial value of 30 or 45 DOS and gradually drops to as close to, and higher than, 15 days of supply as possible at the 90th day. In general, these two practices either require fewer ships, less runs or allow more rest days.

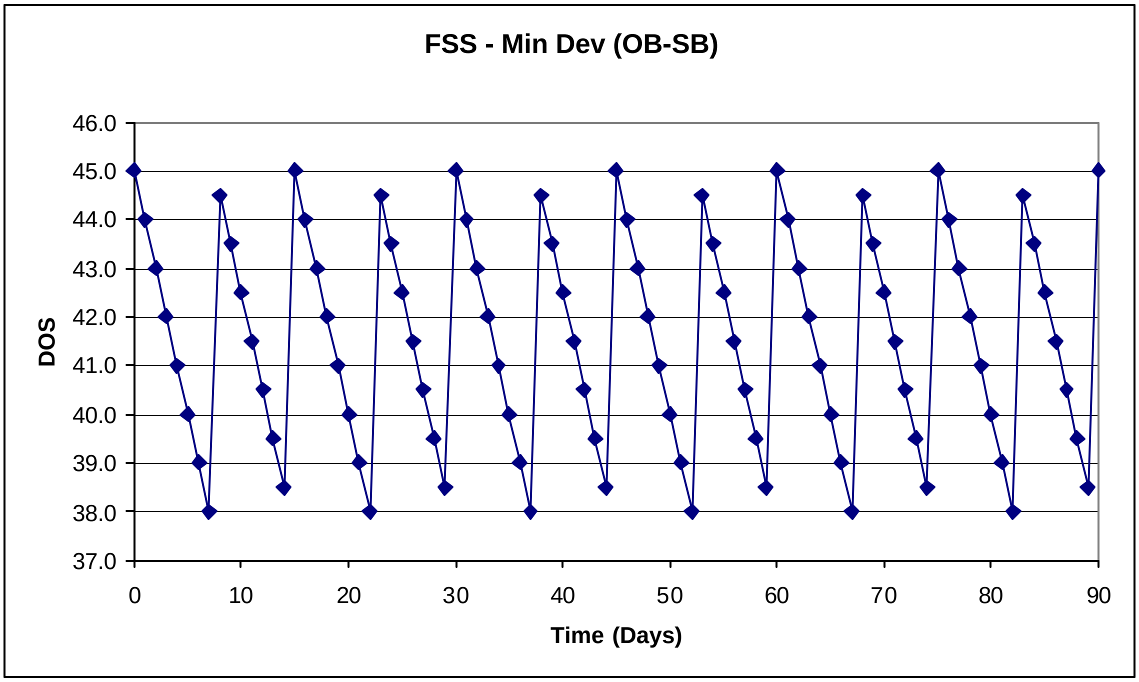

Figure XIX-1: Plot of DOS versus Time for FSS in Min Dev Re-supplying from Offshore Base to Sea Base (2 FSS required)

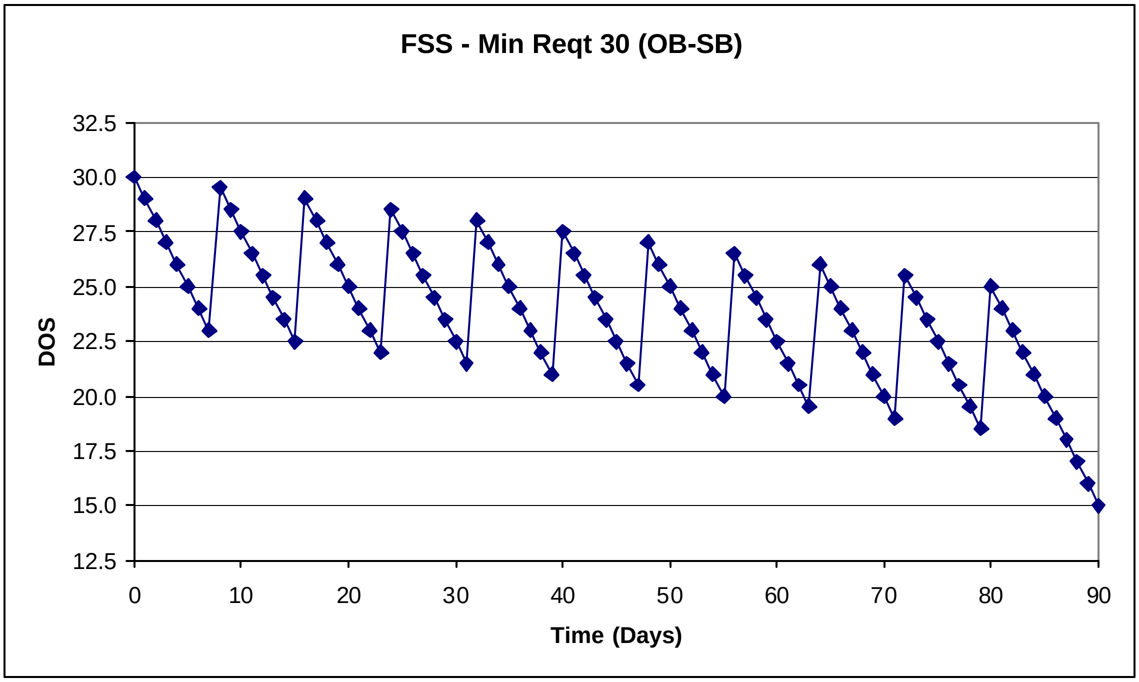

Figure XIX-2: Plot of DOS versus Time for FSS in Min Reqt 30 Re-supplying from Offshore Base to Sea Base (2 FSS required)

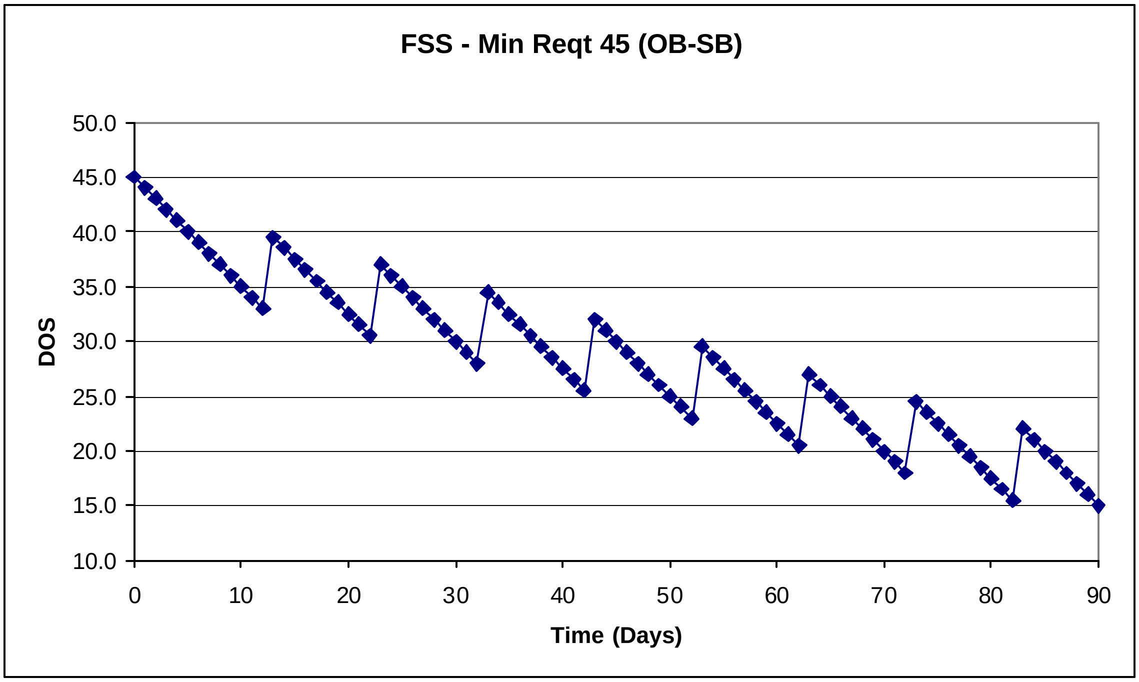

Figure XIX-3: Plot of DOS versus Time for FSS in Min Reqt 45 Re-supplying from Offshore Base to Sea Base (2 FSS required)

b. HSV Squadron

The HSVs are grouped into squadrons of 12, with each squadron capable of carrying 2.3 days of supply. The number of HSVs required is rounded up to a squadron size force for this portion of the study. The Min Dev re-supply practice requires the largest number of HSVs to sustain the Sea Base for 90 days: 3 squadrons or 36 HSVs. The Min Reqt 30 and Min Reqt 45 re-supply practices both require 24 HSVs. However, the HSVs in Min Reqt 45 are required to make fewer runs and have more rest days in between runs. The plots of DOS versus Time for HSV are shown as follow:

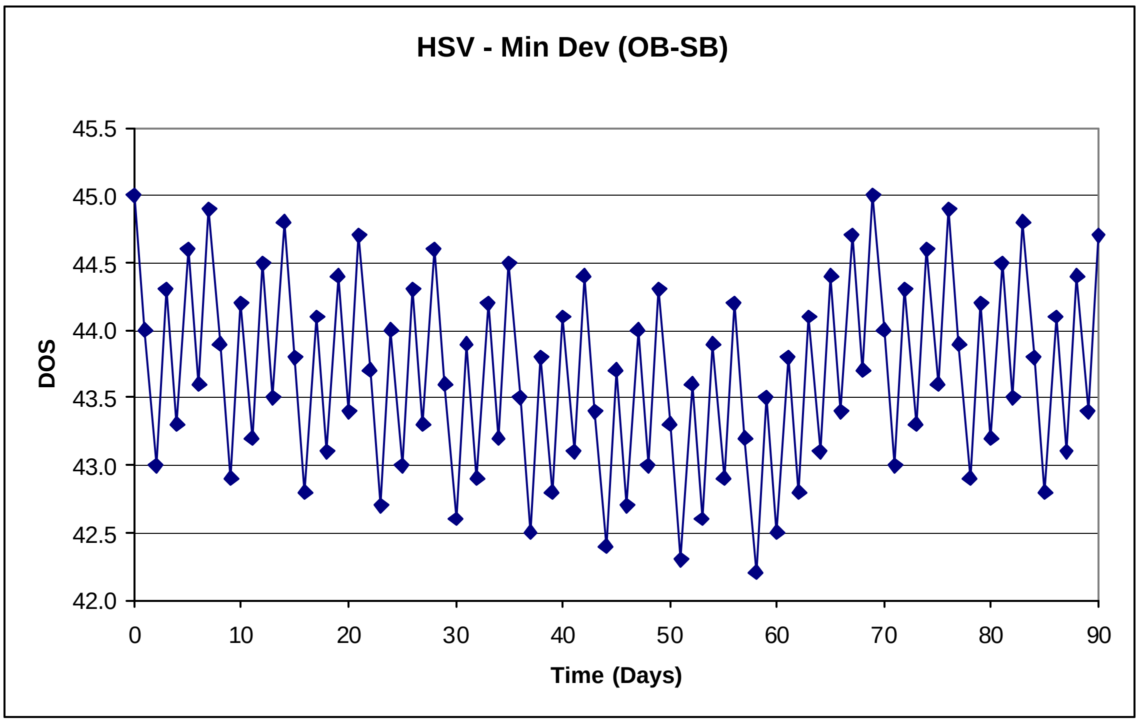

Figure XIX-4: Plot of DOS versus Time for HSV in Min Dev Re-supplying from Offshore Base to Sea Base (36 HSVs required)

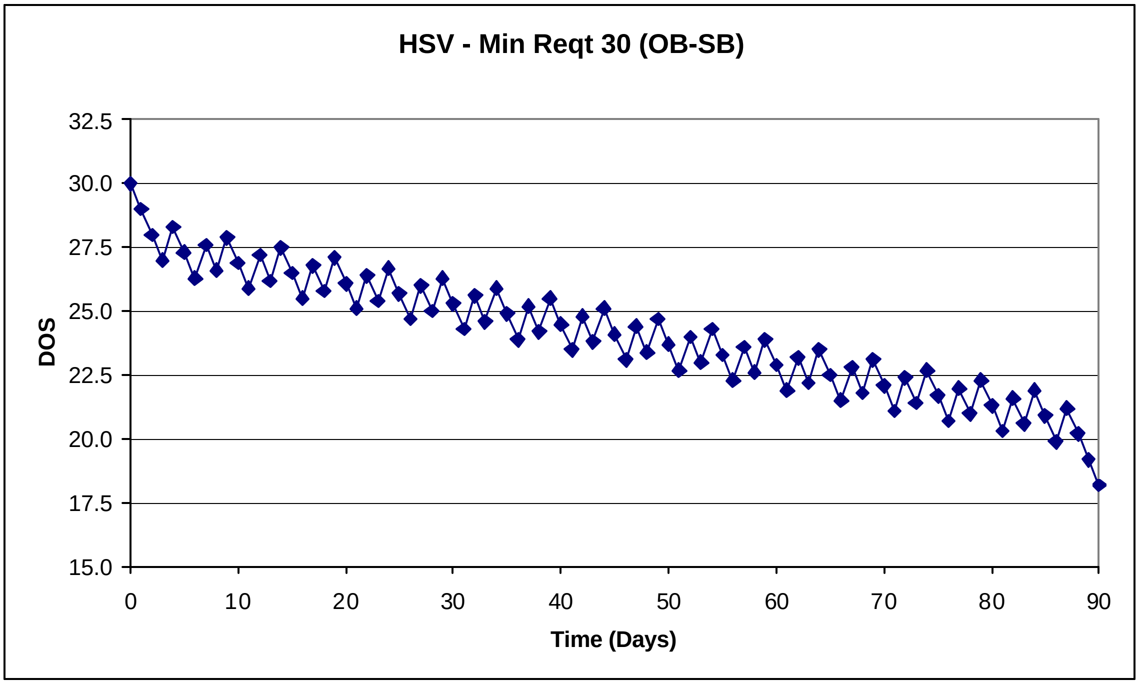

Figure XIX-5: Plot of DOS versus Time for HSV in Min Reqt 30 Re-supplying from Offshore Base to Sea Base (24 HSVs required)

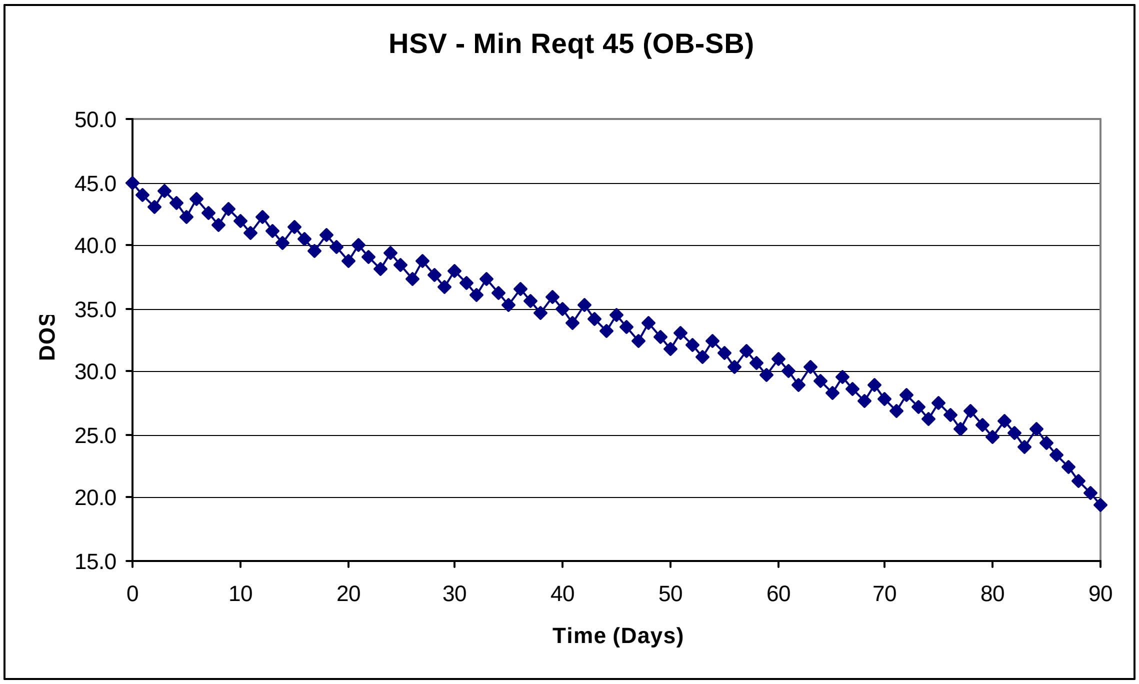

Figure XIX-6: Plot of DOS versus Time for HSV in Min Reqt 45 Re-supplying from Offshore Base to Sea Base (24 HSVs required)

b. Cost Comparison

The cost of one FSS is estimated to be equivalent to the cost of 6 HSVs. The number of HSVs required in Min Dev is three times more than the number of equal cost HSVs available. The numbers of HSVs required in Min Reqt 30 and Min Reqt 45 are two times more than the number of equal cost HSVs available. The results are summarized in the table below:

	Min Dev		Min Reqt 30		Min Reqt 45	
	FSS	HSV	FSS	HSV	FSS	HSV
Number of Ships Required	2	36	2	24	2	24
Number of Runs per Ship	6	13	5	17	4	14
Rest Day between Runs	4	2	5	0	9	1
Number of Equal Cost HSVs Available	12		12		12	
Ratio of HSV to FSS	18:1		12:1		12:1	
Number of Times Over Cost	3		2		2	

Table XIX-2: Summary Table for Re-supply from Offshore Base to Sea Base

2. From CONUS to Sea Base

a. T-AKR/Fast Sealift Ship (FSS)

The Min Dev and Min Reqt 30 re-supply practices both require the same number of FSSs in order to sustain the Sea Base for 90 days. However, the FSSs in Min Reqt 30 make slightly fewer runs and have more rest days between runs. In fact, the FSSs in Min Reqt 30 make the smallest number of runs and have the most number of rest days. Min Reqt 45 requires only three FSS and has the same number of runs and rest days as Min Dev. The plots of DOS versus Time for FSS are shown as follows:

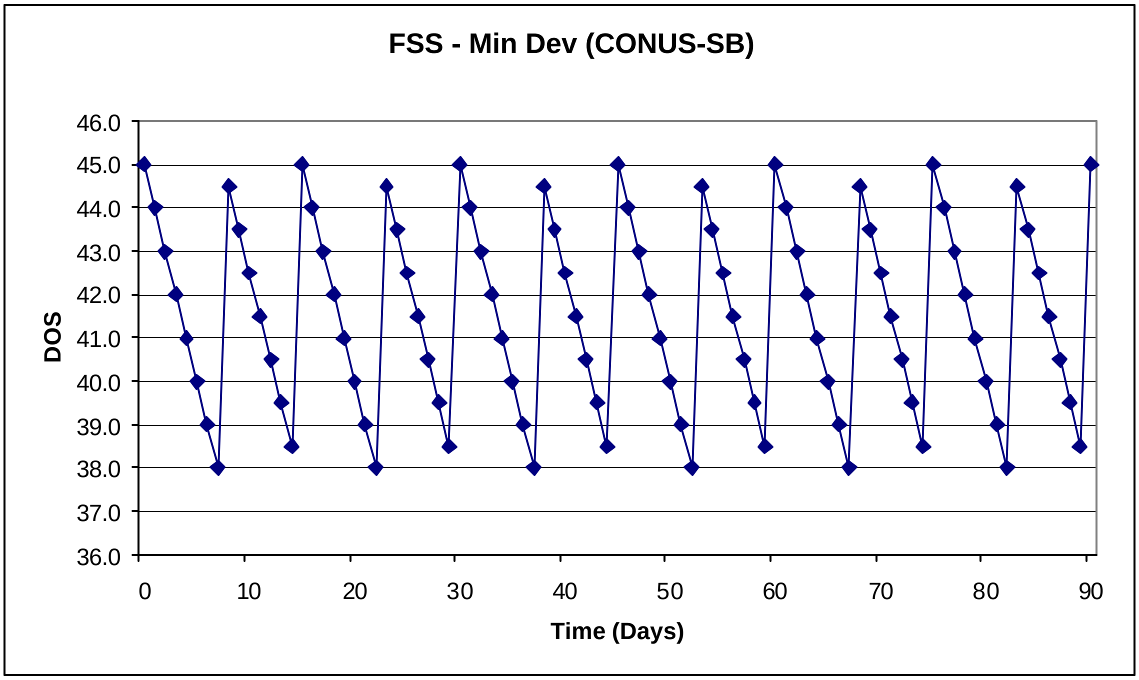

Figure XIX-7: Plot of DOS versus Time for FSS in Min Dev Re-supplying from CONUS to Sea Base (4 FSS required)

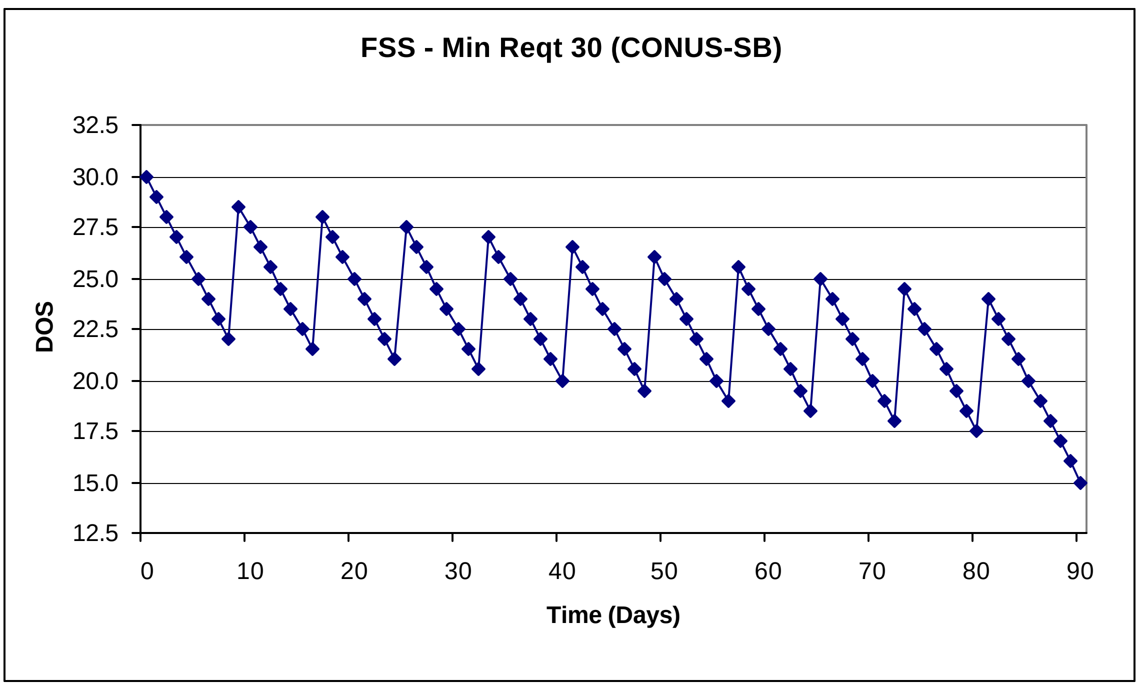

Figure XIX-8: Plot of DOS versus Time for FSS in Min Reqt 30 Re-supplying from CONUS to Sea Base (4 FSS required)

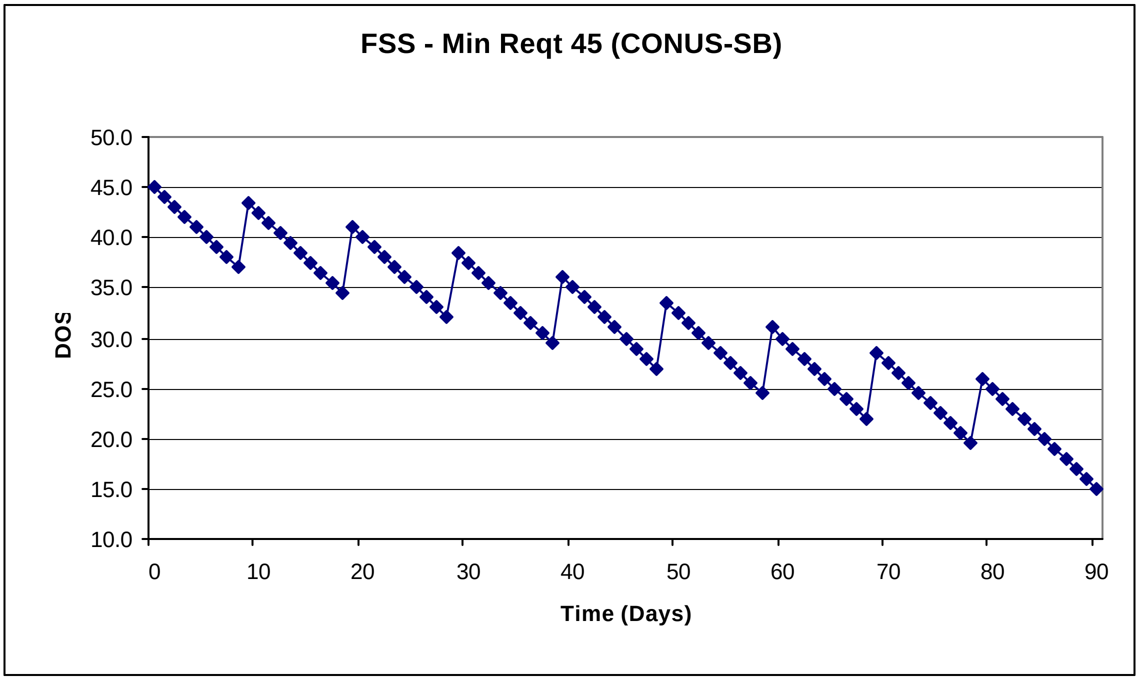

Figure XIX-9: Plot of DOS versus Time for FSS in Min Reqt 45 Re-supplying from CONUS to Sea Base (3 FSS required)

b. HSV Squadron

The Min Dev re-supply practice requires the largest number of HSVs to sustain the Sea Base for 90 days: 8 squadrons or 96 HSVs. Min Reqt 30 requires 84 HSVs, and Min Reqt 45 requires 72. The number of runs and rest days for all three re-supply practices are similar. The plots of DOS versus Time for HSV are shown as follows:

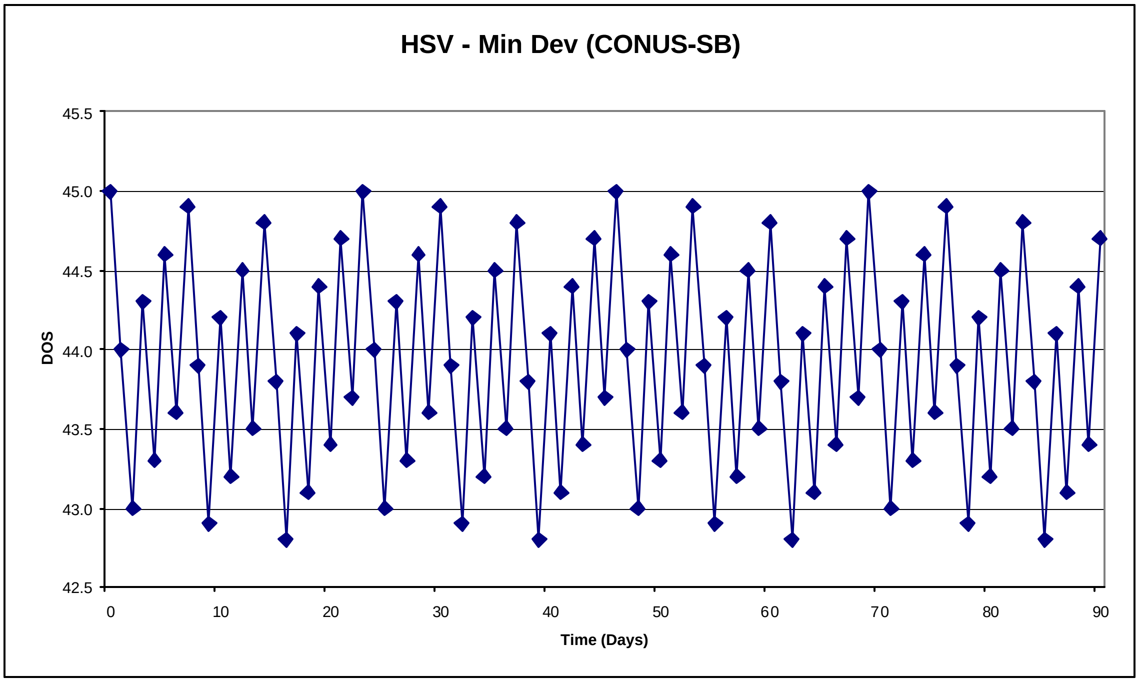

Figure XIX-10: Plot of DOS versus Time for HSV in Min Dev Re-supplying from CONUS to Sea Base (96 HSVs required)

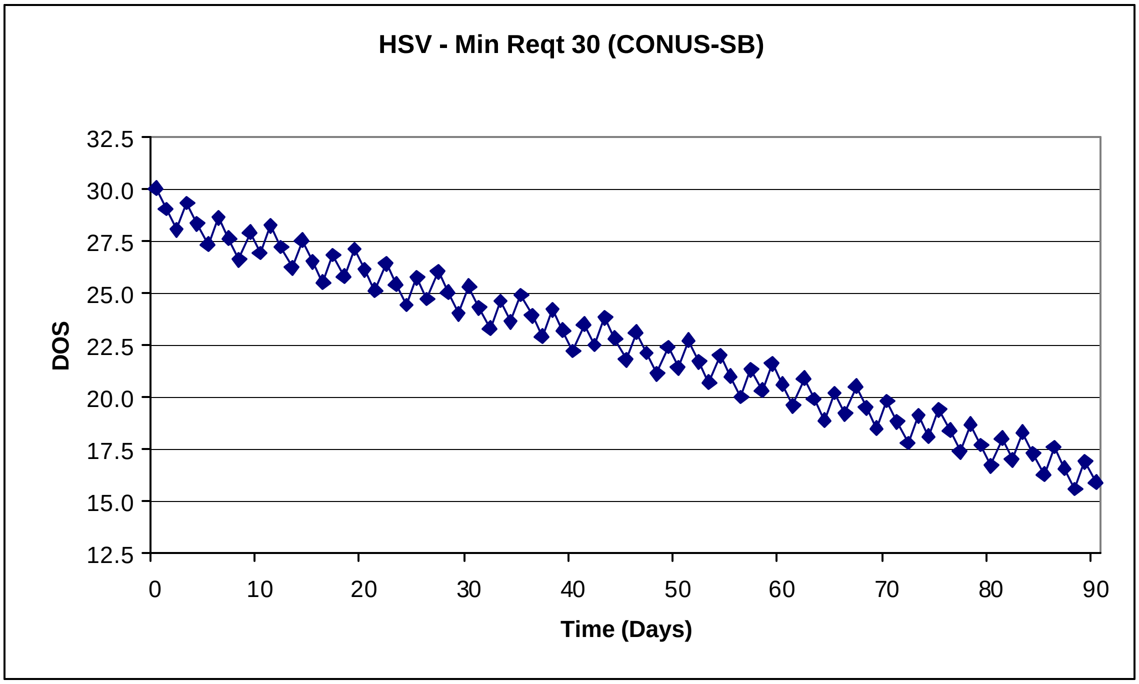

Figure XIX-11: Plot of DOS versus Time for HSV in Min Reqt 30 Re-supplying from CONUS to Seabase (84 HSVs required)

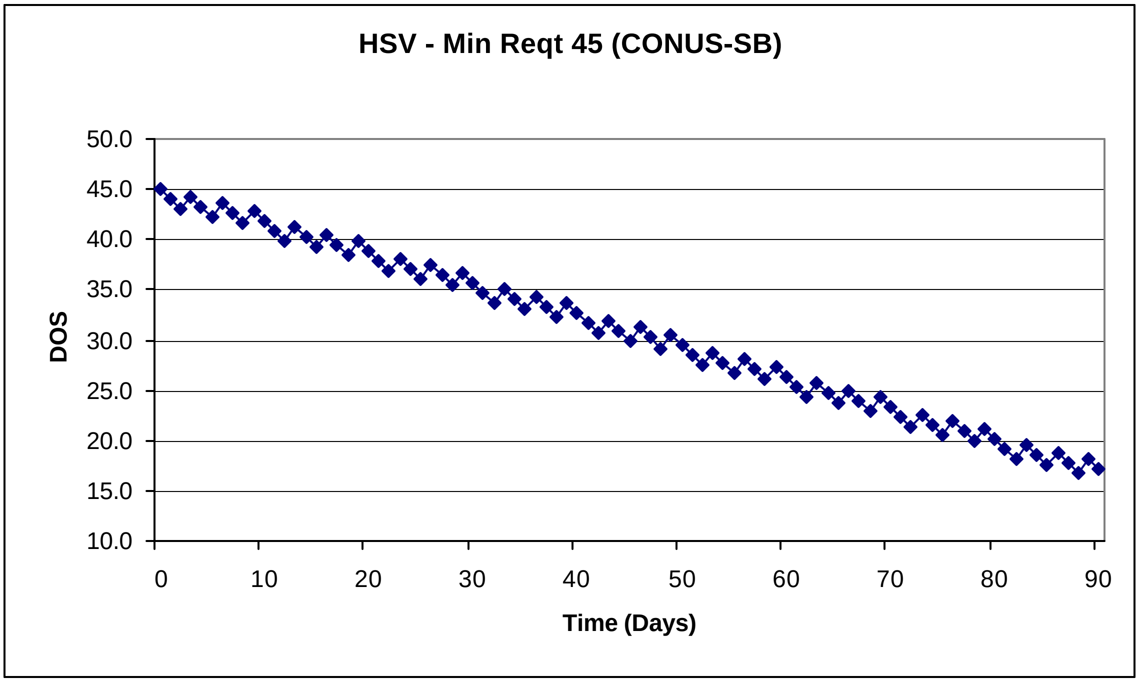

Figure XIX-12: Plot of DOS versus Time for HSV in Min Reqt 45 Re-supplying from CONUS to Sea Base (72 HSVs required)

c. Cost Comparison

The number of HSVs required in Min Dev and Min Reqt 45 is four times more than the number of equal cost HSVs available, while the number of HSVs required in Min Reqt 30 is 3.5 times more than the number of equal cost HSVs available. The results are summarized in the table below:

	Min Dev		**Min Reqt 30**		**Min Reqt 45**	
	FSS	**HSV**	**FSS**	**HSV**	**FSS**	**HSV**
Number of Ships Required	4	96	4	84	3	72
Number of Runs per Ship	3	5	2.5	5	3	4.5
Rest Day between Runs	3	1	5	1.5	3	3
Number of Equal Cost HSVs Available	24		24		18	
Ratio of HSV to FSS	24:1		21:1		24:1	
Number of Times Over Cost	4		3.5		4	

Table XIX-3: Summary Table for Re-supply from CONUS to Sea Base

3. Recommended Distance for HSV Usage

Given the current cost, speed and payload of the HSV, the number of HSVs required to sustain the seabase for 90 days using all three re-supply practices for both distances exceeds the equal cost number of HSVs available. For the shorter distance between the Offshore Base and Sea Base, the exceeding factor varies between 2 to 3. For the longer distance between CONUS and the Sea Base, the exceeding factor varies between 3.5 and 4.

The distance for re-supply runs were varied to determine the maximum distance recommended for HSV usage based on the current FSS to HSV cost ratio of 6 to 1 (that is, a FSS costs 6 times a HSV). Through the same run, the required HSV to FSS cost ratio at each distance can also be deduced. The results are shown in the table below. The following figure shows a graph of maximum and minimum ratio versus distance.

Distance (nm)	**Ratio of HSV to FSS (X:1)**		
	Min Dev	Min Reqt 30	Min Reqt 45
250	11	9	7
500	8	13	11
750	8	13	11
1000	11	9	15
1250	11	9	15
1500	13	11	18
1750	13	11	9
2000	16	13	11
2250	16	13	11
2500	13	16	13
2750	15	18	15
3000	15	18	15
3250	16	13	16
3500	16	13	16
3750	18	15	18

4000	18	15	18
4250	15	16	13
4500	15	16	13
4750	17	19	15
5000	17	19	15
5250	20	22	18
5500	20	22	18
5750	16	16	18
6000	16	16	18
6250	16	16	18
6500	19	20	21
6750	19	20	21
7000	19	20	21
7250	19	20	21
7500	19	20	21
7750	19	20	21
8000	24	24	26

Table XIX-4: Ratio of HSV to FSS (X:1) at Various Distances

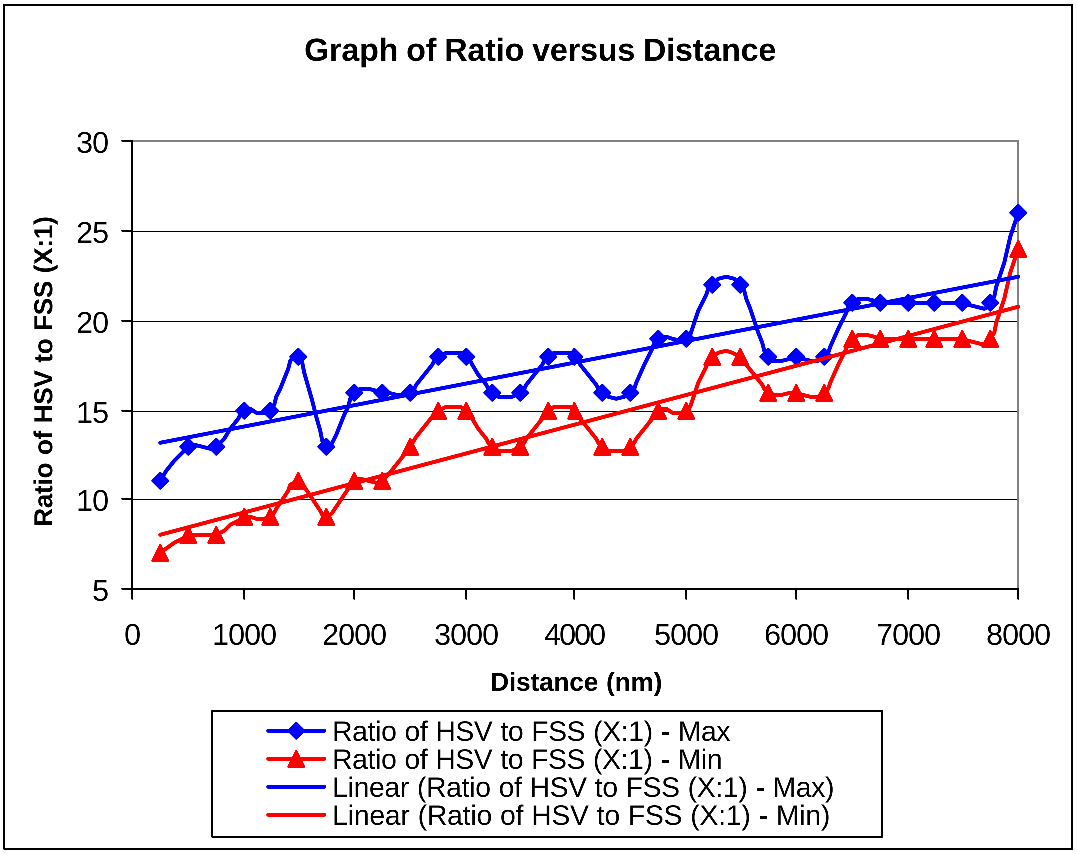

Figure XIX-13: Graph of Maximum and Minimum Ratio versus Distance

It is obvious that the ratio of HSV to FSS generally increases with distance. However, it is not strictly increasing at all points due to the different rate of increase in requirements for the FSS and HSV.

The two ratio versus distance plots are approximated by the following equations using linear regression:

Max Ratio Line: Ratio = 0.001183 * Distance + 12.93145

Min Ratio Line: Ratio = 0.001654 * Distance + 7.552419

From the graph, it can be seen that the ratio is 6:1 is not achievable at any distance. The lowest ratio is 7:1, and that is at a distance of 250 NM. However, if the cost of the HSV is halved, it will be cost effective to replace the FSS with HSV for runs up to 2250 NM.

Thus it can be concluded that at its current speed and payload, (and if our estimate of relative cost is correct), the HSV can only match or better the performance of the FSS at very short distances. Obviously the HSV has many other advantages like expeditious supply of urgent supplies and higher survivability, but for general and routine re-supply runs, the current HSV should be limited to a 250 NM radius until its cost can be lowered (or it can be determined that the real cost ratio between FSS and HSV is more favorable to the HSV than our assumption of 6 HSV = 1 FSS as a valid cost comparison).

4. Speed and Payload at Current Cost Analysis

The next portion of the analysis attempts to determine the cost requirement of the HSV at various speeds and payloads. For this portion, the distance was fixed at 1765 NM, which is the distance between the Offshore Base and the Sea Base in the scenario.

a. Speed Analysis

The payload of the HSV was fixed at 2.3 DOS per squadron for this portion of the study on the effect of variance in speed. The results obtained by varying speed are shown in the table and graph below. It is shown that even if the speed of the HSV is increased to between 50 and 55 knots, the system still requires 8 HSVs to replace a FSS. The number of HSVs required increases as its speed reduces. If the speed of the HSV is fixed at the current 38 knots, the number of HSVs required to replace a FSS at 1765 Nm is between 9 and 13.

Speed (knots)	Ratio of HSV to FSS (X:1)		
	Min Dev	Min Reqt 30	Min Reqt 45
30	16	13	11
31	16	13	11
32	16	13	11
33	16	13	11
34	16	13	11
35	16	13	11
36	16	13	11
37	13	11	9
38	13	11	9
39	13	11	9
40	13	11	9
41	13	11	9
42	13	11	9
43	13	11	9
44	13	11	9
45	13	11	9
46	13	11	9
47	13	11	9
48	13	11	9
49	13	11	9
50	11	9	8
51	11	9	8
52	11	9	8
53	11	9	8
54	11	9	8
55	11	9	8

Table XIX-5: Ratio of HSV to FSS (X:1) at Various Speeds

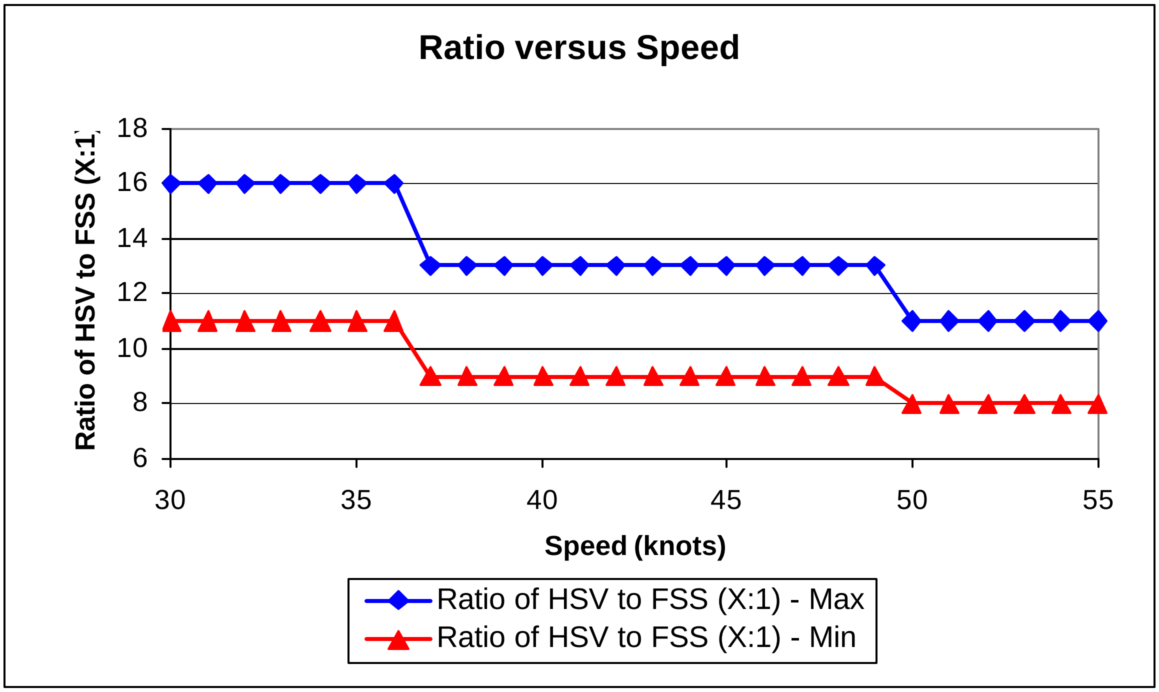

Figure XX-14: Graph of Maximum and Minimum Ratio versus Speed

b. Payload Analysis

The speed of the HSV is fixed at 38 knots for this portion of the study on the effect of variance in payload. The results obtained by varying speed are shown in the table and graph below. The lowest payload required of the HSV in order to effectively replace the FSS is 3.5 DOS per squadron, occurring when the Min Reqt 45 practice is used. This implies a requirement to increase the payload by approximately 1.5 times. If the payload of the HSV is fixed at the current 2.3 DOS per squadron, the number of HSVs required to replace a FSS at 1765 nm is between 8 and 13.

Payload (DOS)	Ratio of HSV to FSS (X:1)		
	Min Dev	Min Reqt 30	Min Reqt 45
2	15	13	10
2.3	8	13	11
2.5	12	10	8
3	10	9	7
3.5	9	7	6
4	8	6	5
4.5	7	6	5
5	6	5	4

Table XIX-6: Ratio of HSV to FSS (X:1) at Various Payloads

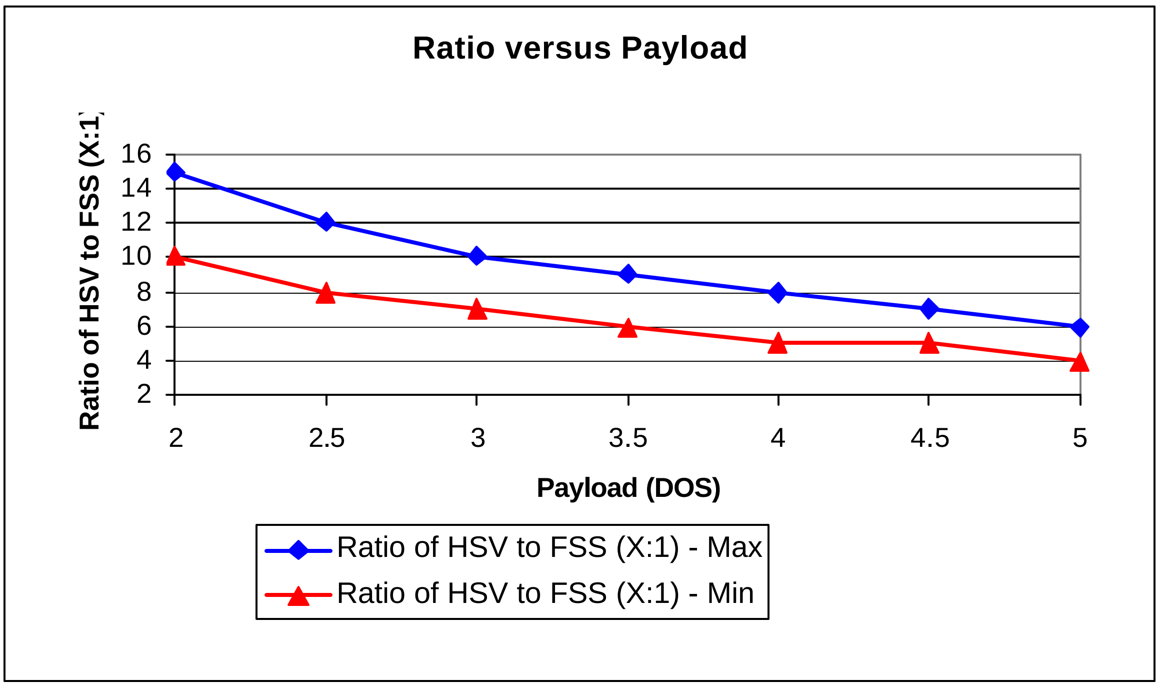

Figure XIX-15: Graph of Maximum and Minimum Ratio versus Payload

I. DESIGN OF EXPERIMENT FOR HSV

1. Introduction

An experiment was designed separately using the EXTEND^{TM} model was conducted to investigate the effects of key factors like architecture, speed and Sea Basing concept, as well as noise factors on the combat power projected ashore and DOS available. In order to specifically examine the effects of speed using HSVs, the following experiment was set up to run on the EXTEND^{TM} model and analyzed using the Analysis of Variance methodology. This experiment aimed at examining the effects of speed of HSVs and FSSs using an environment-based model, given other interacting key and noise factors.

2. Objective Function

The objective function for this experiment was the amount of supplies transferred from CONUS to the Sea Base by the HSV within a 90-day period.

3. Factors and Levels

The three factors examined in this experiment were the speed of the HSV, survivability of the HSV, and the unloading rate for the HSV. These are discussed below along with their levels:

a. Speed

The loaded speed of the HSV is 38 knots, and its lightship speed is 48 knots. Assuming a linear load – speed relationship, the speed of the HSV at half load will be 43 knots. The two levels used for speed are low (38 knots) and high (43 knots).

b. Attrition

The attrition rate of the HSV is defined at three different periods of the operation, namely the first 7 days of operation, days 8 to 14 of operation, and day 15 onwards. These attrition figures were derived from the MAGTF Planner's Guide. The two levels used for survivability are low (high attrition rate) and high (low attrition rate).

c. Unloading Rate

The cargo from the HSV can be transferred to the Sea Base or MPF(F) ship by two methods, namely craning and surface craft. The throughput rate of the crane is one standard ISO container (25 LT, 20' to 52' long x 8' wide x 8.5' high) every two minutes (National Institute of Standards and Technology, 1998). The payload of the fully loaded HSV is 275 LT, which equates to approximately 11 containers. Assuming that it takes three minutes to transfer the containers from the vehicle deck to the flight deck using the multifunctional elevator, it will take a total of five minutes to transfer one container from the HSV to the Sea Base or MPF(F) ship. The total unloading time for the 11 containers will then be 55 minutes, and the rate of transfer using crane is 12 containers, or 300 LT per hour.

It takes 15 minutes to load or unload each Heavy Landing Craft Air Cushion (HLCAC) (144-tonne payload capacity, approximately 141 LT), and the transit time between the HLCAC and Sea Base or MPF (F) ship is five minutes each way. This equates to a full turnaround time (from loading LCAC in HSV to LCAC's return to HSV) of 40 minutes. To unload the 275 LT of payload on the fully loaded HSV, 2 HLCAC round trips will be required, and thus the time taken to unload the HSV using HLCACs will be the time taken for two round trips, i.e. 80 minutes (1.33 hours). The rate of transfer using a LCAC will be 206.25 LT per hour.

If both unloading methods are used simultaneously, the time taken to unload the fully loaded HSV will be equal to the time taken for a HLCAC round trip, i.e. 40 minutes. One HLCAC will be used to transfer 50% of the load while the crane will be used to transfer the other 50% in 25 to 30 minutes. Even when the HSV is half loaded, the composite method is constrained by the round trip time for the HLCAC, and will still take 40 minutes to unload.

The factors and their levels are summarized in the table below:

Factor	Level	Description
Speed	Low	38 knots (Speed of the HSV at full load)
	High	43 knots (Speed of the HSV at half load)
Survivability	Low	Attrition rate of HSV: 1st 7 days of operation – 0.005743 Days 8 to 14 of operation - 0.003446 Day 15 onwards - 0.002297
	High	Attrition rate of HSV: 1st 7 days of operation – 0.002987 Days 8 to 14 of operation - 0.001792 Day 15 onwards - 0.001195
Unloading Rate	Slow	206.25 long tons per hour (Using 1 HLCAC) 1.33 hours or 80 minutes for full load 0.67 hour or 40 minutes for half load
	Fast	300 long tons per hour (Using 1 crane) 0.917 hour or 55 minutes for full load 0.5 hour or 30 minutes for half load
	Composite	Using 1 crane to transfer 50% of the load and 2 LCACs to transfer 50% of the load 0.67 hour or 40 minutes for full load and half load

Table XIX-7: Experiment Factors and Levels

4. Noise Factors and Other Constant Factors

The experiment attempted to stretch the capability of the Sea Base to the limit. As such, the experiment was conducted with the following noise factors and other factors set constant at the indicated values:

Factor	**Type**	**Value(s)**
Attrition of Other Friendly Forces	Noise	Low / High
Mine Warfare	Noise	Threat / No Threat
Consumption Rate	Noise	High / Low
Weather	Constant	Good
Architecture	Constant	Planned
Ship to Objective Proximity	Constant	Far

Table XIX-8: Noise and Other Constant Factors

5. Frequency of Replenishment

In order to ensure a minimum of 15 days supply at the Sea Base or MPF(F) ships throughout the 60-day period, timeline analysis indicated that a total of 24 HSVs was required. These HSVs were divided into 2 squadrons of 12 each, and each fleet re-supplied the Sea Base or MPF(F) ships once every three days (that is, 12 HSVs arrived at the Sea Base or MPF(F) ships on every 3rd day).

6. Conduct of Experiment

This experiment was conducted as a full factorial design, that is, 12 combinations (2 x 2 x 3). Using the half-factorial method, each combination was run four times with different combinations of noise factors, totaling 48 runs.

7. Analysis of Data

Analysis of Variance was used to analyze the data collected, with the objective of determining factor effects and interaction between factors.

J. FINDINGS FROM EXTEND™ EXPERIMENT ON SPEED

1. Department of Energy Setup – Noise Factors

Based on the Analysis of Variance analysis for the planned architecture in the ExWar model, it was observed that certain noise factors (consumption rate, weather and mine threat) are statistically more significant to the MSE at the Sea Base than other noise factors (attrition rate of other friendly forces). As such, for the sub-study on design factors for the HSV as a means of replenishment for the Sea Base in the planned architecture, attrition rate of other friendly forces was ignored as a noise factor (that is, it is kept at a constant level).

2. Assumptions

The following assumptions were made for the conduct of the experiment:

a. There is a deterministic demand for supplies at the Sea Base from forces at the objective.

b. The unloading of resources is not done in real time but instead as a step function.

c. The HSV replenishes the Sea Base with a fixed load at fixed intervals throughout the duration of the simulation.

d. The availability of the HSV is equal to 1, and there is no operational threshold time being applied to the HSV for back-to-back replenishment.

3. Analysis

The main effects plot from analysis done by Analysis of Variance for the HSV experiment indicates that the design factor speed, i.e. speed and payload for the HSV, is the only statistically significant factor on the Measure of Performance (MOP) set for the study, which is the aggregated MSE of the 3 types of resources - MREs, fuel and ammunition that are maintained at the Sea Base and the objective. The result is intuitive and can be explained as follows:

a. The maximum unloading delay used in the study was about 80 minutes and its impact on the variability of resources at the Sea Base was insignificant as compared to the time taken for the HSV to transit from the Offshore Base to Sea Base, which is about 53 hours. However, the unloading delay should increase in significance when the distance between the Offshore Base and Sea Base is reduced.

b. Based on the survivability value set in the simulation, at low survivability, an average of 4 to 5 out of 24 HSVs were destroyed at the end of 90 days. This relatively small number of destroyed HSVs is not sufficient to degrade the performance of HSVs in replenishing the Sea Base.

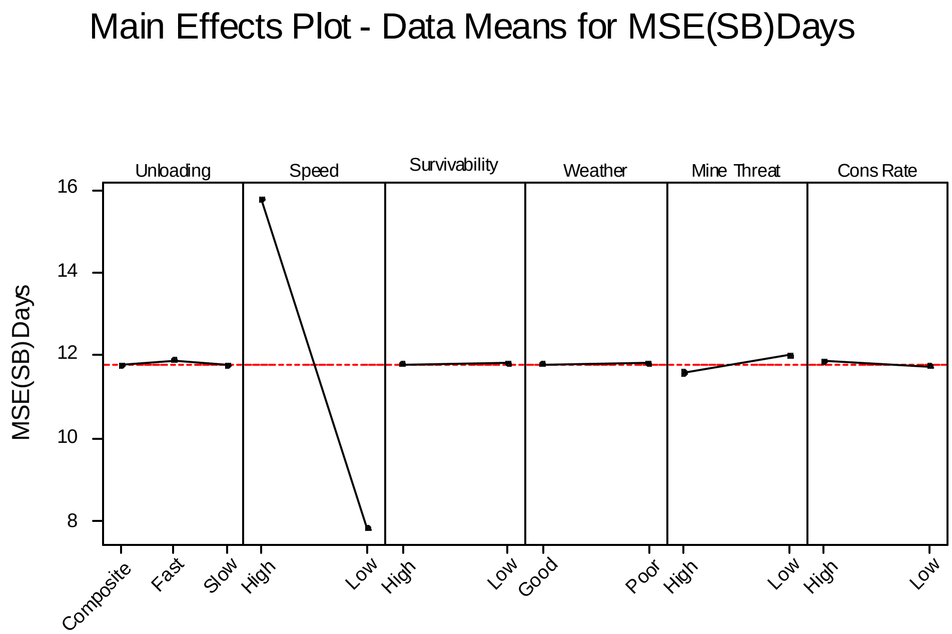

Figure XIX-16: Main Effects Plot from Analysis using Analysis of Variance

From the main effect plot, it is observed that the HSV performs better and is more robust to noise at the speed of 38 knots, as compared to 43 knots. The finding here depicting HSVs with lower speed but higher payload re-supply runs outperforms faster, lower payload HSVs contradicts what the ExWar EXTEND™ experiment arrived at. However it should be noted that in the ExWar EXTEND™ experiment, the conclusion of high speed, low payload replenishment as a better choice was based on a different classifying comparison between a 15 knots commercial ship and a 30 knots HSV. In this study, a more realistic and specific comparison between a FSS at operational speed of 27 knots (Full Load) versus HSVs with operational speeds of 38 knots (Full Load) and 43 knots (Half Load) was adopted. It was found that in this experiment, there is a diminishing return in performance when too much payload is traded off for the increase in speed. Hence, a lower speed, higher payload configuration is preferred.

K. CONCLUSIONS AND RECOMMENDATIONS

1. Conclusions from Scheduling Model Analysis

The results from the Scheduling Model Analysis have quantitatively determined the numbers of each type of ship (FSS and HSV) required at various distances. From these results, the following were deduced:

a. The maximum cost effective distance that the HSV should be utilized for re-supply runs based on the current HSV to FSS cost ratio of 6:1, given the current HSV speed and payload capability.

b. The cost ratio of HSV and FSS required at each distance. Sequentially, the speed and payload requirements to fulfill the 6:1 cost ratio at a pre-set distance of 1,765 NM (Distance between Offshore Base and Sea Base in the scenario) were also determined using the same methodology.

2. Recommendations from Scheduling Model Analysis

The recommendations from the previous sections are summarized below:

ITEM	RECOM.	REMARKS
Maximum Distance for Re-supply Runs (Speed and Payload fixed)	250 NM	At the lowest possible HSV to FSS cost ratio of 7:1
	2,250 NM	If HSV to FSS cost ratio is halved to 12:1
Cost Ratio Required at Various Distances (Speed and Payload fixed)	Varies	Nil
Speed Required to Fulfill Current Cost Ratio of 6:1 (Distance set at 1,765 nm, Payload fixed)	> 55 knots	Cost ratio at 55 knots is 8:1 Higher speeds not investigated
Payload Required to Fulfill Current Cost Ratio of 6:1 (Distance set at 1,765 nm, Speed fixed)	3.5 DOS per Squadron	Approximately 1.5 times of current payload

Table XIX-9: Summary of Recommendations

From the summarized recommendations, it is apparent that at its current cost, speed, and payload, the HSV is not an effective replacement for the FSS for re-supply missions. To be an effective replacement, either one of the following has to be implemented for future HSV designs:

a. Reduce the cost of the HSV relative to the FSS. The exact cost requirement varies according to the distance that the HSV would be utilized for.

b. Increase the speed of the HSV. Again, the exact speed requirement varies with distance involved. At 1,765 NM, the speed required is beyond 55 knots, which may render the HSV unstable or significantly reduce its practical payload capability.

c. Increase the payload of the HSV. The exact payload requirement varies with distance the HSV is utilized for. At 1,765 NM, the payload required is approximately 1.5 times the current payload.

3. Conclusions from EXTEND™ Experiment

The results obtained from the experiment using the EXTEND™ modeling analysis showed the effects of speed evolving from the interactions with the environmental and noise factors. The interactions showed that the model prefers payload to speed in the case of the specific HSV investigated, where the returns from increasing speed does not compensate for the loss of payload in the transporting platform.

4. Recommendations from EXTEND™ Experiment

The model in this case, is unable to quantify the value of low survivability, and hence unable to deduce what level of force protection is required for the HSVs to perform their mission. A separate study on how the level of protection interacts with the payload and speed of the HSV is recommended to derive the degree of force protection required for the HSV.

5. General Conclusion and Recommendations

The Replenishment model analysis had quantitatively shown the effects of speed versus payload and its relevant cost relationship based on the comparison between a conventional FSS and a conceptual employment of a HSV. The recommendations resulting from this analysis allows the decision maker to understand the relationships between these three factors, thus allowing a decision to be crystallized anchoring on either one or more of the three factors. It is important to note that increasing the speed or payload of the HSV may bring about an associated increase in cost, and there is a need to balance these requirements. However, even at its current cost and specifications, the HSV is still useful in niche areas like mine warfare, special operations, intra-theatre troop lift, and casualty evacuation.

The EXTEND™ experiment was aimed at examining the interactions with environmental and noise factor, which were not factored in the Replenishment model that concentrated on the direct impact between speed, payload and cost. However, the results from the EXTEND™ experiment were only able to identify a distinct relationship between speed and payload, with the other environmental and noise factors were deemed statistically insignificant.

Other than the above investigated key and environmental factors, other operational cost effectiveness issues like quantifying the holding cost for resources held above the target value at the Sea Base, penalty cost for using the safety stock, and operating cost for delivery of resources to the Sea Base are recommended for further investigation to achieve a more detailed tradeoff analysis.