# XX. IMPLICATIONS OF SEA BASING

## A. ASSUMPTIONS

The results of any major study are only as good as the assumptions – the better the assumptions, the better the results. We carefully selected several key assumptions that shape the Conceptual architecture for future Sea Base operations. The key ExWar project assumptions are as follows:

- **MEB operations occur in the 2015-2020 timeframe.**
- **MEB and Sea Base operations are conducted up to 200 nautical miles inland with a standoff distance from land ranging from 25-250 NM offshore, but not to exceed 275 NM from Sea Base to Objective.**
- **Current USN and USMC legacy platforms projected will remain operational through 2015 - 2020 and will not retire early.**
- **All current USN and USMC acquisitions of new aircraft and land vehicles will be available in 2015-2020 and will be delivered on schedule.**
- **A MEB size MAGTF composition and sustainment requirements remain relatively constant between the present and 2015 - 2020.**
- **A MEB size Expeditionary Force will not conduct a forcible entry, without the support of at least one CSG provides support.**
- **The Sea Base will be formed by merging at a minimum of two MEUs sized ARG, their escorts, logistics and prepositioned equipment support ships, and associated CSG.**
- **Future ARGs deploy as ESGs with surface combatant escorts as envisioned in the Chief of Naval Operation's (CNO) *Sea Power 21* (Clark, 2002).**

## B. INTRODUCTION

The USN and the USMC together are transforming the current force structure towards a Sea Basing concept that is highly maneuverable, flexible, and less vulnerable.

The Planned architecture for future ExWar does not provide a robust enough capability to surge and sustain a MEB size Landing Force of approximately 6,800 personnel ashore at 225 to 275 NM from the Sea Base to the Objective for an indefinite period of time. With a major gap identified in the Planned architecture, we were tasked to examine "new seabasing options for logistics, command facilities, and support of sustain operations ashore" (McGinn, 2002). The Conceptual architecture for ExWar we designed is capable and robust enough to strike and sustain deep from the sea to deep inland. As stated in the *Naval Transformation Roadmap*, the future Navy and Marine Corps Team is fostering a culture that is transforming itself to "project responsive force worldwide with the capability to fight and win, operate continuously from an expanded and secure maneuver area—the sea, and minimize vulnerabilities tied to oversea land support." (Department of the Navy, 2002, 4). Our Conceptual architecture, incorporating a Sea Base concept, provides a possible framework to meet this transformational revolution.

Sea Basing is the catalyst that enhances the Navy and Marine Corps' capability to carry out OMFTS, STOM, EMW, and other ExWar concepts.

OMFTS is the maneuver of expeditionary forces at the operational level. "The heart of *Operational Maneuver from the Sea* is the maneuver of naval forces at the operational level, a bold bid for victory that aims at exploiting a significant enemy weakness in order to deal a decisive blow" (Headquarters U.S. Marine Corps, 1996, V-9). OMFTS uses the sea as a maneuver space and emphasizes rapid movement, not merely from ship to shore, but from ship to objectives that may be miles away from blue water and from inland positions back to offshore vessels. Additionally, operational maneuver is focus on attacking the enemy's center of gravity – something vital to the enemy's ability to carry out operations (Headquarters U.S. Marine Corps 1996, V-9).

STOM is a tactical concept that supports OMFTS. STOM permits units to move from shipboard platforms that are positioned over the horizon to objectives lying far inland and back. "True *Ship-to-Objective Maneuver* is not aimed at seizing a beach, but at thrusting combat units ashore in their fighting formations, to a decisive place, and in sufficient strength to ensure mission accomplishment" (MCCDC 1997, II-7). An essential ingredient to rapid and successful STOM operations is a highly capable Sea

Base. The Sea Base must have the capability to move combat forces, equipment, and supplies ashore rapidly so they can engage and conquer the enemy in an expedient fashion.

"*EMW*, moves us down the path outlined in *Marine Corps Strategy 21*, and provides the foundation for the way the Marine Corps will conduct operations the complex environment of this new century." EMW is much broader than OMFTS. "It is the union of the Marine Corps' core competencies; maneuver warfare philosophy; expeditionary heritage; and the concepts by which we organize, deploy, and employ forces" (Headquarters U.S. Marine Corps, 10 November, 2001).

## C. THE NEED -WHY SEABASING

"Seventy percent of the world's population lives within 200 miles of a coast, and 80% of the world's capitals are located within 300 miles of a coast. This urbanization of the world's littoral regions mean that operations from the sea provide the nation with an enduring means to influence and shape the evolving international environment." (Krulak, 1997). With a high probability of engaging enemy forces within 200 to 300 miles of a coast, the United States must have a global reach capability to protect our national interests, as well as our allies' and friends' national interests. Sea Basing supports that global reach.

As the United States changes from a two major war strategy to a "4-2-1" strategy, a transformation in the architecture has to match that strategy. The new "4-2-1" strategy is "deterrence in four places at one time, quickly defeat an adversary in two places and overwhelmingly and decisively defeat and have regime change in one other place" (Clark, October 2002). Sea Basing is the transformation architecture that supports the "4-2-1" strategy at the strategic, operational, and tactical level.

The United States' military presence overseas has significantly decreased over the past 20 years. Examples of this decrease in forward presence are the closure of bases in the Philippines and Panama, as well as the reduction of troops stationed in Europe and Southeast Asia. This reduction abroad decreases responsiveness and deterrence. Sea Basing allows us to maintain a continuous presence that decreases deployment times and deters adversarial threats against the United States, its allies, and friends. If deterrence fails, then Sea Basing gives Joint Force Commanders the capability to respond quickly and decisively.

Forward deployed troops stationed on land are susceptible and vulnerable to terrorist attacks. In recent years, the United States has experienced several such attacks.

### 1. USS Cole (DDG 67)

On October 12, 2000, terrorists exploded a small boat alongside the USS Cole while the ship was refueling in Aden, Yemen. As a result of the powerful explosion, 17 sailors died as well as hundreds of millions of dollars in damage to the ship.

### 2. Khobar Towers

On June 25, 1996, terrorists exploded a massive improvised explosive truck bomb outside the Khobar Towers housing barracks, in Dhahran, Saudi Arabia. The terrorist act killed nineteen American service members, and injured hundreds of others.

### 3. Beirut

On October 23, 1983 terrorists exploded a massive truck bomb in the Marine barracks in Beirut, Lebanon, killing 220 Marines and 21 other U. S. Service members.

A Sea Base, although not free from risk of attack, is less vulnerable than stationary facilities ashore or assets in close proximity to shore. A moving target is much harder to hit than a stationary target. A Sea Base can station itself at distances greater than 25 NM from the coast of a hostile country and use the sea as a maneuvering space to gain a tactical advantage over the enemy. For troops stationed ashore the risk of being attacked by WMD is a possibility. The Sea Base offers a safer place for deployed troops.

As the United States shifts from a threat-based strategy to a capabilities-based strategy, NPS' Conceptual Sea Base design provides two desired transformational capabilities as stated in the Naval Transformation Roadmap. First, the Sea Base allows accelerated deployment and employment times that decrease from months to days. Second, the Sea Base presents the Joint Force Commander the ability to extend the battle space beyond the enemy's reach, as well as move critical components from the shore to a secure operating area – the sea (Department of the Navy, 2002, 24 - 25).

As anti-American sentiments increase outside the borders of the United States, the chance of regional conflict increases as well. The Sea Base allows a forward presence without the difficulty of gaining sovereign rights to access friendly ports or airfields. Sea Basing assures access without dependence.

The MPS and the LHA Ships are nearing the end of their service lives. Without the replacement of these lift assets, the Marine Corps will not have its recommended lift capability. NPS' Sea Base will provide the necessary lift capability.

In conclusion, Sea Basing is a transformational concept that will enhance the United States' ability to maintain global military dominance and help carry out the national and military strategy.

## D. WHAT IS SEA BASING

Sea Basing, as stated in the *Naval Transformation Roadmap,* is a transformational concept that will revolutionize the projection, protection, and sustainment of sovereign warfighting capabilities around the world for the United States Navy and Marine Corp. Sea Basing capitalizes on the inherent mobility, security, and flexibility of naval forces to overcome the emerging military and political limitations to overseas access. This capability will be conducted efficiently and aims to reduce the need to build up logistical stockpiles ashore that may burden or endanger allies and drastically complicate force-protection requirements. It will also reduce the early demands on the national strategic lift capability. Sea Basing will enable the Navy to conduct sustained, persistent combat operations from the sea and when fully implemented will provide a viable option to totally eliminate the limitations imposed by reliance on overseas shore-based support.

## E. CONCEPT OF OPERATION

Sea Basing requires accomplishing at sea, often under severe weather and sea-state conditions, many of the functions traditionally undertaken by logistics bases established on shore. The challenge is to achieve organizational design, shipboard distribution operations, integration of sustainment efforts and strategic resupply efficiently, effectively and safely from the sea.

By providing sustainment to warfighters ashore directly over-the-horizon from the safer sanctuary of the sea base, OMFTS and STOM can become a reality. The Sea Base is mobile and can maneuver as part of the Expeditionary Task Force to support sustained operations ashore. By employing direct replenishment from ship to the objectives, the "Iron Mountain" and operational pause can be reduced or eliminated. In addition, there is no need to allocate resources to protect this "Iron Mountain," though the force protection need is now transferred to ensuring safe transit between the Sea Base and the objectives. When operating under the umbrella of a battle group, the Sea Base will allow positioning of networked joint forces for immediate employment ashore. With future networked communications capabilities, the Sea Base will further enhance maneuver ashore by reducing the need to project major command and control elements, heavy fire support systems, or logistics stockpile necessary under the current mode of expeditionary operations.

## F. ANALYSIS OF SEA BASE SUSTAINMENT OF FORCES ASHORE USING EXTEND™

This section presents an analysis of the Sea Base as a system for sustaining the forces ashore using the EXTEND™ models; specifically the model for the ExWar Planned architecture. The Planned Architecture was chosen in this excursion study because it offers us more readily available materials for cross referencing. This analysis will describe how the Sea Base is affected by varying its distance from the Objective and how the replenishment system is affected by using different proportions of air and sea transportation means. The effectiveness of the system is measured using several MOPs namely TBU to 80% of Forces at the Objective and MSE of Supply at both the Sea Base and the Objective. For detailed description on the workings of the model and the MOP, please refer to Chapter XII.

The main assumption used for modeling the Sea Base is that the replenishment to the Sea Base is a fixed quantity of resources so as to determine when and where areas of concerns arise. This assumption creates a baseline for comparison when the factors affecting the Sea Base are varied. In the models used for the Sea Base analysis, the environmental factors have been fixed as good weather, high attrition, no mine threat and high consumption rate at the Objective. For detailed explanations of these factors, please refer to Chapter XII.

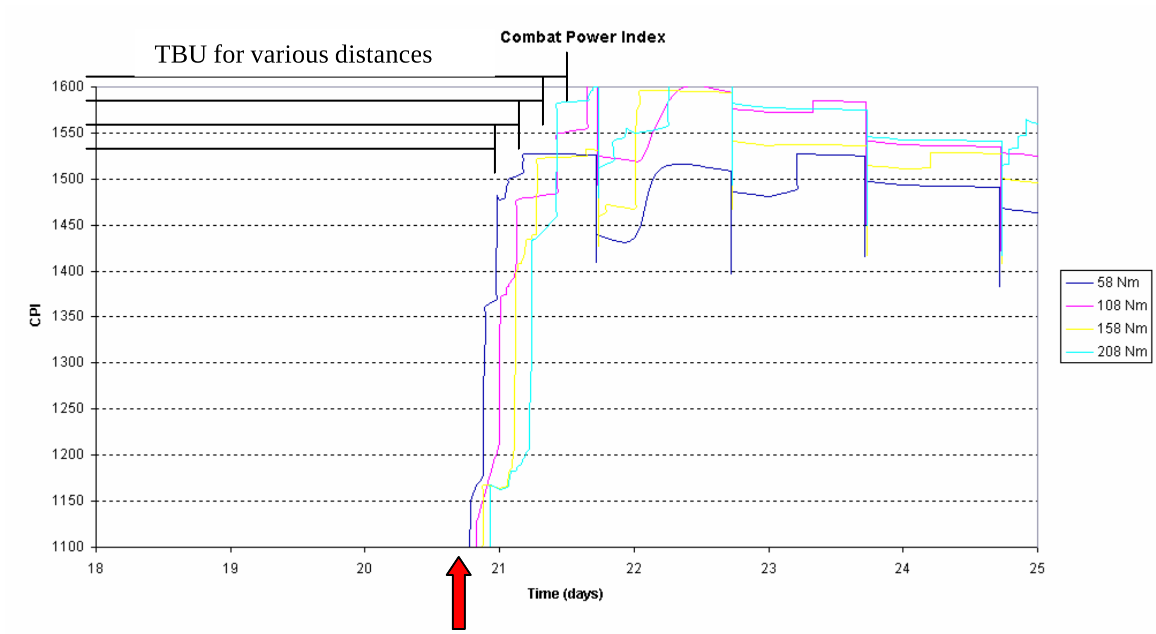
### 1. Distance of Sea Base Relative to Objective

In this analysis, four different distances are compared; 58 NM, 108 NM, 158 NM, 208 NM. Fifty-eight NM is the distance of the Sea Base from the Objective that was used in the scenario during the ExWar architectures analysis. Increments of 50 NM are used here to observe the effects varying distances have on the system as a whole. Please refer to Chapter V for details on the scenario used in this model.

#### a. Time to Build Up (TBU) 80% of Forces at the Objective

This MOP will indicate the amount of time that the forces are being built up at the Objective. It will specifically measure the time that it takes the forces to reach 80 percent of the planned level at the Objective. This desired level is calculated based on a tabulated Combat Power Index (Chapter XIII – Appendix 13-1).

Increasing the distance between the Sea Base and the Objective results in an increase in the TBU. This is represented in the following figure and table:




(Note: The red arrow indicates the time as calculated from the departure from CONUS when the forces first set foot on the Objective. The build-up time to the desired force level at the objective (TBU) is summarized in Table XX-1 for the various distances from the Sea Base to the Objective. TBU is in days as measured from the departure from CONUS.)

**Figure XX-1:** Combat Power Build Up From Varying Distances

| | **Distance of Sea Base from Objective** | | | |
|---|---|---|---|---|
| | 58 NM | 108 NM | 158 NM | 208 NM |
| **TBU (days)** | 20.9 | 21.1 | 21.25 | 21.4 |

(Note: The build-up time indicated is the time calculated from the departure of the forces from CONUS)

**Table XX-1:** TBU from Varying Distances

This difference in build up time is intuitive but it proves that it is possible to build up the forces ashore to the required level. Varying the distance between the Sea base and the Objective from 58 NM to 208 NM does not significantly delay the combat power build-up at the Objective. These TBU results however do not present any evidence on whether the forces ashore can be sustained from the different distances. This will be examined in the next section.

### b. Days Of Supply (DOS) At The Objective

This MOP will indicate the bias and variability of the level of resources from the desired level at the Objective: 5 DOS. This MOP will indicate the robustness and consistency of the resource levels at the Objective and will represent how well the Sea Base is sustaining the forces ashore.

Charts depicting the DOS at the Objective pertaining to each distance are shown below. The vertical axis is the days of supplies of the type of resources and the horizontal axis is time in days.

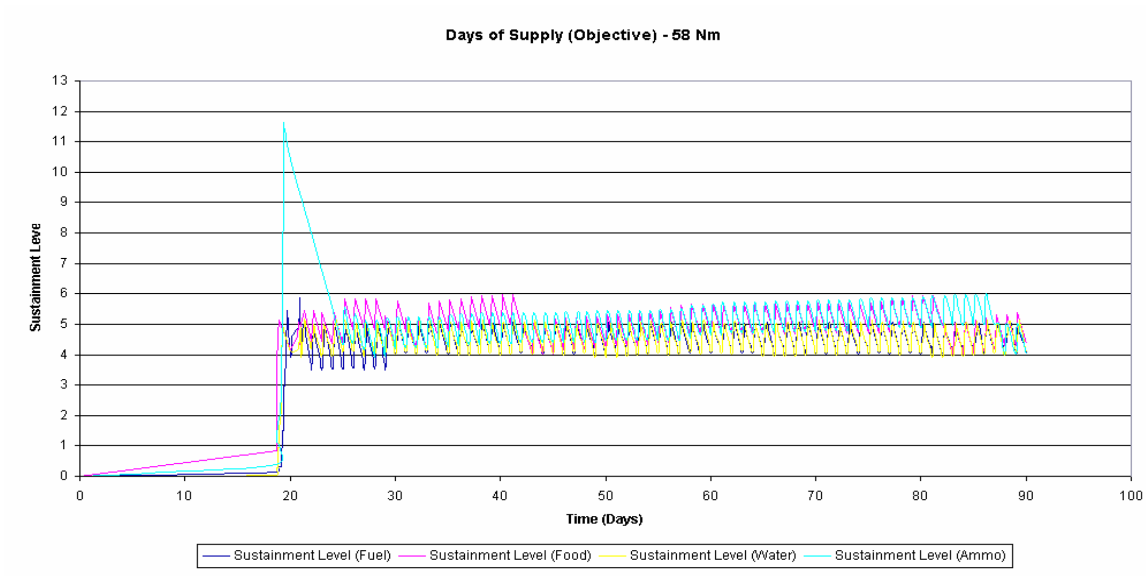
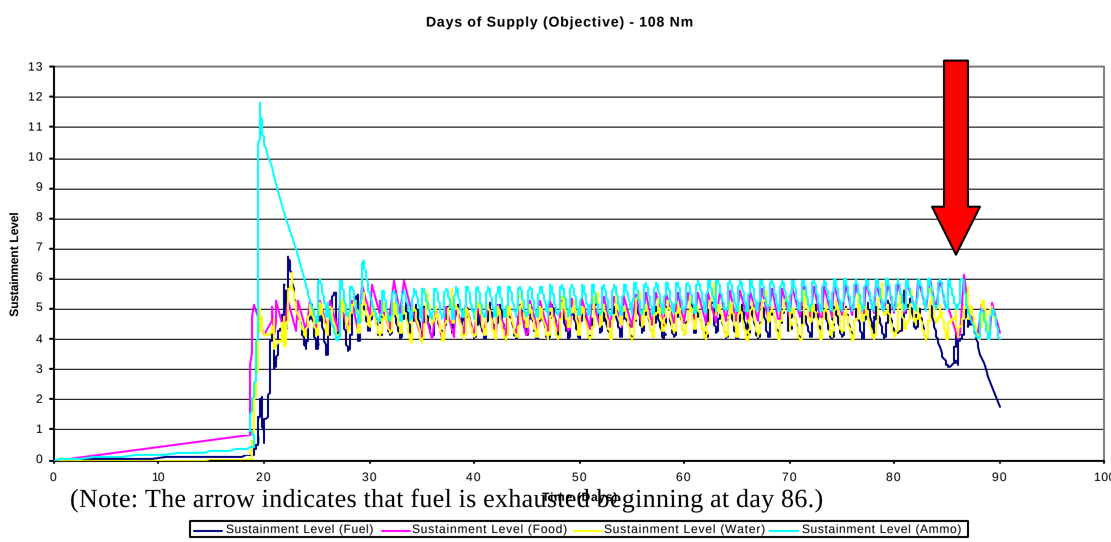



**Figure XX-2:** DOS at Objective with distance = 58 NM




(Note: The arrow indicates that fuel is exhausted beginning at day 86.)

**Figure XX-3:** DOS at Objective with distance = 108 NM

(Note: The arrow indicates that fuel is exhausted beginning at day 50.)

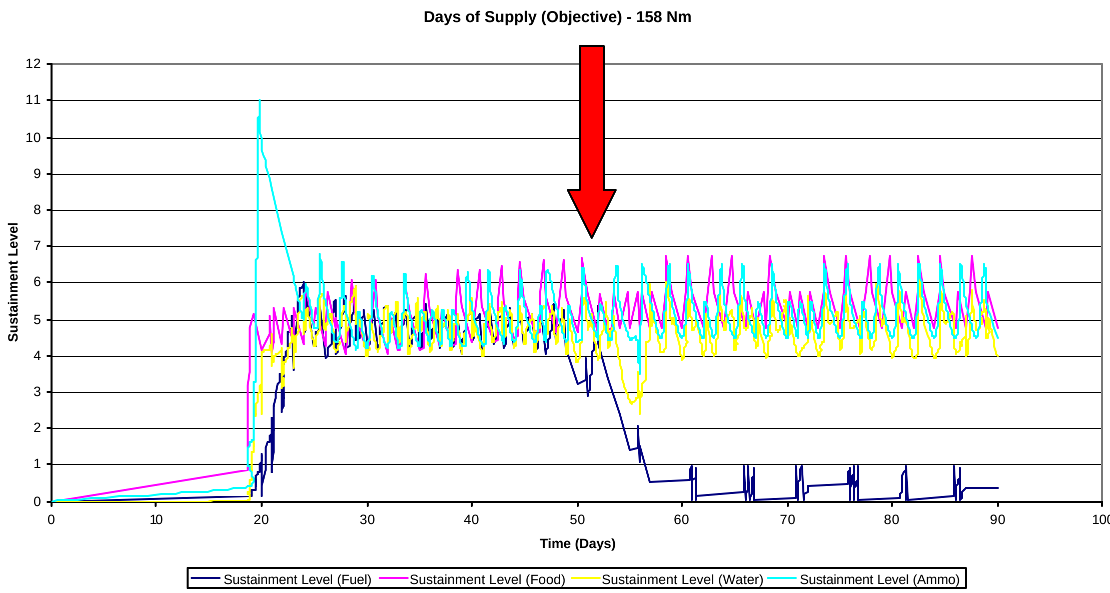
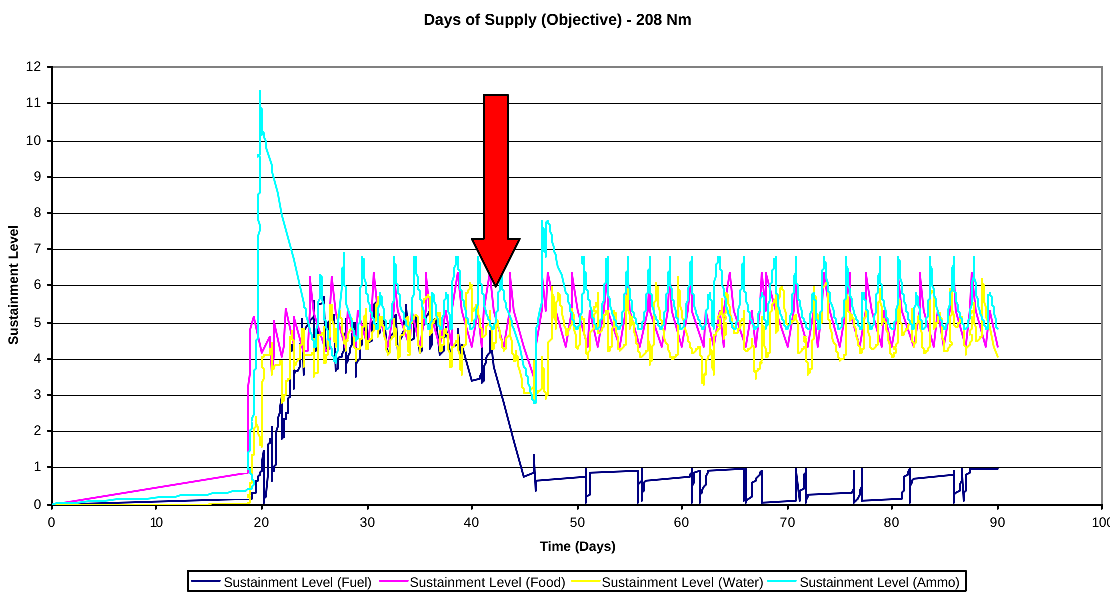



**Figure XX-4:** DOS at Objective with distance = 158 NM




(Note: The arrow indicates that fuel is exhausted beginning at day 42.)

**Figure XX-5:** DOS at Objective with distance = 208 NM

It can clearly be seen that the Sea Base can sufficiently sustain the Objective at distances of 58 NM and 108 NM for a period of 90 days. At 158 NM, the Sea Base is unable to sustain the forces ashore for more than 30 days of ashore operations. At 208

NM, the Sea Base will fail its sustainment operations at the 20th day ashore. The area of concern arises when the fuel re-supply begins to collapse on the 65th day at 108 NM, 30th day at 158 NM and 20th day at 208 NM. This problem is two-fold: one is due to the fixed fuel re-supply to the Sea Base, and the other is due to the increasing fuel demand from the air re-supply platforms and the land vehicles when we stretch the ranges up to 208 nm. This concern for the fuel re-supply can be eradicated by ensuring there are more frequent fuel re-supply runs to the Sea Base and the Objective, or by ensuring that the Sea base ships are designed with a bigger fuel storage capacity.

| | **Distance of Sea Base from Objective** | | | |
|---|---|---|---|---|
| | 58 NM | 108 NM | 158 NM | 208 NM |
| **MSE (days)** | 0.707 | 0.784 | 1.673 | 1.812 |

**Table XX-2:** MSE at Objective at Varying Distances

The MSE at the Objective increases as the distance of the Sea Base from the Objective increases. At 58 NM and 108 NM, the variability of the resource levels is 0.707 and 0.784 days of supply respectively. This increases to 1.673 and 1.812 days of supply at the Objective when the distance increased to 158 NM and 208 NM. In absolute terms, 1.673 and 1.812 days of supply is minute, however in percentage terms, these translate into 33.4% and 36.24% of resource drawdown.

Distance of the Sea Base to the Objective is a critical factor in designing the Sea Base. In order to have a functioning Sea Base that can sustain the forces ashore indefinitely at OTH distances, the replenishment system needs to be made more robust or the load on the system reduced, so it can function at longer distances.

One of the interesting points to note is the depletion of fuel as the distances increased. As we have a fixed rate of fuel replenishment to the Sea Base, the fuel supply was unable keep up with the increased consumption as more re-supply missions were flown or launched. Therefore, flexibility in increasing or decreasing the supply, especially fuel, to the Sea Base is highly desirable.

This can also be accomplished by reducing the consumption of resources at the Objective. This implies efficient usage of fuel and ammunition. Having more fuel efficient hardware systems and using precision strike weaponry will translate into less consumption at the Objective and will also mean that fewer resources need to be sent to the Objective from the Sea Base.

Moving the ashore support fires onto the Sea Base can also relieve the load on the replenishment system. This reduced strain on the replenishment system will mean it can function at longer distances.

## 2. Replenishment Options for Sustaining Forces Ashore

This section discusses varying the proportions of air and sea transport for replenishing the Objective from the Sea Base. Four different options are tested and compared using the EXTEND$^{TM}$ models and each option is also tested under different weather conditions.

Under the architecture, some equipment, such as the M1A1 tank, cannot be airlifted. Even when a 100% air replenishment option is used, the M1A1 will still be a surface delivered combat system. Resources like food, fuel, and ammunition, etc., will be air or sea delivered depending on the option chosen.

One of the early results of this analysis is that a 100% air replenishment option is subject to high levels of attritions. This is due to the tremendous number of sorties that need to be flown in order to replace a single Heavy Landing Craft Air Cushion (HLCAC) load, thus increasing the aircraft' exposure to enemy fire. The draw down on aircraft will impact the replenishment system within the first 10 days, bringing the Sea Base re-supply missions to a halt. It was concluded that a 100% air replenishment option is only viable in a low or no attrition environment, which translates to air superiority and dominance of theater's air space with ISR assets. Therefore, we tested this option with a zero attrition rate to garner the insights.

### a. Days of Supply (DOS) at the Objective

The first eye-catching result from the analysis is that neither air nor sea means of replenishment can be omitted. When 100% air replenishment was used, the model came to an abrupt halt due to attrition of the aircraft. On the other hand, when 100% sea means was used, the variability of the resource levels at the Objective increased.

| | **Mean Squared Error at Objective** | |
|---|---|---|
| | **Good Weather** | **Poor Weather** |
| **50% Air Means & 50% Sea Means** | 0.784 | 2.824 |
| **0% Air Means & 100% Sea Means** | 0.957 | 2.877 |
| **75% Air Means & 25% Sea Means** | 0.737 | 2.847 |
| ***100% Air Means & 0% Sea Means*** | ***0.677*** | ***0.777*** |

(Note: Based on no aircraft attrition)

**Table XX-3:** MSE at Objective with different Replenishment Options

A 100% air replenishment option in a no air attrition environment results in a lower MSE and is also more robust under inclement weather conditions. This suggests that using air transportation to deliver resources ashore is more reliable as it provides a stable resource level at the Objective. However, this conclusion must be qualified. This result was only possible by zeroing the attrition for the air route between the Sea Base and the Objective. In reality, this is only possible if true air superiority is gained, and only then will attrition be minimized or eliminated.

### b. Days of Supply (DOS) at the Sea Base

| | Mean Squared Error at Sea Base | |
|---|---|---|
| | Good Weather | Poor Weather |
| 50% Air Means & 50% Sea Means | 13.354 | 11.091 |
| 0% Air Means & 100% Sea Means | 14.151 | 11.667 |
| 75% Air Means & 25% Sea Means | 13.492 | 12.257 |
| *100% Air Means & 0% Sea Means* | *8.489* | *9.936* |

(Note: Based on no aircraft attrition)

**Table XX-4:** MSE at Sea Base with different Replenishment Options

At the Sea Base, the same picture was presented. Omitting either air or sea means of replenishments from the Sea Base to the Objective results in an increased variability or a quick halt to the re-supply missions due to the attrition of the aircraft.

Similarly at the Sea Base, the option of using 100% air replenishments in a no air attrition environment results in the lowest variability and increased robustness in inclement weather conditions. Conclusively, replenishments via air can improve the stability of the resource levels at both the Sea Base and the Objective.

## G. AERIAL THROUGHPUT OF THE SEA BASE

### 1. Scope of the Problem

One of the most important capabilities of the Sea Base is to support and sustain the warfighters ashore. Having the means to get "the right stuff, to the right place, at the right time" is critical in order to carry out STOM. Moving large quantities of logistical supplies OTH from the Sea Base to 200 NM inland requires a large dependence on air assets and a large enough Sea Base to support those air assets.

Concentrating on the Conceptual Sea Base architecture designed by NPS' TSSE Team and the Heavy Lift Aircraft designed by NPS' AERO Team, this study examines the aerial throughput required to support and sustain indefinitely a notional MEB's Landing Force in 2015-2020.

The main objectives of this aerial throughput study are to compare sustainment capabilities of the Planned architecture to the Conceptual architecture at 25, 55, and 250 NM, calculate the throughput rate (tons delivered per day) for the Conceptual architecture at 225, 250, and 275 NM, develop a spreadsheet model that produces charts and graphs that can be used as a planning tool, and analyze the Heavy Lift Aircraft using a modeling and simulation program – ARENA™.

In order to carry out these objectives, the force and the supporting assets need to be identified.

## 2. Marine Expeditionary Brigade

The Marine Corps is a rapid-action response force that deploys as a MAGTF and is scalable depending on the mission. The MEU is the smallest scalable force with approximately 2,200 personnel. The MEU is able to sustain itself for 15 days and has a limited capability.

The intermediate scalable force is the MEB, consisting of approximately 17,000 personnel and having the following capabilities:

- Responsive to a full range of crises
- Has a forcible entry capability
- Enabler for follow-on joint or combined forces
- Operates as an independent operational maneuver element
- Creates and exploits the enemies weaknesses attacks the center of gravity
- Deploys either by air, sea, or both
- 30 Days self-sustainment capability

As one of the key project assumptions, the future MEB size MAGTF of 2015-2020 will remain relativity the same as the current. The table below represents a representative MEB of 2015 – 2020.

| | Marines | | Navy | | | |
|---|---|---|---|---|---|---|
| ***Detachment/Unit*** | Officer | Enlisted | Officer | Enlisted | Civilian | Total |
| ***Command Element (CE)*** | 111 | 635 | 5 | 10 | 2 | 763 |
| ***Ground Combat Element (GCE)*** | 315 | 5,477 | 18 | 272 | 0 | 6,082 |
| ***Aviation Command Element (ACE)*** | 608 | 4,470 | 35 | 130 | 0 | 5,243 |
| ***Brigade Service Support Group (BSSG)*** | 87 | 1924 | 76 | 228 | 0 | 2,315 |
| ***MPF MEB TOTAL*** | 1121 | 12506 | 134 | 640 | 2 | 14,403 |
| ***MPF MEB*** | | | | | | 14,403 |

**Table XX-5:** Maritime Prepositioning Force (MPF) Marine Expeditionary Brigade (MEB) (Source: Headquarters U.S. Marine Corps)

The largest MAGTF force is the Marine Expeditionary Force (MEF). The MEF is most capable of the three Marine Corps forces. It is self-sustainable for approximately 60 days and has approximately 50,000 combat personnel.

Although the three force structures vary in size, they have the same common denominator -- organizational elements. All three of the scalable Marine Corps force packages consist of the following elements: Command Element (CE), Ground Combat Element (GCE), Aviation Combat Element (ACE), and Combat Service Support Element (CSSE).

### 3. Daily Sustainment Requirement for a MEB Size Landing Force

For the purpose of this study, the daily sustainment requirements are based on a reduced MEB ashore -- MEB size Landing Force only. What makes up the reduced MEB size Landing Force? The Landing Force consists of three elements – the CE, the GCE, and the CSSE. The CE is reduced by approximately half its original composition. Half of the CE goes ashore, while the other half remains at the Sea Base. The GCE retains the same number of personnel, whereas, the GSSE is reduced by 75 percent. With an effective Sea Base, the logistical footprint ashore is greatly reduced – the more robust the Sea Base, the less the logistical tail ashore. Refer to Table XX-6 for the composition and number of personnel assigned to a reduced MEB size Landing Force.

| ***MEB Landing Force*** | ***Personnel*** |
|---|---|
| ***Command Element*** | 365 |
| ***Ground Combat Element*** | 5,694 |
| ***Combat Service Support Element*** | 747 |
| ***Total*** | 6,806 |

**Table XX-6:** Marine Expeditionary Brigade Landing Force (Source: Naval Board Studies, 1999)

The daily sustainment requirement is calculated using the following factors: the number of personnel, equipment required, consumption rates, environment, and opposing force. Based on characteristics and purpose, the Marine Corps divides their supplies into 10 classes. The following is a list of the 10 classes of supplies (MCCDC, 1999, 1-7):

a. Class I - Subsistence (Food and Water)
b. Class II - Individual Equipment
c. Class III – Petroleum, Oils, Lubricants (POL)
d. Class IV – Construction Material
e. Class V – Ammunition (W) represents ground, (A) represents air
f. Class VI – Personal Demand Items or Non-Military Sales Items
g. Class VII – Major End Items
h. Class VIII – Medical and Dental Items
i. Class IX – Repair Parts
j. Class X – Non-Military Program Materials

Although all the classes are important, Classes I, III, V, and IX receive special attention because they require the most logistical effort ashore. As a result, this study concentrates on the logistical challenge that faces the Sea Base's ability to meet these demands – moving large amounts over long distances. This study examines throughput as the Measure of Effectiveness (MOE). Throughput is the average quantity of cargo, equipment, and/or passengers that can pass from the Sea Base to the Objective on a daily basis. In this case, throughput is expressed in short tons per day. In different scenarios bad weather and attrition reduce the throughput rate, but in this study we assume good weather and no attrition. Additionally, throughput may be delivered by surface, air, or both, but this study concentrates on the aerial throughput.

To scope the problem, the throughput in this study examines the short tons per day of daily supply requirements that air assets are capable of delivering. Table XX-7 shows the daily requirements (tons per day) required to sustain a MEB size Landing Force.

| **I** | **I** | **III** | **V** | **IX** | |
|---|---|---|---|---|---|
| ***Food*** | ***Water*** | ***Fuel*** | ***Ammunition*** | ***Other Cargo*** | ***Total*** |
| 14.97 | 189.89 | 225.01 | 33.48 | 26.54 | 489.89 |

**Table XX-7:** Marine Expeditionary Brigade size Landing Force Daily Re-supply Requirements. (Source: Naval Studies Board, Appendix C)

Clearly, the largest burdens imposed on aerial delivery assets are fuel, water, and ammunition. To meet the MOE, we proposed a Heavy Lift Aircraft to complement the MV-22; thereby ensuring daily re-supply requirements could reach their Objective.

#### 4. MV-22 and Heavy Lift Aircraft

The MV-22 is the Marine Corps' medium range assault and support aircraft that takes off vertically and can transition to fly like a fixed-wing aircraft. The MV-22 is scheduled to replace the aging and maintenance prone CH-46 helicopter. The MV-22 provides several advantages over the CH-46. First, with greater speed, range, and external cargo capacity, the MV-22 can build up combat power ashore much faster and at greater distances. Second, with its longer combat radius, the enemy has to defend a larger area, diluting their combat power. Third, unlike the CH-46, the MV-22 has the capability to conduct in-flight refueling, thus increasing its range even further. Fourth, and most importantly, the MV-22's OTH capability, coupled with its heavier payload capacity and long range, is better suited to support the operational concept OMFTS, and its implementing concepts – STOM, and Sea Based Logistics (SBL) (MCCDC and NDC 1998).

We discovered that the Planned air assets consisting of thirty-six MV-22s and eight CH-53Es are not capable of supporting and sustaining a MEB size Landing Force for an indefinite period at long distances without setting up a vulnerable refueling site. A mobile Forward Refueling and Arming Position could be established, but the tradeoff would be survivability and slower build up times at the Objective. As envisioned in operational concept OMFTS, and its implementing concept – STOM, and SBL, the distance from the Sea Base to the Objective could exceed 225 NM – 25 NM from the Sea Base to the beach and 200 NM inland.

Current trends suggest that the safe standoff distances between the Sea Base and the beach will increase because of improved advanced technologies in threat missiles and gunfire. With an increased standoff distance from the Sea Base to the beach, the aviation assets re-supplying the combat troops ashore will require larger payload capacities at longer ranges, thus generating a need for a Heavy Lift Aircraft.

Having examined the potential risks associated with future ExWar operations in terms of re-supplying the combat forces ashore, we wrote requirements for NPS' AERO Design Team. Refer to Chapter XV for additional information on the Long Range, Heavy Lift Aircraft and its requirements. If designed to the requirements, the Heavy Lift Aircraft will have the capability to carry an external payload of 37,500 pounds 300 NM from the Sea Base to the Objective, offload its payload, and return to the Sea Base without refueling. Additionally, the Heavy Lift Aircraft will be capable of carrying an internal load of 20,000 pounds for 300 NM, offloading, and returning to the Sea Base without refueling.

### 5. Sea Base

In order to handle the high volume of air operations required to surge and sustain a MEB size Landing Force indefinitely, the Sea Base becomes an integral part of the system of systems needed to carry out future ExWar as envisioned. NPS' TSSE Team designed a family of six ships to form a Sea Base. Figure XX-6 is a conceptual illustration of one of the six ships that forms the Sea Base. Additionally, three other ships with the same hull form are used as shuttle ships to transit back and forth from a mobile or fixed off shore base to re-supply the Sea Base.

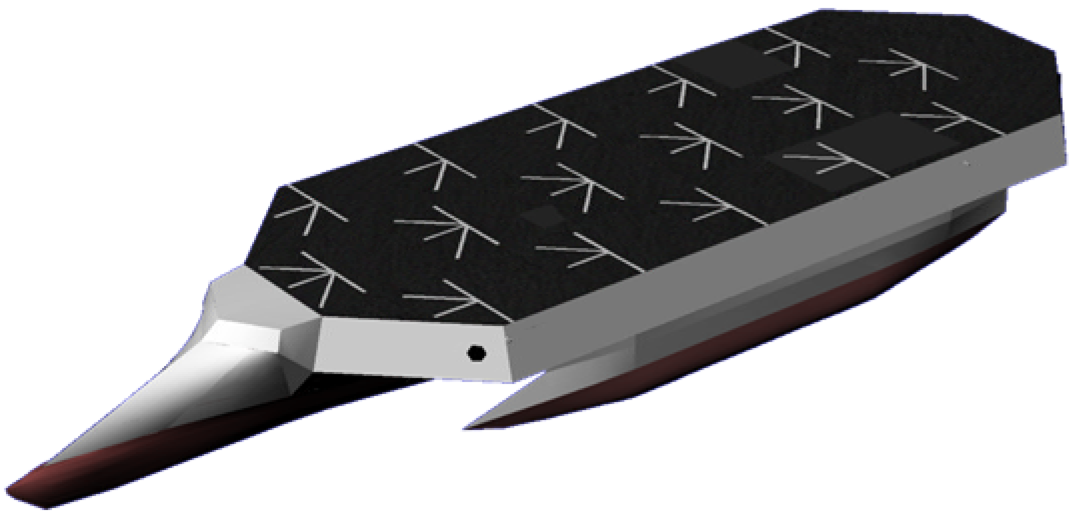


**Figure XX-6:** NPS' TSSE Ship Design

With a high volume of cargo requiring transportation to support combat troops ashore, the flight deck provides sixteen possible spots capable of conducting air operations. In comparison, the LHD and LHA each have 9 usable helicopter spots. The MV-22 requires one spot and the Heavy Lift Aircraft requires 2 spots. Figure XX-7 is an illustration of the flight deck spots on the X-Ship.

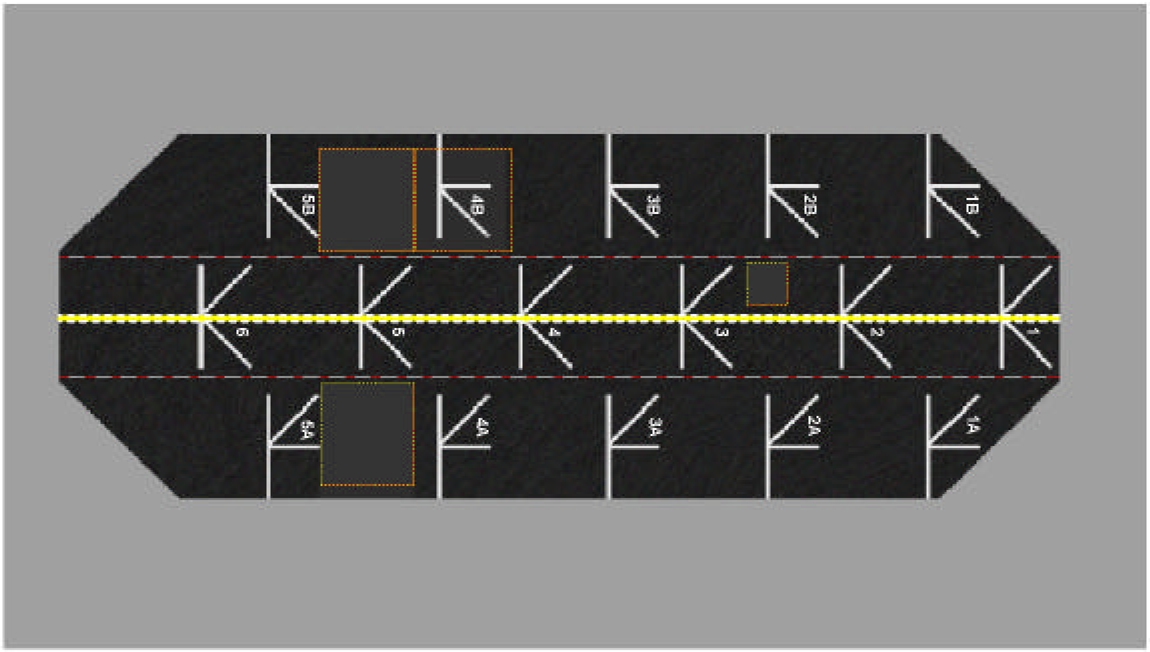



**Figure XX-7:** X-Ship's Flight Deck Layout

### 6. Planned Aviation Asset versus Conceptual Aviation Assets

In order to conduct a comparative analysis between the Planned aviation assets and the Conceptual aviation assets, a baseline for aerial throughput sustainment had to be established. The baseline was established by using the results from the *Naval Expeditionary Logistics* study conducted by the Naval Studies Board in 1999. After the baseline was established, the throughput for the Conceptual aviation assets was calculated. Using the same methodology that was used in the 1999 Naval Studies Board on Naval Expeditionary Logistics, the aerial throughput for the Conceptual aviation assets was calculated. The Conceptual aviation assets showed a dramatic improvement in aerial throughput for sustaining combat forces ashore.

### 7. Approach and Assumptions

The approach used to calculate aerial throughput uses the same method as in Appendix C of *Naval Expeditionary Logistics: Enabling Operational Maneuver From the Sea* (Naval Board Studies, 1999, Appendix C). Using Microsoft Excel, a spreadsheet model of throughput - tons delivered per day for each type of air transporter - was calculated for the Planned Aviation Assets - 36 MV-22s and 8 CH-53Es, as well as the Conceptual Aviation Assets 96 MV-22s and 24 Heavy Lift Aircraft.

Table XX-8, although slightly different from Table C.3 in Appendix C of the *Naval Expeditionary Logistics* publication, shows the basic layout for calculating tons delivered per 10 hours of operating time. Table XX-8, unlike Table C.3 in Appendix C, provides a range of operational availabilities instead of just one for the MV-22 and the CH-53E. The numbers for total tons delivered are slightly different due to rounding errors. Table XX-8, a sample of the Aerial Throughput Model has sixteen columns that contribute to the final results of total tons delivered. The following describes the contents of each column:

**a. First Column**

The first column lists the ranges of interest – specifically, 55, 125, and 250 NM.

**b. Second Column**

The second column refers to eighty-five percent capacity of the maximum payload in short tons (ST). Due to different internal and external payload weights, the percent percent factor multiplied by the maximum payload accounts for the average payload weight for a light or heavy payload. Unlike the MV-22 and CH-53E, the Heavy Lift Aircraft uses a seventy percent factor vice eighty-five percent factor because the Conceptual design has not been tested. Typically, as range increases, payload decreases. The Heavy Lift Aircraft, on the other hand, uses a maximum payload of 37,500 pounds for external lifts and 20,000 pounds for internal lift for all range up to and including 300 NM as stated in the Operational Requirements Documents (ORD). Refer to Chapter XV for additional information on the Heavy Lift Aircraft.

| Distance (NM) | 85 % of Max Payload (short tons) | Speed w/load (knots) | Speed w/o load (knots) | Time To Objective (TTO) (hours) | Return Time to Sea Base (RTTSB) | Cycle Time | Cycle Time With Delay | Cycles Per Aircraft | Cycle(s) | Deliveries Per Cycle | Operational Availability | Number of Aircraft | Total Operational Availability (Ao) | Fully Mission Capable (FMC) | Total Tons Delivered |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 55 | 4.93 | 240 | 240 | 0.229 | 0.229 | 0.458 | 1.208 | 8.28 | 8 | 39.44 | 0.9 | 36 | 32.40 | 32 | 1262 |
| 55 | 4.93 | 240 | 240 | 0.229 | 0.229 | 0.458 | 1.208 | 8.28 | 8 | 39.44 | 0.85 | 36 | 30.60 | 30 | 1183 |
| 55 | 4.93 | 240 | 240 | 0.229 | 0.229 | 0.458 | 1.208 | 8.28 | 8 | 39.44 | 0.8 | 36 | 28.80 | 28 | 1104 |
| 55 | 4.93 | 240 | 240 | 0.229 | 0.229 | 0.458 | 1.208 | 8.28 | 8 | 39.44 | 0.75 | 36 | 27.00 | 27 | 1065 |
| 55 | 4.93 | 240 | 240 | 0.229 | 0.229 | 0.458 | 1.208 | 8.28 | 8 | 39.44 | 0.7 | 36 | 25.20 | 25 | 986 |
| 55 | 4.93 | 240 | 240 | 0.229 | 0.229 | 0.458 | 1.208 | 8.28 | 8 | 39.44 | 0.65 | 36 | 23.40 | 23 | 907 |
| 55 | 4.93 | 240 | 240 | 0.229 | 0.229 | 0.458 | 1.208 | 8.28 | 8 | 39.44 | 0.6 | 36 | 21.60 | 21 | 828 |
| 55 | 4.93 | 240 | 240 | 0.229 | 0.229 | 0.458 | 1.208 | 8.28 | 8 | 39.44 | 0.55 | 36 | 19.80 | 19 | 749 |
| 55 | 4.93 | 240 | 240 | 0.229 | 0.229 | 0.458 | 1.208 | 8.28 | 8 | 39.44 | 0.5 | 36 | 18.00 | 18 | 710 |
| | | | | | | | | | | | | | | | |
| 125 | 4.46 | 240 | 240 | 0.521 | 0.521 | 1.042 | 1.792 | 5.58 | 5 | 22.3 | 0.9 | 36 | 32.40 | 32 | 714 |
| 125 | 4.46 | 240 | 240 | 0.521 | 0.521 | 1.042 | 1.792 | 5.58 | 5 | 22.3 | 0.85 | 36 | 30.60 | 30 | 669 |
| 125 | 4.46 | 240 | 240 | 0.521 | 0.521 | 1.042 | 1.792 | 5.58 | 5 | 22.3 | 0.8 | 36 | 28.80 | 28 | 624 |
| 125 | 4.46 | 240 | 240 | 0.521 | 0.521 | 1.042 | 1.792 | 5.58 | 5 | 22.3 | 0.75 | 36 | 27.00 | 27 | 602 |
| 125 | 4.46 | 240 | 240 | 0.521 | 0.521 | 1.042 | 1.792 | 5.58 | 5 | 22.3 | 0.7 | 36 | 25.20 | 25 | 558 |
| 125 | 4.46 | 240 | 240 | 0.521 | 0.521 | 1.042 | 1.792 | 5.58 | 5 | 22.3 | 0.65 | 36 | 23.40 | 23 | 513 |
| 125 | 4.46 | 240 | 240 | 0.521 | 0.521 | 1.042 | 1.792 | 5.58 | 5 | 22.3 | 0.6 | 36 | 21.60 | 21 | 468 |
| 125 | 4.46 | 240 | 240 | 0.521 | 0.521 | 1.042 | 1.792 | 5.58 | 5 | 22.3 | 0.55 | 36 | 19.80 | 19 | 424 |
| 125 | 4.46 | 240 | 240 | 0.521 | 0.521 | 1.042 | 1.792 | 5.58 | 5 | 22.3 | 0.5 | 36 | 18.00 | 18 | 401 |
| | | | | | | | | | | | | | | | |
| 250 | 3.27 | 240 | 240 | 1.042 | 1.042 | 2.083 | 2.833 | 3.53 | 3 | 9.81 | 0.9 | 36 | 32.40 | 32 | 314 |
| 250 | 3.27 | 240 | 240 | 1.042 | 1.042 | 2.083 | 2.833 | 3.53 | 3 | 9.81 | 0.85 | 36 | 30.60 | 30 | 294 |
| 250 | 3.27 | 240 | 240 | 1.042 | 1.042 | 2.083 | 2.833 | 3.53 | 3 | 9.81 | 0.8 | 36 | 28.80 | 28 | 275 |
| 250 | 3.27 | 240 | 240 | 1.042 | 1.042 | 2.083 | 2.833 | 3.53 | 3 | 9.81 | 0.75 | 36 | 27.00 | 27 | 265 |
| 250 | 3.27 | 240 | 240 | 1.042 | 1.042 | 2.083 | 2.833 | 3.53 | 3 | 9.81 | 0.7 | 36 | 25.20 | 25 | 245 |
| 250 | 3.27 | 240 | 240 | 1.042 | 1.042 | 2.083 | 2.833 | 3.53 | 3 | 9.81 | 0.65 | 36 | 23.40 | 23 | 226 |
| 250 | 3.27 | 240 | 240 | 1.042 | 1.042 | 2.083 | 2.833 | 3.53 | 3 | 9.81 | 0.6 | 36 | 21.60 | 21 | 206 |
| 250 | 3.27 | 240 | 240 | 1.042 | 1.042 | 2.083 | 2.833 | 3.53 | 3 | 9.81 | 0.55 | 36 | 19.80 | 19 | 186 |
| 250 | 3.27 | 240 | 240 | 1.042 | 1.042 | 2.083 | 2.833 | 3.53 | 3 | 9.81 | 0.5 | 36 | 18.00 | 18 | 177 |

**Table XX-8:** Tons Delivered Per Day for a MV-22 with an Internal Load and 10-Hour Operating Time (Source: Naval Board Studies, Appendix C)

### c. Third Column

The third column is the speed of the aircraft (knots) for an internal or external load.

### d. Fourth Column

The fourth column is the speed of the aircraft (knots) without the payload. The Naval Studies Board used the same speed for the aircraft both with a load and without a load. In the comparing Planned aviation assets and Conceptual aviation assets the same assumption was made, however, better analysis of the Conceptual aviation assets at 225, 250, and 275 NM required the different speeds.

### e. Fifth Column

The fifth column is the total time (hours) to the objective (TTTO). TTTO is calculated by dividing the first column by the third column.

### f. Sixth Column

The sixth column is the return time (hours) to the Sea Base (RTTSB). RTTSB is calculated by dividing the first column by the fourth column.

### g. Seventh Column.

The seventh column is the total cycle time (operating time) to complete one trip from the Sea Base to the Objective and back to the Sea Base. Cycle time is calculated by adding the fifth and sixth columns.

### h. Eighth Column

The eighth column is the total cycle time plus a 45-minute delay for loading, unloading, and refueling. The internal load requires a longer delay time than an external load, but this study uses the internal load as the standard. Column eight is calculated by adding a 45-minute delay to column seven.

### i. Ninth Column

The ninth column is the number of cycles for 10, 12, or 14-hours of flight.

Cycles per aircraft at the respective 10, 12, 14-hour flight day is calculated by dividing the flight hours by column eight.

### j. Tenth Column

The tenth column is the number of cycles per day as a whole integer. Cycles per day are calculated by using a round-down function on the ninth column. This method ensures a conservative number. To illustrate this point -- assume a Heavy Lift Aircraft with a .75 operational availability is carrying an external load for 250 NM at a 12 hour operating time. The number of cycles per aircraft for 12 hours is 3.83 cycles. Instead of finishing with 4 cycles the number is rounded down to 3 cycles. In terms of total tons delivered -- it is a difference of 945 STs minus 709 STs for a difference of 236 STs.

### k. Eleventh Column

The eleventh column is the total tons delivered (STs) during a 10, 12, or 14 hour operating time for each type of aircraft. Deliveries per aircraft for each day are calculated by multiplying second column by the tenth column.

### l. Twelfth Column

The twelfth column is the operational availability ($A_o$). Operational availability is "the probability that a system or equipment, when used under stated conditions in an actual operational environment, will operate satisfactorily when called upon" (Blanchard and Fabrycky 1998, 359). A range of .5 was incremented by .05 until the maximum $A_o$ of .9 was reached – (.5, .55, .6, .65, .7, .75, .8, .85, .90). Ideally, any aircraft having an operational availability greater than .75 is considered the norm.

### m. Thirteenth Column

The thirteenth column shows the number of aircraft tentatively scheduled to be part of the future Sea Base. The Planned Aviation Assets are as follows: 36 MV-22s and 8 CH-53Es and the Conceptual Aviation Assets are as follows: 96 MV-22s and 24 Heavy Lift Aircraft. The aircraft listed are only part of the ACE. Additional aircraft are assigned to the ACE, but will not use as part of the major re-supply lift.

#### n. Fourteenth Column

The fourteenth column is the available aircraft. Available aircraft is the number of aircraft times the operation availability. Availability is calculated by multiplying the twelfth column by the thirteenth column.

#### o. Fifteenth Column

The fifteenth column uses the round-down function on the fourteenth column to give the Fully Mission Capable (FMC) Aircraft.

#### p. Sixteenth Column

The sixteenth column is the total tons delivered per day. The total tons delivered per day are calculated by multiplying the eleventh column by the fifteenth column.

The methodology used above does not take into account bad weather or attrition due to enemy fire. However, with a range of operational availabilities, the FMC can be adjusted to account for enemy attrition. For example, assume the attrition rate for Heavy Lift Aircraft is 5 percent for the first three days during the initial assault phase. Additionally, assume the operational availability is .75 percent. To find the adjusted total tons delivered, use a new operational availability of .60 instead. To account for weather, the speed and payloads could be adjusted to account for bad weather.

For computations for both internal and external loads at 10, 12, and 14 hour operating times refer to Appendix 20-2.

### 8. Comparing Planned Aviation Assets to Conceptual Aviation Assets

Using the throughput results from the Aerial Throughput model, the percentages of re-supply requirements were calculated and Tables XX-9 and XX-10 shows the results. This study assumed the following: First, there are no aerial or shore based refueling assets available. Second, the distance represented (Sea Base to Objective) is the distance the aircraft can fly one-way form the Sea Base to the Objective with a payload, unload its payload, and return to the Sea Base. Third, the MV-22 does not have the capability to carry an external payload 250 nm or greater. Fourth, the aircraft can carry internal loads or external loads, but not both.

In Table XX-9, we show the percentage of re-supply for air deliveries at a 10-hour flight day utilizing 27 MV-22s and 5 CH-53s. Planned aviation assets consist of 36 MV-22s and 8 CH-53Es; however, the table takes into account operational availabilities for both aircraft. The MV-22 uses an operational availability .75 -- 36 times .75 equals 27 FMC aircraft. The CH-53E, on the other hand, uses a lower operational availability of .70 – 8 times .70 equals 5.6, but this number is rounded down to 5 FMC aircraft. Table XX-9 illustrates two very important points. First, Planned aviation air assets alone do not have the capability to re-supply combat forces ashore at 250 NM. Second, as the supply demand ashore decreases, the percent of re-supply increases.

| ***Percent of Re-supply Requirements Met by Air Deliveries at a 10-Hour Operating Time Using all Planned Sea Base Air Assets -- MV-22s and CH-53Es*** | | | | | |
|---|---|---|---|---|---|
| ***Portion of Force Supported*** | ***Tons Needed short tons*** | ***Number of Personnel*** | **250 nm** | **125 nm** | **55 nm** |
| ***Full MEF (FWD)*** | ***2,235*** | ***17,800*** | **15 percent** | **34 percent** | **62 percent** |
| ***MEF (FWD) less ACE*** | ***848*** | ***10,460*** | **40 percent** | **88 percent** | **165 percent** |
| ***MEF (FWD) less ACE and CE*** | ***785*** | ***9,660*** | **43 percent** | **95 percent** | **178 percent** |
| ***Landing Force only*** | ***490*** | ***6,800*** | **69 percent** | **153 percent** | **285 percent** |

(Note: For Landing Force only at 250 NM, the Planned Aviation Assets cannot meet the daily re-supply requirements, which include fuel, water, food, ammo, and spares.)

**Table XX-9:** Percent of Re-supply for Planned Aviation Assets (Naval Studies Board, 1999, Chapter 4)

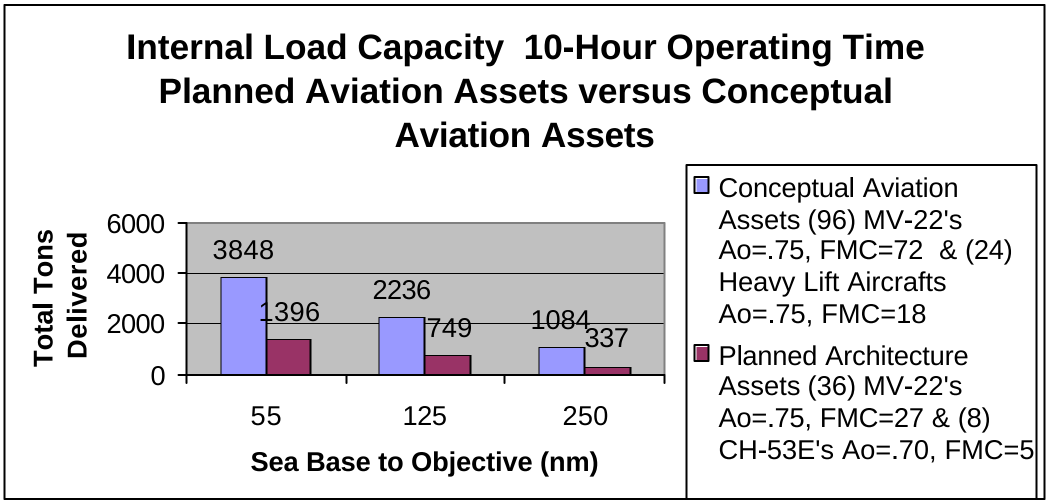
In Table XX-10, we show the percentage of re-supply for air deliveries for a 10-hour flight day utilizing 72 MV-22s and 18 Heavy Lift Aircraft. Conceptual aviation assets consist of 96 MV-22s and 24 Heavy Lift Aircraft; however, the table takes into account operational availabilities for both aircraft. The MV-22 uses an operational availability .75 -- 96 times .75 equals 72 FMC aircraft. The Heavy Lift Aircraft uses an operational availability of .75 – 24 times .75 equals 18 FMC aircraft. Table XX-10 shows dramatic improvements at all ranges and combat troops supported. The only situation where the Conceptual aviation assets are not adequate is the re-supply requirement for a full MEB equivalent force ashore at 250 NM. When comparing Tables XX-9 and XX-10, the Conceptual has 11 out of 12 "100 percent", whereas, the Planned only has 4 out of 12.

| ***Percent of Re-supply Requirements Met by Air Deliveries at a 10-Hour Operating Time Using all Conceptual Sea Base Air Assets -- MV-22s and Heavy Lift Aircraft*** | | | | | |
|---|---|---|---|---|---|
| ***Portion of Force Supported*** | ***Tons Needed short tons*** | ***Number of Personnel*** | **250 nm** | **125 nm** | **55 nm** |
| ***Full MEF (FWD)*** | ***2,235*** | ***17,800*** | **49 percent** | **100 percent** | **172 percent** |
| ***MEF (FWD) less ACE*** | ***848*** | ***10,460*** | **128 percent** | **264 percent** | **454 percent** |
| ***MEF (FWD) less ACE and CE*** | ***785*** | ***9,660*** | **138 percent** | **285 percent** | **490 percent** |
| ***Landing Force only*** | ***490*** | ***6,800*** | **221 percent** | **456 percent** | **785 percent** |

(Note: For a Landing Force only, the Conceptual Aviation Assets can meet the daily re-supply requirements by 221%.)

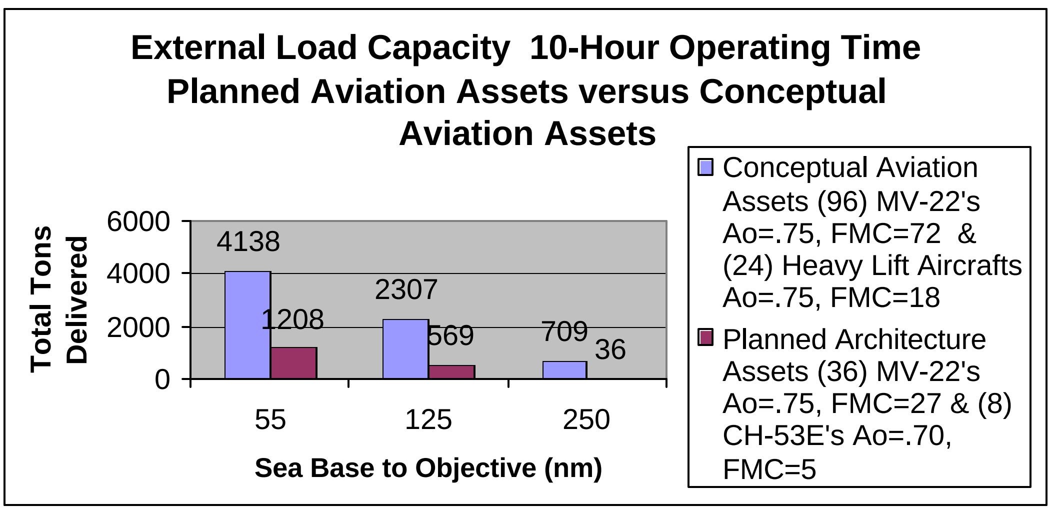
**Table XX-10:** Percent of Re-supply for Conceptual Aviation Assets

Clearly, the Conceptual aviation assets are better suited for re-supply at longer ranges and larger footprints, but how much better? The next several tables will provide a comparative look at the Conceptual aviation assets versus the Planned aviation assets. The comparison shows the total tons delivered for both the Conceptual and Planned aviation assets. We choose three different operating times and two different loads. The normal operating time (flight day) for aviation operations is 12 hours, so we selected 12 hours plus and minus 2 hours. All three aircraft carry either internal or external loads.




(Note: Daily re-supply requirement for Landing Force only is 490 tons.)

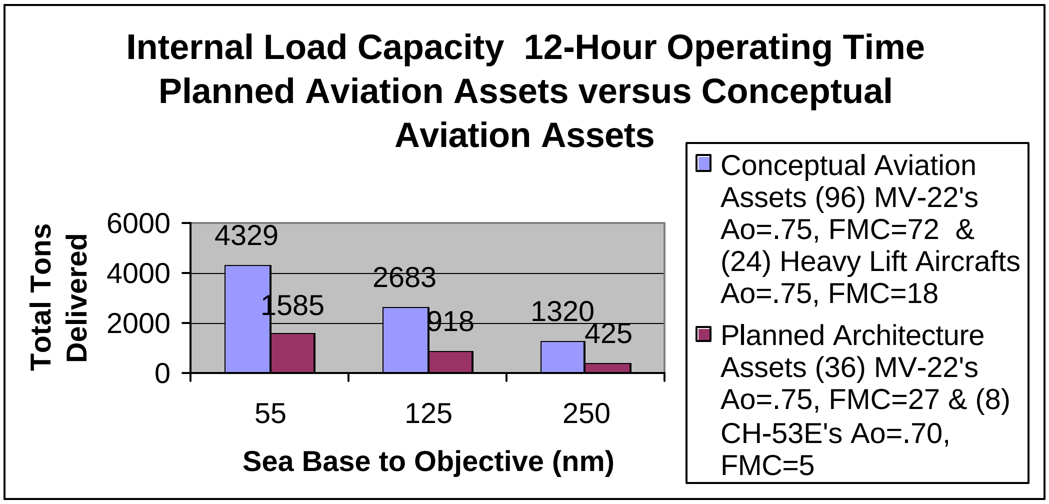
**Figure XX-8:** Throughput of Planned versus Conceptual Aviation Assets with an Internal Load and 10-Hour Operating Time




(Note: Daily re-supply requirement for Landing Force only is 490 tons.)

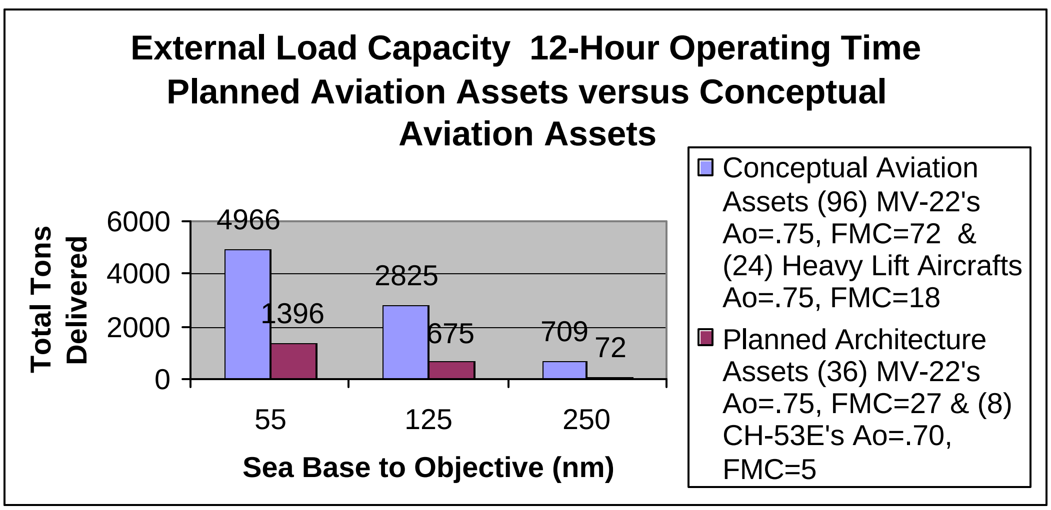
**Figure XX-9:** Throughput of Planned versus Conceptual Aviation Assets with an External Load and 10-Hour Operating Time

Figures XX-8 and XX-9 provide a comparative look at Planned aviation assets and NPS' Conceptual aviation assets for internal and external loads. In Figure XX-8, the internal load capacity of the Conceptual has a much higher throughput rate than the Planned. As the range increases, the throughput ratio, Conceptual throughput divided by Planned throughput, increases -- 2.76 times more throughput at 55NM, 2.98 at 125 NM, and 3.22 at 250. Figure XX-9 shows the same throughput ratio increase, but at a much faster rate. The throughput ratios are as follows: 3.43 at 55 NM, 4.05 at 125 NM, and 19.69 at 250 NM. This suggests that the external load capacity for the Planned architecture lacks a long-range capability. Additionally, Planned has a better internal throughput capability than the external throughput capability, whereas, the Conceptual is better suited for external lift than internal lift.




(Note: Daily re-supply requirement for Landing Force only is 490 tons.)

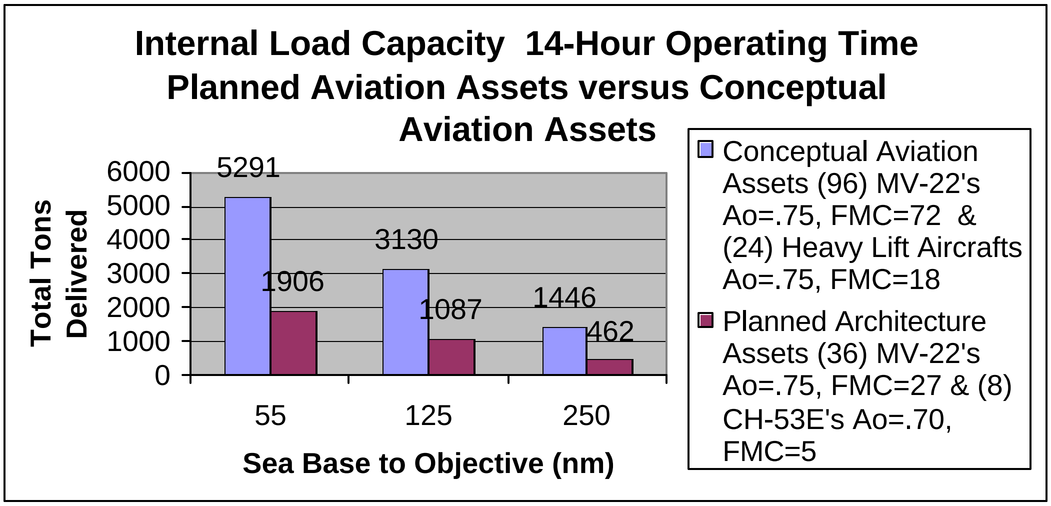
**Figure XX-10:** Throughput of Planned versus Conceptual Aviation Assets with an Internal Load and 12-Hour Operating Time




(Note: Daily re-supply requirement for Landing Force only is 490 tons.)

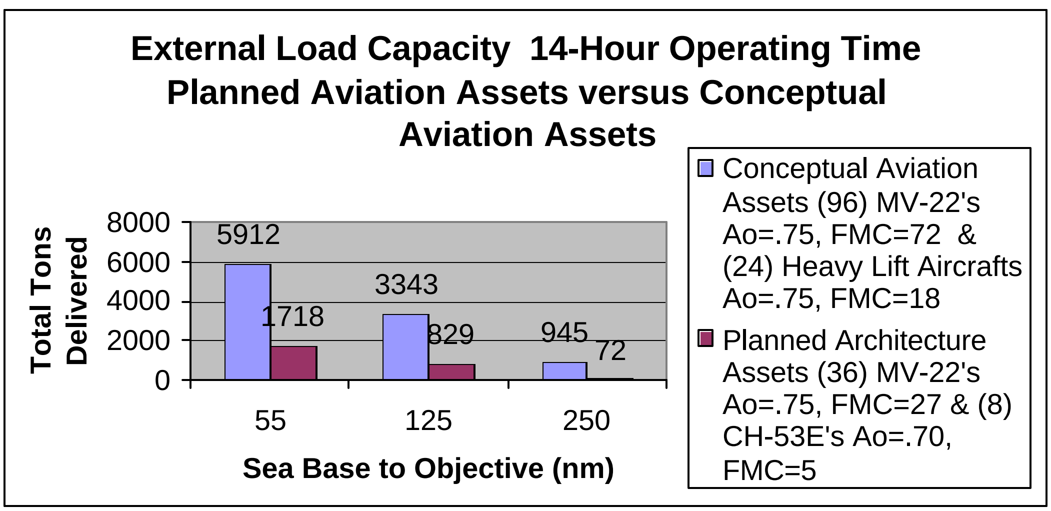
**Figure XX-11:** Throughput of Planned versus Conceptual Aviation Assets with an External Load and 12-Hour Operating Time

Figures XX-10, XX-11, XX-12, and XX-13 are the basically the same and yield similar results as Figures XX-8 and XX-9, but have different operating times. This suggests longer operating times can help meet short term surge requirements.




(Note: Daily re-supply requirement for Landing Force only is 490 tons.)

**Figure XX-12:** Throughput of Planned versus Conceptual Aviation Assets with an Internal Load and 14-Hour Operating Time




(Note: Daily re-supply requirement for Landing Force only is 490 tons.)

**Figure XX-13:** Throughput of Planned versus Conceptual Aviation Assets with an External Load and 14-Hour Operating Time

### 9. Conceptual Aviation Assets at Long-Range

The approach used to calculate throughput at long ranges uses the same methodology as applied in Table XX-8, but with two differences. First, the ranges of interest were changed to 225, 250, and 275 NM. Having the capability to use the sea as a maneuver space and the ability to strike deep inland enhances the Navy and Marine Corps ability to be first to the fight and first to fight. Second, the speed of the MV-22 with an external load was changed from 180 knots to 167 knots; and speed without a load was changed from 180 knots to 240 knots, both these speed changes provide a more realistic number.

Appendix 20-3 shows the calculated throughput for the Conceptual aviation assets of (24) Heavy Lift Aircraft and (96) MV-22s for internal and external loads. Using the information in Appendix 20-3, several graphs were developed to show the throughput required for one, two, and three days of re-supply. The daily re-supply requirement for a MEB size Landing Force of approximately 6,800 personnel is 490 STs. Comparing the days of supplies to the Conceptual throughput capability provides an excellent planning tool for an operational planner. Having flexibility and throughput capability to move large amounts of supplies to combat troops ashore helps reduce their footprint, making them more mobile to engage the enemy. Using Figures XX-14 though XX-19, Tables XX-11, 12, and 13 were created to show whether or not the Conceptual aviation assets could delivered 1 DOS, 2 DOS, or 3 DOS within 10, 12, or 14 hours for either an external or internal load. Green means the daily re-supply requirement can be achieved and Red means the daily re-supply requirement cannot be achieved, assuming an operational availability of .75 – (18) Heavy Lift Aircraft and (72) MV-22s. The Conceptual aviation assets have the capability to deliver a one- day re-supply for all three distances with the exception of an external load at 275 NM and a 10-hour operating time. The requirement to conduct a two-day re-supply is possible with the exception of external loads at 250 and 275 NM. Additionally, it is possible to conduct a three-day re-supply at 225 NM, but not at 250 and 275 NM. At 14 hours for 225 NM, it is possible to conduct a three-day re-supply for both internal and external loads. At 12 hours for 225 NM only the internal load is possible.

| 225 NM | | | | |
|---|---|---|---|---|
| **Cycle Time** | **Payload** | **1 DOS** | **2 DOS** | **3 DOS** |
| **10** | **Internal** | **Green** | **Green** | **Red** |
| **10** | **External** | **Green** | **Green** | **Red** |
| **12** | **Internal** | **Green** | **Green** | **Green** |
| **12** | **External** | **Green** | **Green** | **Red** |
| **14** | **Internal** | **Green** | **Green** | **Green** |
| **14** | **External** | **Green** | **Green** | **Green** |

(Note: Operational Availability = .75 and the payload is all internal or all external, but not both. Green means can achieve daily re-supply requirements; Red means cannot achieve requirements.)

**Table XX-11:** Capability Matrix for Conceptual Aviation Assets at 225 NM

| 250 NM | | | | |
|---|---|---|---|---|
| **Cycle Time** | **Payload** | **1 DOS** | **2 DOS** | **3 DOS** |
| **10** | **Internal** | **Green** | **Green** | **Red** |
| **10** | **External** | **Green** | **Red** | **Red** |
| **12** | **Internal** | **Green** | **Green** | **Red** |
| **12** | **External** | **Green** | **Red** | **Red** |
| **14** | **Internal** | **Green** | **Green** | **Red** |
| **14** | **External** | **Green** | **Red** | **Red** |

(Note: Operational Availability = .75 and the payload is all internal or all external, but not both. Green means can achieve daily re-supply requirements; Red means cannot achieve requirements)

**Table XX-12:** Capability Matrix for Conceptual Aviation Assets at 250 NM

| 275 NM | | | | |
|---|---|---|---|---|
| **Cycle Time** | **Payload** | **1 DOS** | **2 DOS** | **3 DOS** |
| **10** | **Internal** | **Green** | **Green** | **Red** |
| **10** | **External** | **Red** | **Red** | **Red** |
| **12** | **Internal** | **Green** | **Green** | **Red** |
| **12** | **External** | **Green** | **Red** | **Red** |
| **14** | **Internal** | **Green** | **Green** | **Red** |
| **14** | **External** | **Green** | **Red** | **Red** |

(Note: Operational Availability = .75 and the payload is all internal or all external, but not both. Green means can achieve daily re-supply requirements; Red means cannot achieve requirements)

**Table XX-13:** Capability Matrix for Conceptual Aviation Assets at 275 NM

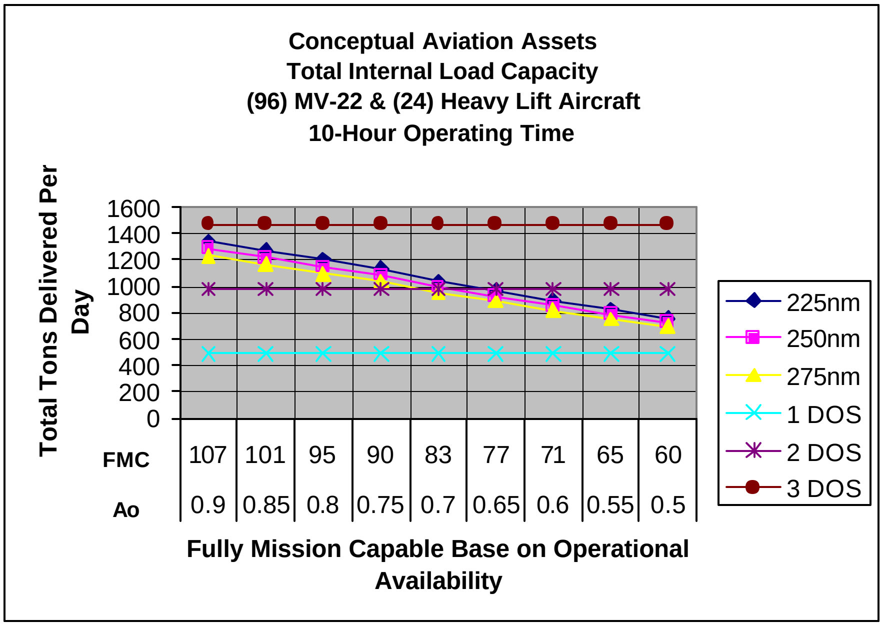



**Figure XX-14:** Comparison Between Conceptual Throughput to Days of Supply for an Internal Load at 10-Hour Operating Time

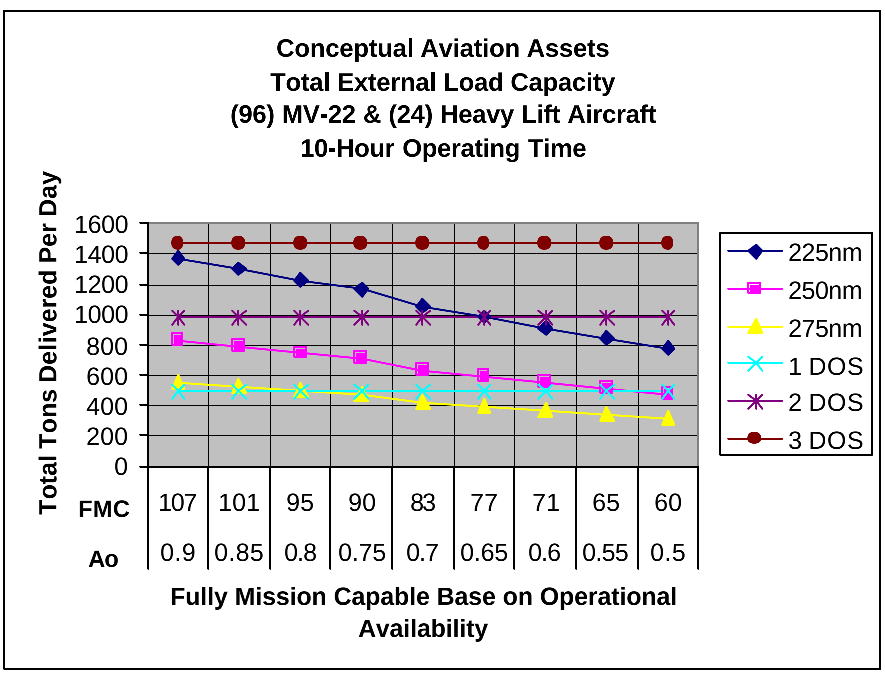



**Figure XX-15:** Comparison Between Conceptual Throughput to Days of Supply for an External Load at 10-Hour Operating Time

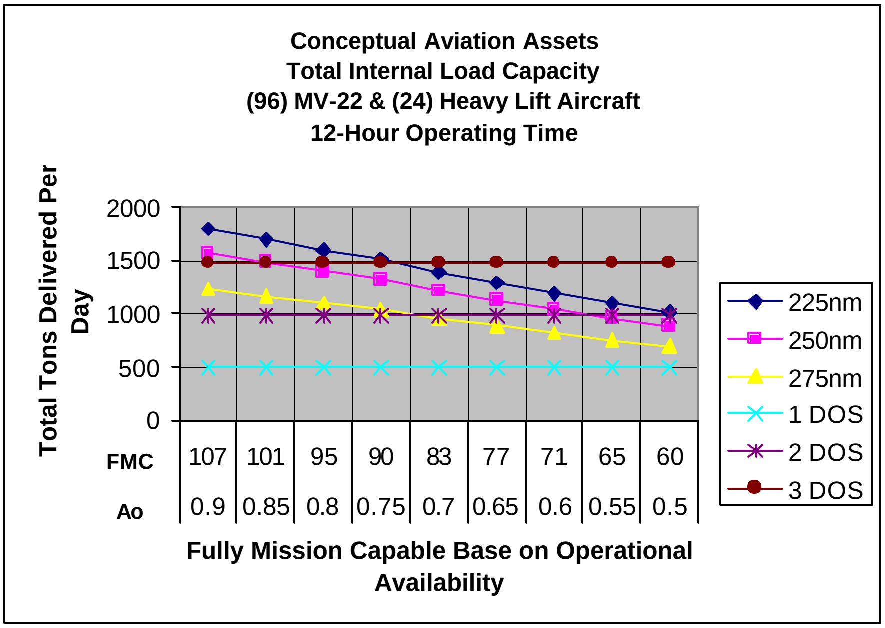



**Figure XX-16:** Comparison Between Conceptual Throughput to Days of Supply for an Internal Load at 12-Hour Operating Time

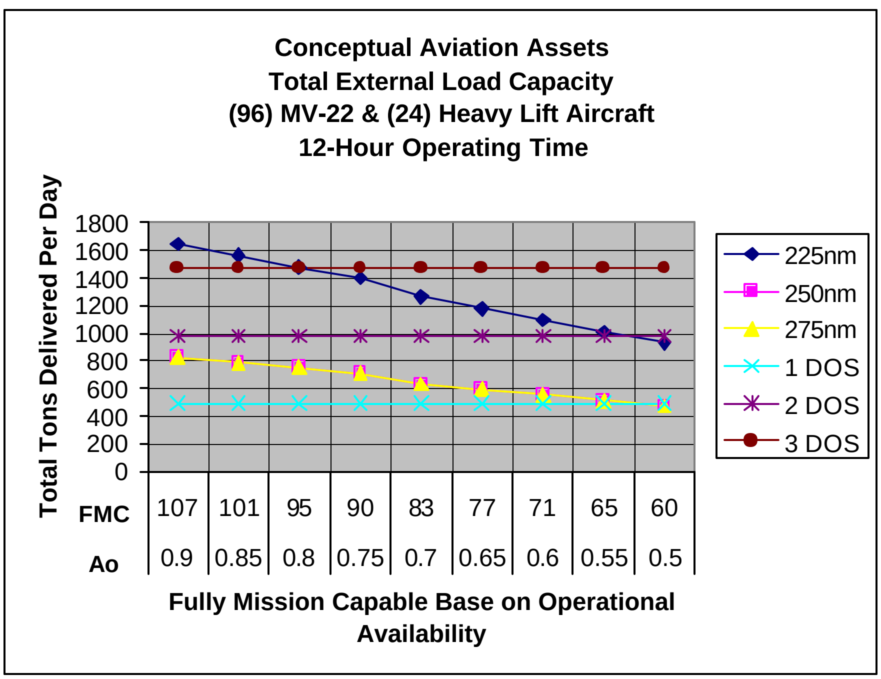



**Figure XX-17:** Comparison Between Conceptual Throughput to Days of Supply for an External Load at 12-Hour Operating Time

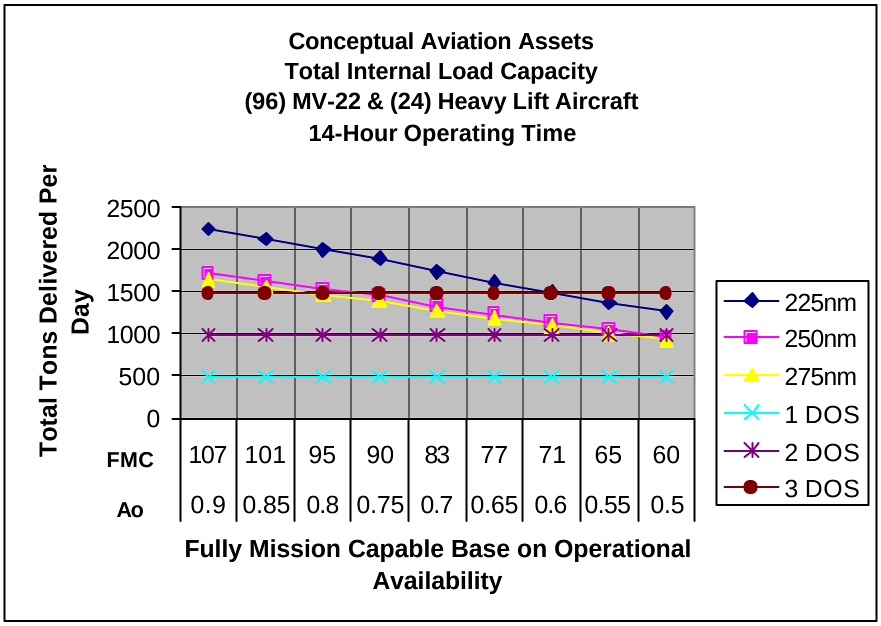



**Figure XX-18:** Comparison Between Conceptual Throughput to Days of Supply for an Internal Load at 14-Hour Operating Time

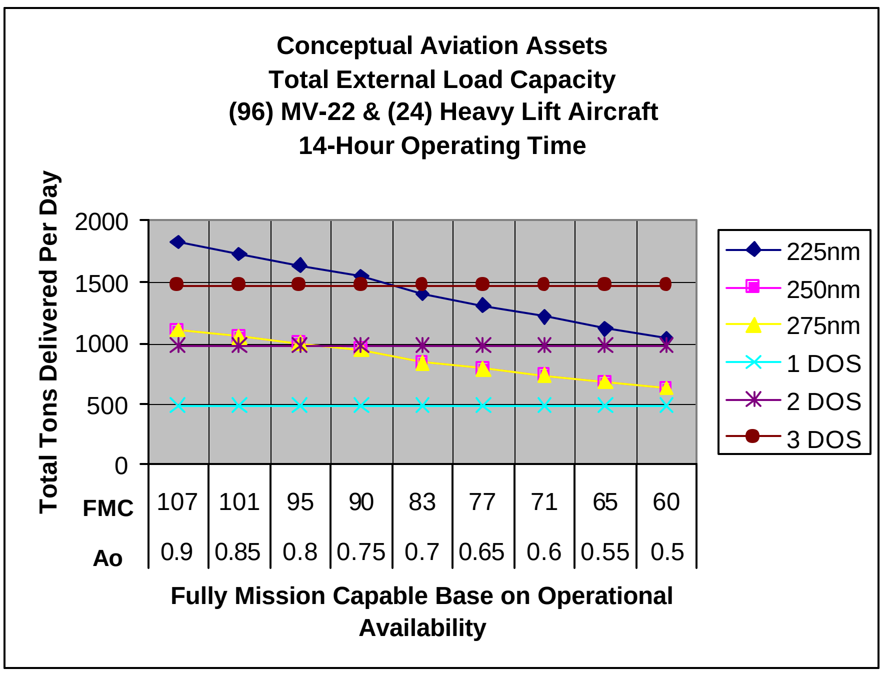



**Figure XX-19:** Comparison Between Conceptual Throughput to Days of Supply for an External Load at 14-Hour Operating Time

**External Load -- Heavy Lift Aircraft**

**Internal Load -- MV-22**

| | | | 21 | 20 | 19 | 18 | 16 | 15 | 14 | 13 | 12 | 21 | 20 | 19 | 18 | 16 | 15 | 14 | 13 | 12 | 21 | 20 | 19 | 18 | 16 | 15 | 14 | 13 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 225 | 225 | 225 | 225 | 225 | 225 | 225 | 225 | 225 | 250 | 250 | 250 | 250 | 250 | 250 | 250 | 250 | 250 | 275 | 275 | 275 | 275 | 275 | 275 | 275 | 275 | 275 |
| | | | 1103 | 1050 | 998 | 945 | 840 | 788 | 735 | 683 | 630 | 827 | 788 | 748 | 709 | 630 | 591 | 551 | 512 | 473 | 827 | 788 | 748 | 709 | 630 | 591 | 551 | 512 | 473 |
| 86 | 225 | 1204 | 2307 | 2254 | 2202 | 2149 | 2044 | 1992 | 1939 | 1887 | 1834 | 2031 | 1992 | 1952 | 1913 | 1834 | 1795 | 1755 | 1716 | 1677 | 2031 | 1992 | 1952 | 1913 | 1834 | 1795 | 1755 | 1716 | 1677 |
| 81 | 225 | 1134 | 2237 | 2184 | 2132 | 2079 | 1974 | 1922 | 1869 | 1817 | 1764 | 1961 | 1922 | 1882 | 1843 | 1764 | 1725 | 1685 | 1646 | 1607 | 1961 | 1922 | 1882 | 1843 | 1764 | 1725 | 1685 | 1646 | 1607 |
| 76 | 225 | 1064 | 2167 | 2114 | 2062 | 2009 | 1904 | 1852 | 1799 | 1747 | 1694 | 1891 | 1852 | 1812 | 1773 | 1694 | 1655 | 1615 | 1576 | 1537 | 1891 | 1852 | 1812 | 1773 | 1694 | 1655 | 1615 | 1576 | 1537 |
| 72 | 225 | 1008 | 2111 | 2058 | 2006 | 1953 | 1848 | 1796 | 1743 | 1691 | 1638 | 1835 | 1796 | 1756 | 1717 | 1638 | 1599 | 1559 | 1520 | 1481 | 1835 | 1796 | 1756 | 1717 | 1638 | 1599 | 1559 | 1520 | 1481 |
| 67 | 225 | 938 | 2041 | 1988 | 1936 | 1883 | 1778 | 1726 | 1673 | 1621 | 1568 | 1765 | 1726 | 1686 | 1647 | 1568 | 1529 | 1489 | 1450 | 1411 | 1765 | 1726 | 1686 | 1647 | 1568 | 1529 | 1489 | 1450 | 1411 |
| 62 | 225 | 868 | 1971 | 1918 | 1866 | 1813 | 1708 | 1656 | 1603 | 1551 | 1498 | 1695 | 1656 | 1616 | 1577 | 1498 | 1459 | 1419 | 1380 | 1341 | 1695 | 1656 | 1616 | 1577 | 1498 | 1459 | 1419 | 1380 | 1341 |
| 57 | 225 | 798 | 1901 | 1848 | 1796 | 1743 | 1638 | 1586 | 1533 | 1481 | 1428 | 1625 | 1586 | 1546 | 1507 | 1428 | 1389 | 1349 | 1310 | 1271 | 1625 | 1586 | 1546 | 1507 | 1428 | 1389 | 1349 | 1310 | 1271 |
| 52 | 225 | 728 | 1831 | 1778 | 1726 | 1673 | 1568 | 1516 | 1463 | 1411 | 1358 | 1555 | 1516 | 1476 | 1437 | 1358 | 1319 | 1279 | 1240 | 1201 | 1555 | 1516 | 1476 | 1437 | 1358 | 1319 | 1279 | 1240 | 1201 |
| 48 | 225 | 672 | 1775 | 1722 | 1670 | 1617 | 1512 | 1460 | 1407 | 1355 | 1302 | 1499 | 1460 | 1420 | 1381 | 1302 | 1263 | 1223 | 1184 | 1145 | 1499 | 1460 | 1420 | 1381 | 1302 | 1263 | 1223 | 1184 | 1145 |
| 86 | 250 | 1125 | 2227 | 2175 | 2122 | 2070 | 1965 | 1912 | 1860 | 1807 | 1755 | 1952 | 1912 | 1873 | 1834 | 1755 | 1716 | 1676 | 1637 | 1597 | 1952 | 1912 | 1873 | 1834 | 1755 | 1716 | 1676 | 1637 | 1597 |
| 81 | 250 | 1059 | 2162 | 2109 | 2057 | 2004 | 1899 | 1847 | 1794 | 1742 | 1689 | 1886 | 1847 | 1808 | 1768 | 1689 | 1650 | 1611 | 1571 | 1532 | 1886 | 1847 | 1808 | 1768 | 1689 | 1650 | 1611 | 1571 | 1532 |
| 76 | 250 | 994 | 2097 | 2044 | 1992 | 1939 | 1834 | 1782 | 1729 | 1677 | 1624 | 1821 | 1782 | 1742 | 1703 | 1624 | 1585 | 1545 | 1506 | 1467 | 1821 | 1782 | 1742 | 1703 | 1624 | 1585 | 1545 | 1506 | 1467 |
| 72 | 250 | 942 | 2044 | 1992 | 1939 | 1887 | 1782 | 1729 | 1677 | 1624 | 1572 | 1769 | 1729 | 1690 | 1651 | 1572 | 1532 | 1493 | 1454 | 1414 | 1769 | 1729 | 1690 | 1651 | 1572 | 1532 | 1493 | 1454 | 1414 |
| 67 | 250 | 876 | 1979 | 1926 | 1874 | 1821 | 1716 | 1664 | 1611 | 1559 | 1506 | 1703 | 1664 | 1624 | 1585 | 1506 | 1467 | 1428 | 1388 | 1349 | 1703 | 1664 | 1624 | 1585 | 1506 | 1467 | 1428 | 1388 | 1349 |
| 62 | 250 | 811 | 1913 | 1861 | 1808 | 1756 | 1651 | 1598 | 1546 | 1493 | 1441 | 1638 | 1598 | 1559 | 1520 | 1441 | 1402 | 1362 | 1323 | 1283 | 1638 | 1598 | 1559 | 1520 | 1441 | 1402 | 1362 | 1323 | 1283 |
| 57 | 250 | 746 | 1848 | 1796 | 1743 | 1691 | 1586 | 1533 | 1481 | 1428 | 1376 | 1572 | 1533 | 1494 | 1454 | 1376 | 1336 | 1297 | 1257 | 1218 | 1572 | 1533 | 1494 | 1454 | 1376 | 1336 | 1297 | 1257 | 1218 |
| 52 | 250 | 680 | 1783 | 1730 | 1678 | 1625 | 1520 | 1468 | 1415 | 1363 | 1310 | 1507 | 1468 | 1428 | 1389 | 1310 | 1271 | 1231 | 1192 | 1153 | 1507 | 1468 | 1428 | 1389 | 1310 | 1271 | 1231 | 1192 | 1153 |
| 48 | 250 | 628 | 1730 | 1678 | 1625 | 1573 | 1468 | 1415 | 1363 | 1310 | 1258 | 1455 | 1415 | 1376 | 1337 | 1258 | 1218 | 1179 | 1140 | 1100 | 1455 | 1415 | 1376 | 1337 | 1258 | 1218 | 1179 | 1140 | 1100 |
| 86 | 275 | 789 | 1892 | 1839 | 1787 | 1734 | 1629 | 1577 | 1524 | 1472 | 1419 | 1616 | 1577 | 1538 | 1498 | 1419 | 1380 | 1341 | 1301 | 1262 | 1616 | 1577 | 1538 | 1498 | 1419 | 1380 | 1341 | 1301 | 1262 |
| 81 | 275 | 744 | 1846 | 1794 | 1741 | 1689 | 1584 | 1531 | 1479 | 1426 | 1374 | 1570 | 1531 | 1492 | 1452 | 1374 | 1334 | 1295 | 1255 | 1216 | 1570 | 1531 | 1492 | 1452 | 1374 | 1334 | 1295 | 1255 | 1216 |
| 76 | 275 | 698 | 1800 | 1748 | 1695 | 1643 | 1538 | 1485 | 1433 | 1380 | 1328 | 1525 | 1485 | 1446 | 1406 | 1328 | 1288 | 1249 | 1210 | 1170 | 1525 | 1485 | 1446 | 1406 | 1328 | 1288 | 1249 | 1210 | 1170 |
| 72 | 275 | 661 | 1763 | 1711 | 1658 | 1606 | 1501 | 1448 | 1396 | 1343 | 1291 | 1488 | 1448 | 1409 | 1370 | 1291 | 1252 | 1212 | 1173 | 1133 | 1488 | 1448 | 1409 | 1370 | 1291 | 1252 | 1212 | 1173 | 1133 |
| 67 | 275 | 615 | 1718 | 1665 | 1613 | 1560 | 1455 | 1403 | 1350 | 1298 | 1245 | 1442 | 1403 | 1363 | 1324 | 1245 | 1206 | 1166 | 1127 | 1088 | 1442 | 1403 | 1363 | 1324 | 1245 | 1206 | 1166 | 1127 | 1088 |
| 62 | 275 | 569 | 1672 | 1619 | 1567 | 1514 | 1409 | 1357 | 1304 | 1252 | 1199 | 1396 | 1357 | 1317 | 1278 | 1199 | 1160 | 1120 | 1081 | 1042 | 1396 | 1357 | 1317 | 1278 | 1199 | 1160 | 1120 | 1081 | 1042 |
| 57 | 275 | 523 | 1626 | 1573 | 1521 | 1468 | 1363 | 1311 | 1258 | 1206 | 1153 | 1350 | 1311 | 1271 | 1232 | 1153 | 1114 | 1075 | 1035 | 996 | 1350 | 1311 | 1271 | 1232 | 1153 | 1114 | 1075 | 1035 | 996 |
| 52 | 275 | 477 | 1580 | 1527 | 1475 | 1422 | 1317 | 1265 | 1212 | 1160 | 1107 | 1304 | 1265 | 1225 | 1186 | 1107 | 1068 | 1029 | 989 | 950 | 1304 | 1265 | 1225 | 1186 | 1107 | 1068 | 1029 | 989 | 950 |
| 48 | 275 | 441 | 1543 | 1491 | 1438 | 1386 | 1281 | 1228 | 1176 | 1123 | 1071 | 1268 | 1228 | 1189 | 1149 | 1071 | 1031 | 992 | 953 | 913 | 1268 | 1228 | 1189 | 1149 | 1071 | 1031 | 992 | 953 | 913 |

**Table XX-14:** Heavy Lift Aircraft and MV-22 Throughput at a 10-Hour Operating Time (shorts tons)

Table XX-14 is one of 12 different tables listed in Appendix 20-4. This table represents the total tons delivered per day for both the Heavy Lift Aircraft with an external load and the MV-22 with an internal load. Appendix 20-4 has the following tables at 10-hour, 12-hour, and 14-hour operating times: External Load – Heavy Lift Aircraft and Internal Load MV-22, External Load – Heavy Lift Aircraft and External Load MV-22, Internal Load – Heavy Lift Aircraft and External Load MV-22, and Internal Load – Heavy Lift Aircraft and Internal Load MV-22. The External Load – Heavy Lift Aircraft and the Internal Load – MV22 provides the greatest throughput capability for all three different operating times, whereas, the Internal Load – Heavy Lift Aircraft and the External Load – MV22 provides the least throughput capability for all three different operating times. The difference between the greatest and the least throughput ranges from 100 to 500 total tons delivered, depending on the number of aircraft available, distance, and operating time.

The tables in Appendix 20-4 are very user friendly. First, select the operating time of interest -- 10-hours, 12-hours, or 14-hours. Second, select the payloads of interest for the Heavy Lift Aircraft and the MV-22 -- internal or external load. Third, select the number of fully mission capable aircraft. The Conceptual Sea Base has 96 MV-22s and 24 Heavy Lift Aircraft. Typically, not all aircraft are available for daily operations because of scheduled maintenance, unscheduled maintenance, and logistical delays. Fully mission capable aircraft are computed by multiplying the operational availability by the total numbered of aircraft – example 96 times .9 equals 86. The following table represents the fully mission capable aircraft based on the different operational availabilities.

| $A_o$ | .9 | .85 | .8 | .75 | .7 | .65 | .6 | .55 | .5 |
|---|---|---|---|---|---|---|---|---|---|
| ***HLA*** | 21 | 20 | 19 | 18 | 16 | 15 | 14 | 13 | 12 |
| ***MV-22*** | 86 | 81 | 76 | 72 | 67 | 62 | 57 | 52 | 48 |

**Table XX-15**: Fully Mission Capable Heavy Lift Aircraft and MV-22s

In Table XX-14, the light blue vertical column represents the fully mission capable aircraft for the MV-22 with an internal load. The light blue horizontal row represents the fully mission capable aircraft for the Heavy Lift Aircraft with an external load. Fourth, select a distance of interest – 225, 250, or 275 NM. The green horizontal and vertical lines represent the three distances. The highlighted yellow rectangles represent the same distances for both the Heavy Lift Aircraft and the MV-22. Fifth, after selecting the fully mission capable aircraft for both the Heavy Lift and the MV-22 and the distance move horizontally across and vertically down until the two meet. The intersection is the throughput capacity (STs delivered per day). Table XX-16 illustrates how to find the throughput capability for following: Operating Time – 12-hours, 18 Heavy Lift Aircraft with external loads, 72 MV-22s with internal load, and distance from Sea Base to Objective equals 225 NM. The total throughput capability equals 1953 STs. 1953 STs is approximately four times the daily sustainment requirement (490 ST) for a

MEB size Landing Force. Being able to meet the daily re-supply requirements by almost four times has significant ramifications. First, the Sea Base must be able to surge its personnel, equipment, and supplies ashore quickly. The surge requirements are always greater than the sustainment requirement, so having a capability to surge four times the sustainment is definitely a force enabler. Second, even if attrition and other air tasking deplete the re-supplying air capable assets by 50 percent, the Heavy Lift Aircraft and MV-22 could still carry out its re-supply mission. 12 Heavy Lift Aircraft and 48 MV-22s have the capability to move 1302 STs of supplies – well above 490 STs. Third, weather was not taken into account in this model, but it could easily be accounted for. If bad weather was to restrict flight operations for a four day period, then the Conceptual aviation assets could take approximately four days re-supply requirements within 12 hours prior to any bad weather arriving. Having a robust capability provides a lot of flexibility in flight hours per day and re-supply periodicity.

External Load -- Heavy Lift Aircraft

Internal Load -- MV-22

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 21 | 20 | 19 | 18 | 16 | 15 | 14 | 13 | 12 |
| | | | 225 | 225 | 225 | 225 | 225 | 225 | 225 | 225 | 225 |
| | | | 1103 | 1050 | 998 | 945 | 840 | 788 | 735 | 683 | 630 |
| 86 | 225 | 1204 | 2307 | 2254 | 2202 | 2149 | 2044 | 1992 | 1939 | 1887 | 1834 |
| 81 | 225 | 1134 | 2237 | 2184 | 2132 | 2079 | 1974 | 1922 | 1869 | 1817 | 1764 |
| 76 | 225 | 1064 | 2167 | 2114 | 2062 | 2009 | 1904 | 1852 | 1799 | 1747 | 1694 |
| 72 | 225 | 1008 | 2111 | 2058 | 2006 | 1953 | 1848 | 1796 | 1743 | 1691 | 1638 |
| 67 | 225 | 938 | 2041 | 1988 | 1936 | 1883 | 1778 | 1726 | 1673 | 1621 | 1568 |
| 62 | 225 | 868 | 1971 | 1918 | 1866 | 1813 | 1708 | 1656 | 1603 | 1551 | 1498 |
| 57 | 225 | 798 | 1901 | 1848 | 1796 | 1743 | 1638 | 1586 | 1533 | 1481 | 1428 |
| 52 | 225 | 728 | 1831 | 1778 | 1726 | 1673 | 1568 | 1516 | 1463 | 1411 | 1358 |
| 48 | 225 | 672 | 1775 | 1722 | 1670 | 1617 | 1512 | 1460 | 1407 | 1355 | 1302 |

**Table XX-16:** Heavy Lift Aircraft and MV-22 Throughput at a 12-Hour Operating Time (shorts tons)

## 10. Heavy Lift Aircraft Simulation Model

We developed an ARENA™ Heavy Lift Aircraft Model to find the minimum number of Heavy Lift Aircraft required for meeting the daily sustainment requirements for a MEB size Landing Force ashore. The model simulates a Heavy Lift Aircraft carrying an internal or external load at either 225, 250, or 275 NM for a 12-hour flight day. Each X-Ship uses 4 of its 16 spots to conduct flight operations, utilizing two spots forward and two spots aft on either side of the X-Ship. The center flight spots remains clear for Joint Strike Fighters. MREs, ammunition, and spare parts are palletized and transferred to the flight spot when requested by a forklift. Assume the transfer for the forklift is a uniform distribution -- two to four minutes. After the cargo is transferred to the Heavy Lift Aircraft, it is loaded internally or externally. The Heavy Lift Aircraft has the capacity to carry eight pallets of any type – MREs, ammunition, or spare parts and other. The quadruple container (QUADCON) can carry two pallets per QUADCON for a total eight pallets per container equivalent. Water and fuel are pumped into 500-gallon bladders for external loads and 800-gallon internal tanks for internal loads. The following table summarizes the internal lift capacity for the Heavy Lift Aircraft.

| **Internal Lift Capacity of the Heavy Lift Aircraft** | | | | | | |
|---|---|---|---|---|---|---|
| | Short Tons | Pounds | Approx Weight of Pallet Pounds | Weight 800 Gallon Tank Pounds | Pallets or 800 Gallon Tanks Required Per Day | Carrying Capacity |
| MREs | 15 | 30,000 | 1,000 | | 30 | 8 |
| Water | 190 | 380,000 | | 6,400 | 60 | 3 |
| Fuel | 225 | 450,000 | | 5,440 | 83 | 3 |
| Ammo | 33.5 | 67,000 | 2,500 | | 27 | 8 |
| Spares and Others | 26.5 | 53,000 | 2,000 | | 27 | 8 |

Note: Water is assumed to be 8lbs per gallon and fuel is assumed to be 6.8lbs per gallon.

**Table XX-17:** Internal Lift Capacity of the Heavy Lift Aircraft

| External Lift Capacity of the Heavy Lift Aircraft | | | | | | |
|---|---|---|---|---|---|---|
| | Short Tons | Pounds | Approx Weight of Pallet Pounds | Weight 500 Gallon Bladders Pounds | Pallets or 500 Gallon Bladders Required Per Day | Carrying Capacity |
| MREs | 15 | 30,000 | 1,000 | | 30 | 8 |
| Water | 190 | 380,000 | | 4,000 | 95 | 6 |
| Fuel | 225 | 450,000 | | 3,400 | 133 | 6 |
| Ammo | 33.5 | 67,000 | 2,500 | | 27 | 8 |
| Spares and Others | 26.5 | 53,000 | 2,000 | | 27 | 8 |

Note: Water is assumed to be 8lbs per gallon and fuel is assumed to be 6.8lbs per gallon.

**Table XX-18:** External Lift Capacity of the Heavy Lift Aircraft

The loading and unloading times for internal loads are assumed to be a uniform distribution -- eighteen to twenty-five minutes: whereas, the loading and unloading times for external loads are shorter -- four to six minutes. The Heavy Lift Aircraft can load while refueling, but an additional 20 minutes was allotted to account for unexpected problems and longer refueling times. The travel time from the Sea Base to the Objective depends on the payload and the range. Table XX-19 shows the travel times as triangular distributions (minimum, most likely, maximum).

| Range | Sea Base to Objective | | Objective to Sea Base |
|---|---|---|---|
| | Internal Load | External Load | |
| 225 | (60,61,66) | (67,68,73) | (80,81,86) |
| 250 | (67,68,73) | (74,75,80) | (87,88,93) |
| 275 | (73,74,79) | (82,83,88) | (93,94,99) |

**Table XX-19:** Heavy Lift Aircraft Flight Times

Utilizing the process analyzer embedded within the ARENA™ software program, the simulation runs were set to determine the minimum number of Heavy Lift Aircraft. Thirty replications of six individual runs were simulated with the following shown in Table XX-20.

| | Recommended Minimum Number of HLAs | |
|---|---|---|
| Distance | Internal | External |
| 225 NM | 20 | 13 |
| 250 NM | 20 | 13 |
| 275 NM | 20 | 17 |

(Note: Base on a 12-Hour Operating Time (Flight Day) )

**Table XX-20:** Minimum Number of Heavy Lift Aircraft to re-supply a MEB

## H. PROTECTION OF THE SEA BASE

### 1. Protecting the Sea Base

The Sea Base is a transformational concept that exploits the safer sanctuary offered by the sea and eliminates the attendant risk associated with a current stationary logistics base ashore in conducting expeditionary operations. While a Sea Base is mobile and can maneuver according to the dynamic disposition of enemy forces, thus presenting itself as a relatively harder target to hit than a stationary target like an ashore logistical base generally referred to as the "Iron Mountain", it is not free from concerted enemy attacks. A stand-off Sea Base while relatively safer than its predecessors ashore, is itself still a key lucrative node or a set of nodes (represented by the Sea Base distributed among the collection of amphibious and logistics ships) among the inter-related set of Naval ExWar capability components, which is vulnerable to specific attacks by a capable enemy.

This section is devoted to investigating the protection needs of the Sea Base, the composition of protection escorts for the amphibious task force and subsequently the force sustaining effort of the Sea Based collection of ships, and finally the self-defensive capabilities of the component Sea Based ships. It is recognized in *Naval Expeditionary*

*Warfare: Decisive Power, Global Reach (Dept of Navy, July, 2002)* that amphibious ships and their associated logistics ships must not only be able to protect themselves, but they must also contribute to the collective defense of an amphibious force and a CSG. The future Sea Base will have not only an effective self-defense capability, but also some notable offensive capabilities.

The protection of the Sea Base can be viewed as the individual self-defensive capabilities of each ship and their inherent offensive capabilities or the offensive capabilities of the assets carried by the Sea Based ships which can be relied upon in protecting the overall Sea Base, such as the aircraft carried onboard the amphibious ships. The vulnerability of the Sea Base can be classified according to the phases of the operation: from transit to the area of operations, at the assembly area, at the launch area, at the eventual sustainment location, and finally at the re-constitution or re-deployment location before moving onwards to a new crisis region. The specific threats can be classified into five broad categories: namely, (1) air threat in the form of aircraft and missiles, (2) surface threat from surface combatants and their associated anti-ship missiles or land-based anti-ship missile threats, (3) underwater threat in the form of submarines and their torpedoes, (4) mine warfare threat, and finally (5) the asymmetric threat such as terrorist and suicide attacks by small fast crafts.

In general, the Sea Base is expected to operate under the protective cover of the CSG. However, the Sea Base and the NESG may in the future be entrusted with a more autonomous role without the protective cover of the CSG since the amphibious ships will have organic JSF, surveillance helicopters, and UAVs that can assume some limited protective roles. There may also be occasions when the NESG is urgently needed to arrive on scene of the crisis area well before the CSG arrives. It is under such circumstances that the organic self-defense and limited offensive capabilities of the NESG are crucial in determining the level of defensive capabilities required to meet the anticipated future threats.

Hence, to investigate the organic defensive capabilities of the Sea Based architectures, the analysis assumed the Sea Base is operating without the cover of the CSG. To equalize this imbalance, we will not examine the air threat in terms of enemy ship strike aircraft, sub-surface threats such as submarine, the area denial threat of mines, and asymmetric threats posed by terrorists. The investigative analysis focuses primarily on surface threats, mainly ship-borne anti-ship missiles and naval gun- fire. As a further excursion, land based mobile anti-ship cruise missiles are added to assess the impact on the NESG.

## 2. Objectives of the Study of the Protection of the Sea Base

We layout an analysis tool that is applicable for future dynamic simulation investigations on the force protection structure for sea based forces in future ExWar. The novel approach we explored uses an agent based simulation model called EINSTein, which stands for Enhanced ISAAC Neural Simulation Toolkit. EINSTein was originally developed for land warfare but was later adapted for maritime use by Center for Naval Analysis. A more detailed description of EINSTein is given in the subsequent sections.

Our exclusion of the subsurface and air threats is also partly due to the current limitation of the EINSTein model for effectively emulating these threat and capabilities. Our approach is to determine a minimum protection force level to ensure at least 80% survivability of a MEB-sized Sea Based NESG, and to make a comparative evaluation of the different ExWar Architectures. By substituting or adding to the protection force an incremental number of CGs, DDGs and FFGs with the future Littoral Combat Ship, we will make our comparative analyses.

From this exploratory effort using EINSTein, we show that valuable insights into the refinements needed for the various architectures in terms of defensive capabilities and minimum level of protection escort ships for the Sea Based can be distilled. This first attempt is a stepping-stone to subsequent iterative systems engineering, integration and analysis effort on force protection issues concerning ExWar.

## 3. The EINSTein Model

EINSTein (Enhanced ISAAC Neural Simulation Toolkit) is an agent-based simulation tool that served as an artificial-life laboratory for exploring self-organized emergence in land combat. The simulation, originally designed to model small unit ground combat, was written by Andrew Ilachinski and modified by Greg Cox of the Center for Naval Analysis for use in maritime warfare. Dr. Cox first introduced EINSTein to NPS students when he was a guest lecturer in a Joint Campaign Analysis class in early 2002. EINStein represents the first systematic attempt, within the military operations research community, to simulate combat -- on a small to medium scale -- by using autonomous agents to model individual behaviors and personalities rather than specific weapons. The agents are all endowed with rudimentary form of "intelligence" and can respond to a very large class of changing conditions as they evolve during battle. Each ship type in the NESG is created as a distinct agent with accompanying personality attributes in terms of aggressiveness or affinity towards staying around friendly or pursuing enemy agents, different movement speeds, sensor and weapon ranges, simultaneous engagements, weapon system kill probability and ability to absorb hits, i.e. soft or hard kill incoming enemy missiles. This is that adaptation initiated by Dr. Cox and introduced to the NPS students during the Joint Campaign Analysis class. More details in the features and capabilities can be found in the *EINSTein: An Artificial-Life Laboratory for for Exploring Self- Organized Emergence in Land Combat Beta-Test User's Guide (U).*

The relative simplicity of the underlying dynamical rules of EINSTein allows for rapid outcomes for a wide spectrum of tunable parameter values defining specific scenarios to be extracted, and it can thus be used to effectively map out the space of possible behaviors and provide insights of the collective emergent behaviors of the task force.

Following the initial exploratory work in NPS as introduced by Dr Cox in the NPS Joint Campaign Analysis Class, CAPT Jeff Kline adapted and expanded the effort by applying EINSTein in subsequent Joint Campaign Analysis Classes. As part of the campus-wide integrating project effort on ExWar, CAPT Kline further introduced EINSTein to the System Engineering and Integration-3 students in a specifically designed SI3900 class to equip students with applied methods of operations analysis to military tactical operations and warfare for the ExWar Project.

Our work here is an exploratory application to apply EINSTein to investigate the specific protection of the Sea Base. It is a continuation effort from an earlier two-man sub-team study to adapt EINSTein for the comparative study on the protection needs of the NESG. The methodology adopted here also refers to the "Exploratory Evaluation of the Littoral Combat Ship in an Expeditionary Littoral Environment" conducted by the earlier NPS Joint Campaign Analysis class.

#### 4. Agent-Based Modeling and Simulation

Agent-based simulations of complex adaptive systems are becoming increasingly popular as a practical and theoretical tool to explore the global behavior of very complicated systems. It is predicated that such global behavior is derived collectively from simpler, low-level interactions among constituent agents. Insights about the real-world system can then be gained by looking at the emergent structures induced by the interaction processes taking place within the simulation.

In modeling combat, agent-based simulation is a fundamental shift from simple force-on-force attrition calculations towards a process of examining how complex, high level properties and behaviors of combat emerge out of lower level rules of behaviors and interactions which themselves may also sometimes be evolving. According to Ilachinski, agent-based models focus on finding a set of low-level rules that defines the local behaviors of individual agents. The collective actions of these agents determine the dynamics of the whole system. It is this unique focus on the dynamics of the system-of-systems that prompted the System Engineering and Integration study team to apply the EINSTein model to explore the defensive needs of the ExWar architectures, particularly the protection of the Sea Base. Here, the agents are the individual ship types that make up the NESG, which also constitute the sea-based force. By appropriately assigning attributes, behavior personalities, movement speed, sensors and weapon systems ranges, probabilities of kill, abilities to absorb or neutralize missile hits through both soft or hard kills measures, a representative collection of a task force of ships according to the desired ExWar ship systems architectures can be modeled and studied. While it is recognized that the assignment of the different parameter values of the individual agents will have an impact on the results, it is noted that in comparing the effectiveness of the different architectures, the importance is in assigning the appropriated relative strengths and weaknesses, rather than the precise capabilities since the architectures will be examined across similar baselines.

## 5. The Analysis Approach

### a. Problem Definition and Comparing the Various ExWar Architectures

The task is to investigate the protection requirements for a sea based ExWar system-of-systems in terms of protection force level (Defense of the Sea Base in terms of the numbers and type of escort ships needed) for a MEB size amphibious task force. The investigation covers all three ExWar architectures being examined, namely:

**(1)** **Current**: Today's ExWar force structure. This is based on a combination of 9 amphibious ships consisting of 3 LPD-4, 3 LHD/LHA and 3 LSD-41 classes of ships supported by 6 MPS-type ships to make up a MEB-size NESG. In the simulation model, different amphibious ship types are created separately according to their capabilities and their expected behaviors in operations. In addition, under the Current CONOPS, it is assumed that the enemy force attacks the MEB-size NESG at the most vulnerable launch and supporting Sea Base area.

**(2)** **Planned**: The future ExWar force structure as programmed by the Navy for 2015. The key components here are the inclusion of LHA(R), LPD-17 and the MPF(F) as part of the amphibious assault and support force structures. It is assumed that the entire MEB force arrives in the Area of Operations (AO) on 9 amphibious ships (3 LHA(R), 3 LSD-41 and 3 LPD-17) supported by 6 MPF(F)s.

**(3)** **Conceptual**: The TSSE and System Engineering and Integration students' design of the future system-of-systems force structure solution to the ExWar problem. Within this Conceptual Architecture design, there are two further variants, namely one that includes legacy platforms as defined as Conceptual (With Legacy), consisting of 3 LSD-41, 3 LPD-17, 2 X-ships of the combat variant, 1 X-ship of the logistics variant, and 4 MPF(F) logistics ships; and the other completely replaced by the new X-ships design for both the amphibious and logistics ships, defined as Conceptual (New), i.e. with 6 X-ships of the combat variant and 3 of the logistics variant. We distinguish between the Conceptual (With Legacy) and the Conceptual (New) to investigate the transitional differences and the corresponding protection level needed. Here in terms of force size in the AO, we assume that the entire MEB is onsite, similar as in the Planned Architecture. The table below shows the collective ship composition of the various architectures.

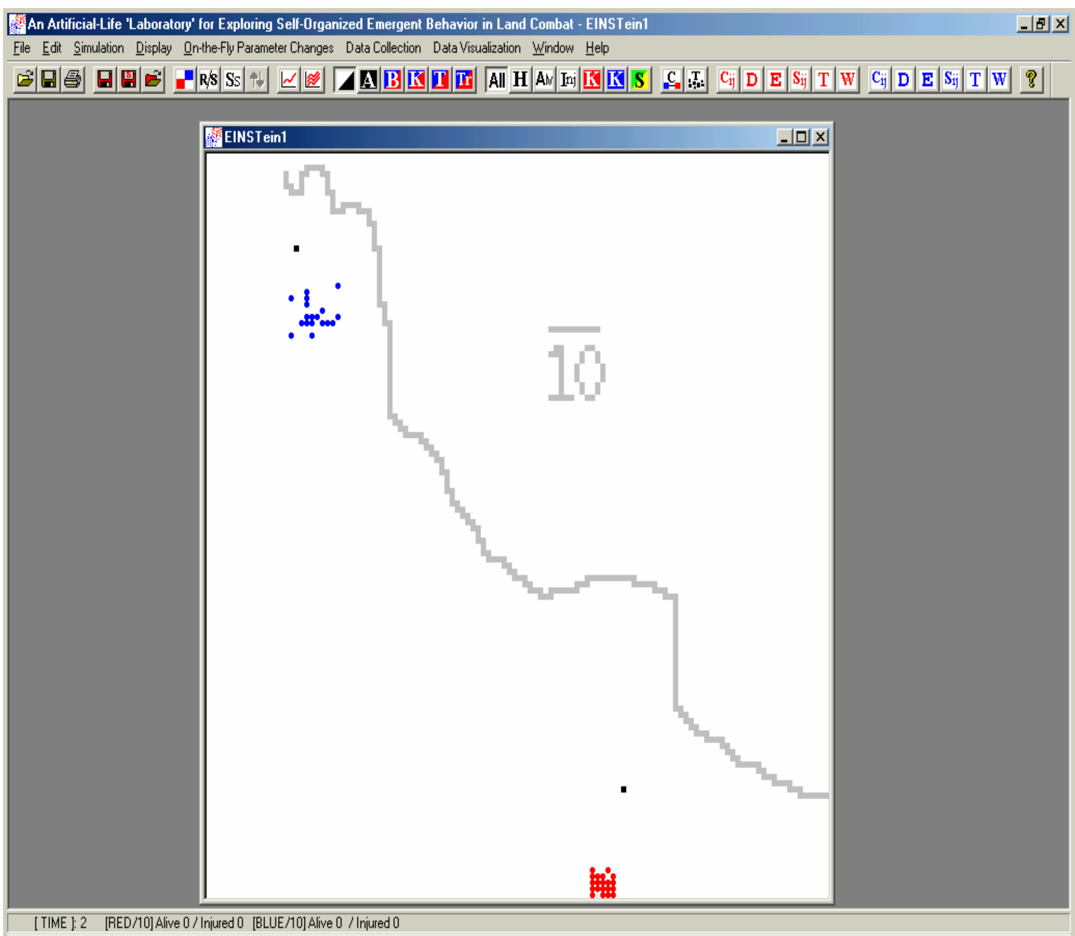
| ExWar Architectures | Component Ships within the Architectures | | | | | | | | | Total |
|---|---|---|---|---|---|---|---|---|---|---|
| | LHD/ LHA | LHA(R) | LPD-4 | LSD-41 | LPD-17 | T-AKR (MPS) | MPF(F) | X-Ship (Combat) | X-Ship (Logistics) | |
| **Current** | **3** | **-** | **3** | **3** | **-** | **6** | **-** | **-** | **-** | **15** |
| **Planned** | **-** | **3** | **-** | **3** | **3** | **-** | **6** | **-** | **-** | **15** |
| **Conceptual (Legacy)** | **-** | **-** | **-** | **3** | **3** | **-** | **6** | **2** | **1** | **15** |
| **Conceptual (New)** | **-** | **-** | **-** | **-** | **-** | **-** | **-** | **6** | **3** | **9** |

**Table XX-21:** Composition of Ships Within the Various ExWar Architectures

## 6. Scenario

The scenario for the EINSTein simulation is based on one of the three projected ExWar scenarios laid out in the ExWar integrating project, namely the projected 2018 Myanmar (Burma) scenario that is discussed in Chapter VI. A MEB-size expeditionary task force consisting of nine to fifteen amphibious and MPF type logistics ships escorted by a composition of CGs, DDGs and FFGs is envisaged to operate in the South-East Asian littoral environment off the Burmese coast. For the purpose of investigating the organic protection capabilities of this ExWar amphibious task force, we assume that a CSG air cover is not yet available on site.

The NESG is subjected to a concerted attack from a fleet of eighteen enemy ships consisting of 10 missile patrol crafts and eight FFG/MGB-type ships. For simplicity, only the surface and land based anti-ship missile threats are examined in the EINSTein model. The air and subsurface threats are not considered in order to keep a focused analysis on the Anti-Surface Warfare tactical scenario, since the protection of a CSG and the escorting submarine and anti-submarine capabilities are not included in the analysis. It is noted that while EINSTein can be adapted to simulate submarines and aircraft, the effort was beyond the limited timeframe for the integrating project. Moreover, these factors will complicate the investigation effort as the simulated submarine and aircraft behaviors have yet to be thoroughly investigated and validated by earlier works on EINSTein. A snapshot of the simulation of the Burmese scenario by EINSTein is shown in Figure XX-20.




(Note: Blue indicates enemy ships and Red indicates Own Forces' ExWar Ships. The Black dot shows the ExWar Assembly and Launch area. The terrain line indicates the Southern Burmese Coastline)

**Figure XX-20:** Snapshot of Burma Scenario for ExWar Simulation Run on EINSTein

## 7. Caveats

In understanding the acceptable boundary of the analysis, we note the following caveats:

a. The limited project timeframe requires the team to have a very focused simplified tactical scenario with single MOE.

b. EINSTein is used to both provide data and to evaluate agent-based simulation in campaign analysis.

c. We use estimates for weapon ranges, sensor ranges, system Probability of kill (P(k)), and the ability to conduct simultaneous engagements and the level of defensive capabilities in terms of soft and hard kill of in-coming missiles before the individual ship is damaged or destroyed. In particular, the figures are our best professional judgment estimated according to the ship types and the projected future capabilities and threat.

d. Cost estimates and evaluations are not included as this is an introductory exploration using EINSTein. Such analysis would be further complicated by the limited information on the full life-cycle costs for the different architectures being investigated. (Cost comparison options using EINSTein can certainly be undertaken if the preliminary findings proved to be useful.)

e. Time did not allow for adequate sensitivity analysis.

## 8. Measure of Effectiveness (MOE)

The MOE that we adopted is the percentage of the NESG (including escorts) remaining unharmed after the engagement, based on 50-battle runs. We assessed that the percentage of ships alive will be more indicative of the interrelated demands for the preservation of the mixed elements of escorts for different roles like anti-air, anti-surface and anti-sub and the amphibious and MPF-type logistics ships. We count the number of escorts and amphibious or logistics ships unharmed, since the loss of escort ships will impact not only protection from surface threats but will also degrade the layered defense against air and sub-surface threats in the real world. As we have not examined the protection level to include air and sub-surface threats in the model, there needs to be a buffer when considering the associated escorts required.

By setting the goal to achieve at least 80% of the NESG ships remaining unharmed after the engagements, we have in fact factored in a buffer for the entire NESG and provided for a defensive capacity to deal with the other threats not investigated here. To assume a case of zero attrition for the amphibious or logistic ships will demand too high an escort protection force level and can lead to unrealistic demands or over-optimism in eventual force structural planning. In separate sampling runs for the model, when at least 80% survival rates of the overall NESG is achieved, we note that there is at most one amphibious or logistics ship damaged or destroyed, albeit relatively infrequently. This observation from the model may indicate that in the expected real-world case, the amphibious and logistics ships may still suffer some damage or losses in operations despite having comprehensive protection. But most of the time (Out of 50 simulation runs) the losses in the EINSTein simulation runs are due to the smaller DDGs, FFGs or LCSs.

### 9. Baseline Inputs and the Incremental Protection Force Level

We first establish a baseline defensive escort force of 1 CG, 1 DDGs and 1 FFGs for each of the ExWar architectures against a baseline enemy force of 10 PCs and 8 FFGs. This baseline protection force is chosen arbitrarily to set a relative level for comparison across the different architectures. From this baseline, incremental protection force levels are added to achieve the set goal of at least 80% of the NESG alive and unharmed. Various combinations of CG, DDG and FFG increases are investigated. Substitution by LCSs is also explored. In summary, the representative approach in applying incremental steps to meet the minimum 80% NESG survival goal can be summarized as follows:

a. Add varying number of CG, DDG and FFG to the baseline protection force.

b. Substitute and add LCSs to the baseline protection force.

c. Improve the offensive and defensive capabilities of the amphibious and logistics ships

## 10. Model Inputs

The inputs for the attributes of the individual ship types that make up the Current, Planned, Conceptual (With Legacy) and Conceptual (New – All X-ships, without legacy ships) Architecture in the EINSTein model are summarized in the tables below. Table XX-22 to XX-25 capture the description, types, numbers, movement, staying power, sensor and weapon ranges, the accompanying single shot probability of hit $SSP_{Hit}$) and

| The Current Architecture MEB-Size NESG Baseline Numbers and Capabilities | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Movement per Time Step (Speed in tens of knots) | | Staying Power (hard /soft kill of enemy missile prior to leaker) | | Sensor/Weapon Range (Equivalent to nm) | | $SSP_{Hit}$ (No. of Simultaneous Engagements) | |
| **Squad No.** | **Asset Type** | **No.** | **Alive** | **Injured** | **Alive** | **Injured** | **Alive** | **Injured** | **Alive** | **Injured** |
| 1 | CG | 1 | 3 | 1 | 3 | 1 | 30/15 | 15/10 | 0.5 (3) | 0.5 (1) |
| 2 | LSD-41 | 3 | 1 | 1 | 1 | 1 | 25/5 | 15/5 | 0.3 (1) | 0.2 (1) |
| 3 | DDG | 1 | 3 | 1 | 2 | 1 | 30/15 | 12/10 | 0.5 (3) | 0.5 (1) |
| 4 | FFG | 1 | 2 | 1 | 2 | 1 | 25/12 | 10/8 | 0.5 (2) | 0.5 (1) |
| 5 | MPS (T-AKR) | 6 | 1 | 1 | 1 | 1 | 20/1 | 15/1 | 0.1 (1) | 0.05 (1) |
| 6 | Comms Net | 0 | 0 | 0 | 99 | 99 | 99/0 | 99/0 | 0 (0) | 0 (0) |
| 7 | LHA | 3 | 1 | 1 | 2 | 1 | 30/15 | 15/8 | 0.5 (2) | 0.3 (1) |
| 8 | LPD-4 | 3 | 1 | 1 | 1 | 1 | 25/5 | 15/5 | 0.3 (1) | 0.2 (1) |
| 9 | LCS | 0 | 4 | 1 | 1 | 1 | 30/15 | 15/5 | 0.5 (2) | 0.5 (1) |
| Total No. of Ships | | 18 | | | | | | | | |

**Table XX-22:** Inputs for Various Current Architecture (Baseline) Agents – With 1 CG, 1 DDG and 1 FFG as Escorts

(simultaneous engagement capabilities of the collection of ships that make up the Current, Planned, Conceptual (With legacy) and Conceptual (New- Without legacy ships) respectively. The tables also included the baseline number of escort ships, namely 1 CG, 1 DDG and 1 FFG, set arbitrarily for comparison. The baseline Current and Planned Architecture MEB size NESG each consists of 18 ships (inclusive of the 3 escorts ships) whereas the Conceptual (With Legacy ships)'s NESG is made up of 16 ships and the Conceptual (New-All X-ship)'s NESG of 12 ships.

| **The Planned Architecture MEB-Size NESG Baseline Numbers and Capabilities** | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | **Movement per Time Step (Speed in tens of knots)** | | **Staying Power (hard /soft kill of enemy missile prior to leaker)** | | **Sensor/Weapon Range (Equivalent to nm)** | | **$SSP_{Hit}$ (No. of Simultaneous Engagements)** | |
| **Squad No.** | **Asset Type** | **No.** | **Alive** | **Injured** | **Alive** | **Injured** | **Alive** | **Injured** | **Alive** | **Injured** |
| **1** | **CG** | **1** | **3** | **1** | **3** | **1** | **30/15** | **15/10** | **0.5 (3)** | **0.5 (1)** |
| **2** | **LSD-41** | **3** | **1** | **1** | **2** | **1** | **30/10** | **15/5** | **0.5 (2)** | **0.3 (1)** |
| **3** | **DDG** | **1** | **3** | **1** | **2** | **1** | **30/15** | **12/10** | **0.5 (3)** | **0.5 (1)** |
| **4** | **FFG** | **1** | **2** | **1** | **2** | **1** | **25/12** | **10/8** | **0.5 (2)** | **0.5 (1)** |
| **5** | **MPF(F)** | **6** | **1** | **1** | **1** | **1** | **25/3** | **15/1** | **0.3 (1)** | **0.05 (1)** |
| **6** | **Comms Net** | **0** | **0** | **0** | **99** | **99** | **99/0** | **99/0** | **0 (0)** | **0 (0)** |
| **7** | **LHA(R)** | **3** | **1** | **1** | **3** | **1** | **45/15** | **15/10** | **0.5 (2)** | **0.3 (1)** |
| **8** | **LPD-17** | **3** | **1** | **1** | **2** | **1** | **30/10** | **15/5** | **0.3 (1)** | **0.2 (1)** |
| **9** | **LCS** | **0** | **4** | **1** | **1** | **1** | **30/15** | **15/5** | **0.5 (2)** | **0.5 (1)** |
| **Total No. of Ships** | | **18** | | | | | | | | |

**Table XX-23:** Inputs for Various Planned Architecture (Baseline) Agents – With 1 CG, 1 DDG and 1 FFG as Escorts

The Planned Architecture's NESG has improvements in terms of the amphibious and logistics ships' staying power, sensor and weapon ranges and effectiveness in terms of SS $P_{Hit}$ as compared to the Current Architecture's NESG. The Conceptual (New) amphibious and logistics ships represented by the X-Ships in both the combat and the logistics variants constitute the ExWar structure with the most effective self-defensive capabilities among the architectures.

The communication net is identified as Squad 6 in the inputs and it was not activated for all the architectures until the specific runs to investigate the impact of a perfectly netted force began.

| The Conceptual (With Legacy) Architecture MEB-Size NESG Baseline Numbers and Capabilities | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Movement per Time Step (Speed in tens of knots) | | Staying Power (hard /soft kill of enemy missile prior to leaker) | | Sensor/Weapon Range (Equivalent to nm) | | $SSP_{Hit}$ (No. of Simultaneous Engagements) | |
| Squad No. | Asset Type | No. | Alive | Injured | Alive | Injured | Alive | Injured | Alive | Injured |
| 1 | CG | 1 | 3 | 1 | 3 | 1 | 30/15 | 15/10 | 0.5 (3) | 0.5 (1) |
| 2 | LSD-41 | 3 | 1 | 1 | 2 | 1 | 30/10 | 15/5 | 0.5 (2) | 0.3 (1) |
| 3 | DDG | 1 | 3 | 1 | 2 | 1 | 30/15 | 12/10 | 0.5 (3) | 0.5 (1) |
| 4 | FFG | 1 | 2 | 1 | 2 | 1 | 25/12 | 10/8 | 0.5 (2) | 0.5 (1) |
| 5 | X-Ship (Logistics) | 1 | 1 | 1 | 3 | 1 | 30/15 | 15/8 | 0.3 (2) | 0.05 (1) |
| 6 | Comms Net | 0 | 0 | 0 | 99 | 99 | 99/0 | 99/0 | 0 (0) | 0 (0) |
| 7 | X-Ship (Combat) | 2 | 1 | 1 | 3 | 1 | 45/15 | 15/10 | 0.5 (3) | 0.3 (1) |
| 8 | LPD-17 | 3 | 1 | 1 | 3 | 1 | 30/10 | 15/5 | 0.3 (2) | 0.2 (1) |
| 9 | LCS | 0 | 4 | 1 | 1 | 1 | 30/15 | 15/5 | 0.5 (2) | 0.5 (1) |
| 10 | MPF | 4 | 1 | 1 | 1 | 1 | 20/1 | 15/1 | 0.1 (1) | 0.05 (1) |
| Total No. of Ships | | 16 | | | | | | | | |

**Table XX-24:** Inputs for Various Conceptual (With legacy) Architecture (Baseline) Agents – With 1 CG, 1 DDG and 1 FFG as Escorts

| The Conceptual (New) Architecture MEB-Size NESG Baseline Numbers and Capabilities | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Movement per Time Step (Speed in tens of knots) | | Staying Power (hard /soft kill of enemy missile prior to leaker) | | Sensor/Weapon Range (Equivalent to nm) | | $SSP_{Hit}$ (No. of Simultaneous Engagements) | |
| Squad No. | Asset Type | No. | Alive | Injured | Alive | Injured | Alive | Injured | Alive | Injured |
| 1 | CG | 1 | 3 | 1 | 3 | 1 | 30/15 | 15/10 | 0.5 (3) | 0.5 (1) |
| 2 | LSD-41 | 0 | 1 | 1 | 2 | 1 | 30/10 | 15/5 | 0.5 (2) | 0.3 (1) |
| 3 | DDG | 1 | 3 | 1 | 2 | 1 | 30/15 | 12/10 | 0.5 (3) | 0.5 (1) |
| 4 | FFG | 1 | 2 | 1 | 2 | 1 | 25/12 | 10/8 | 0.5 (2) | 0.5 (1) |
| 5 | X-Ship (Logistics) | 3 | 1 | 1 | 3 | 1 | 30/15 | 15/10 | 0.5 (2) | 0.3 (1) |
| 6 | Comms Net | 0 | 0 | 0 | 99 | 99 | 99/0 | 99/0 | 0 (0) | 0 (0) |
| 7 | X-Ship (Combat) | 6 | 1 | 1 | 3 | 1 | 45/15 | 15/10 | 0.5 (3) | 0.3 (1) |
| 8 | LPD-17 | 0 | 1 | 1 | 3 | 1 | 30/10 | 15/5 | 0.3 (2) | 0.2 (1) |
| 9 | LCS | 0 | 4 | 1 | 1 | 1 | 30/15 | 15/5 | 0.5 (2) | 0.5 (1) |
| Total No. of Ships | | 12 | | | | | | | | |

**Table XX-25:** Inputs for Various Conceptual (New – All X-Ships) Architecture (Baseline) Agents – With 1 CG, 1 DDG and 1 FFG as Escorts

The attributes of the enemy collection of ships, namely the PCs and FFG/MGB are summarized in Table XX-26. The attributes of the agent representing the land-based mobile anti-ship cruise missile (ASCM) battery are also included in the table. Here, the ASCM battery will only be activated in the excursion investigation on the impact of the ASCM on the ExWar operations.

Finally, the "Personality" weights of the various ExWar component ships and assets are tabulated in Table XX-27. The weights are set for affinity to stick to alive friend, alive foe, injured friend, injured foe, friend flag or foe flag when the agents are alive (unharmed) or when they are injured.

| The Enemy Ship Numbers and Capabilities | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | **Movement per Time Step (Speed in tens of knots)** | | **Staying Power (hard /soft kill of enemy missile prior to leaker)** | | **Sensor/Weapon Range (Equivalent to NM)** | | **$SSP_{Hit}$ (No. of Simultaneous Engagements)** | |
| **Squad No.** | **Asset Type** | **No.** | **Alive** | **Injured** | **Alive** | **Injured** | **Alive** | **Injured** | **Alive** | **Injured** |
| **1** | **PC** | **10** | **3** | **1** | **3** | **1** | **30/15** | **15/10** | **0.5 (3)** | **0.5 (1)** |
| **2** | **FFG/MGB** | **8** | **1** | **1** | **2** | **1** | **30/10** | **15/5** | **0.5 (2)** | **0.3 (1)** |
| **3-6** | **ASCM** | **0** | **0** | **0** | **2** | **1** | **45/35** | **1/1** | **0.4 (2)** | **0.1 (1)** |
| **Total No. of Ships** | | **18** | | | | | | | | |

**Table XX-26:** Inputs for Various Enemy Task Force Agents

| ExWar NESG Component Ships' Alive and Injured Personality Weights | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **When Alive** | | | | | | **When Injured** | | | | | |
| **Asset Type** | To Alive Friend | To Alive Foe | To Injured Friend | To Injured Foe | To Friend Flag | To Foe Flag | To Alive Friend | To Alive Foe | To Injured Friend | To Injured Foe | To Friend Flag | To Foe Flag |
| **CG** | 45 | 30 | 15 | 10 | 0 | 0 | 45 | 10 | 20 | 5 | 20 | 0 |
| **LSD-41** | 30 | 0 | 30 | 0 | 40 | 0 | 50 | 0 | 30 | 0 | 20 | 0 |
| **DDG** | 40 | 35 | 15 | 10 | 0 | 0 | 40 | 10 | 25 | 5 | 20 | 0 |
| **FFG** | 40 | 35 | 15 | 10 | 0 | 0 | 40 | 10 | 25 | 5 | 20 | 0 |
| **X-Ship (Logistics)** | 30 | 0 | 30 | 0 | 40 | 0 | 50 | 0 | 30 | 0 | 20 | 0 |
| **Comms Net** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **X-Ship (Combat)** | 30 | 0 | 30 | 0 | 40 | 0 | 50 | 0 | 30 | 0 | 20 | 0 |
| **LPD-17** | 30 | 0 | 30 | 0 | 40 | 0 | 50 | 0 | 30 | 0 | 20 | 0 |
| **LCS** | 40 | 30 | 15 | 15 | 0 | 0 | 35 | 15 | 20 | 10 | 20 | 0 |
| **LHA** | 30 | 0 | 30 | 0 | 40 | 0 | 50 | 0 | 30 | 0 | 20 | 0 |
| **LHA(R)** | 30 | 0 | 30 | 0 | 40 | 0 | 50 | 0 | 30 | 0 | 20 | 0 |
| **MPF** | 30 | 0 | 30 | 0 | 40 | 0 | 50 | 0 | 30 | 0 | 20 | 0 |
| **MPF(F)** | 30 | 0 | 30 | 0 | 40 | 0 | 50 | 0 | 30 | 0 | 20 | 0 |

(Note: Comms net is simulated as a stationary, indestructible agent and the personality weights are set to zero. The agent's affinity to go towards the Foe Flag is also set to zero as it is NESG's aim is to move towards and stay within the assembly and launch area which is designated as the Friend Flag position in the EINSTein model.)

**Table XX-27:** ExWar Agents' Personality Weights

The corresponding "Personality" weights for the enemy agents are indicated in Table XX-28. These weights determine the behavior of the agent ships in the scenario runs in terms of how each of the ship types would generally behave under operational conditions.

| Enemy Component Ships' Alive and Injured Personality Weights | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | When Alive | | | | | | When Injured | | | | | |
| **Asset Type** | To Alive Friend | To Alive Foe | To Injured Friend | To Injured Foe | To Friend Flag | To Foe Flag | To Alive Friend | To Alive Foe | To Injured Friend | To Injured Foe | To Friend Flag | To Foe Flag |
| **PC & FFG/MGB** | 10 | 30 | 10 | 25 | 0 | 25 | 30 | 0 | 20 | 25 | 10 | 25 |

**Table XX-28:** Enemy Agents' Personality Weights

Additionally, the meta-personality weights and movement controls are not set as more in-depth tactics and movement which are largely dependent on the tactical situation the dynamic changes are not simulated in this limited excursion.

As far as possible, 50 simulation runs per set scenario were recorded and the raw data captured using the inherent features. The mean value of the MOE and the upper and lower 0.95 confidence level of the results were then extracted from the recorded data and presented in the comparison graphical plots.

### 11. Summary of Results From The Baseline Protection Force Comparison

The comparative results from the baseline protection level analysis between the ExWar Current, Planned and the two Conceptual variant Architectures are summarized in the chart shown in Figure XX-21. The vertical axis is the fraction of the NESG unharmed after the engagement and the horizontal axis depicts the different architectures. Within each colored column, the plots of own and enemy forces unharmed or alive are shown. The central blue diamond shape indicates the mean value from the 50 EINSTein simulation runs and the upper and lower bars are the upper and lower 0.95 confidence level indicators of the results. The plots clearly show that the baseline protection level of 1 CG, 1 DDG and 1 FFG is insufficient to achieve 80% of the NESG unharmed when pitted against the collection of 18 enemy ships.

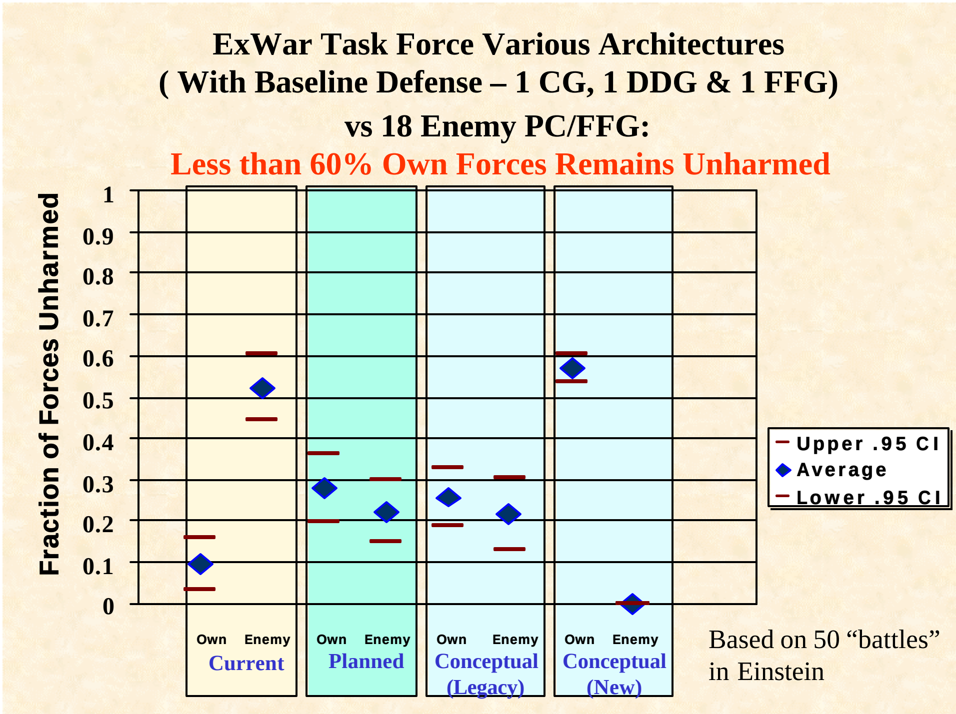



**Figure XX-21:** Comparative Results from the Baseline Protection Force Analysis Among the Different Architectures.

Interestingly, with just the baseline protection, the Conceptual (New-with no legacy ships) architecture suffers comparatively less attrition than the Current, Planned and the Conceptual (with legacy ships) architectures. The Planned architecture also seemed to be only marginally better than the Current. The Planned and the Conceptual (with legacy) are almost comparable.

This difference is attributable to the enhanced defensive and offensive capabilities of the X-ships in the Conceptual (New) Architecture. The X-ship agents are modeled on the assumption that the X-ships will be equipped with sensors and weapon systems comparable with those that are expected to be onboard a future upgraded CG or DDG, though fewer in number of systems. Similarly, the X-ships' organic defensive capabilities are enhanced by both soft and hard kill systems which can absorb or neutralize the equivalent number of incoming missiles that we expect a CG is capable of handling. The relative offensive and defensive capabilities of the X-ship and CG of the Conceptual (New) architecture are shown in Table XX-25.

### 12. Summary of Results From Incremental Step Improvement to the Protection Levels Among the Different Architectures

As the protection force level is increased incrementally, the fraction of the NESG that survive the enemy attacks increases. Before we consolidate the final result plots from the various architectures, the individual architecture plots are compiled. Shown in Figure XX-22 and Figure XX-23 below are the resultant plots from the Planned Architecture. At the extreme left is the baseline plots and as we proceed to the right, the results from the various combination of protection force level are plotted. As shown in

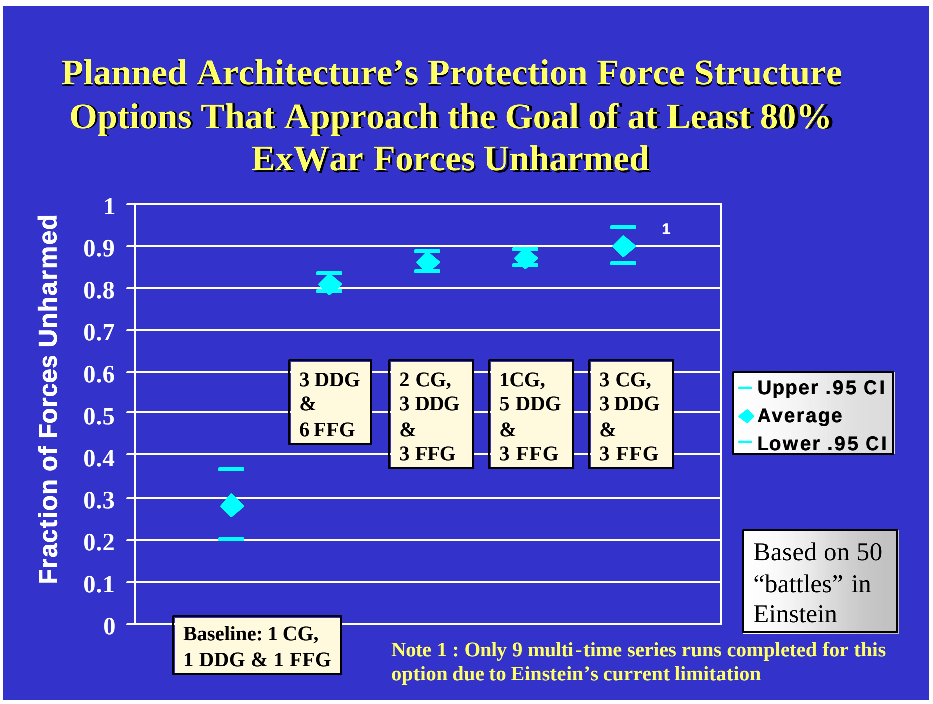



**Figure XX-22:** Results from the Planned Architecture's Protection Force Structure Options that Approach the Goal of at least 80% ExWar Forces Unharmed.

Figure XX-22, all four of the options depicted achieve the MOE of at least 80% of the NESG unharmed. A point to note is that for the option comprising 3 CG, 3 DDG and 3 FFG we make only 9 multi-time series simulation runs due to the limitation of the Beta-version of the EINSTein program. Beyond 9 multi-time series simulation runs, the EINSTein program freezes. This is due to the current limits of the Beta-version of EINSTein being restricted to handle only up to a total of 50 individual agents, counting both own and enemy forces. While an aggregated 50 simulation runs could have been achieved using a combination of 6 separate 9-multi-time series runs we did not pursued this since only a relative indicative level is required in the comparison.

Next in Figure XX-23, the options are changed to combinations of CG and LCS; DDG and LCS; and LCS only. Again, the limits of the EINSTein program are reached whereby beyond having 10 LCSs, the simulation run freezes. Here, only the option of 3 DDG and 7 LCS can meet the MOE as stated.

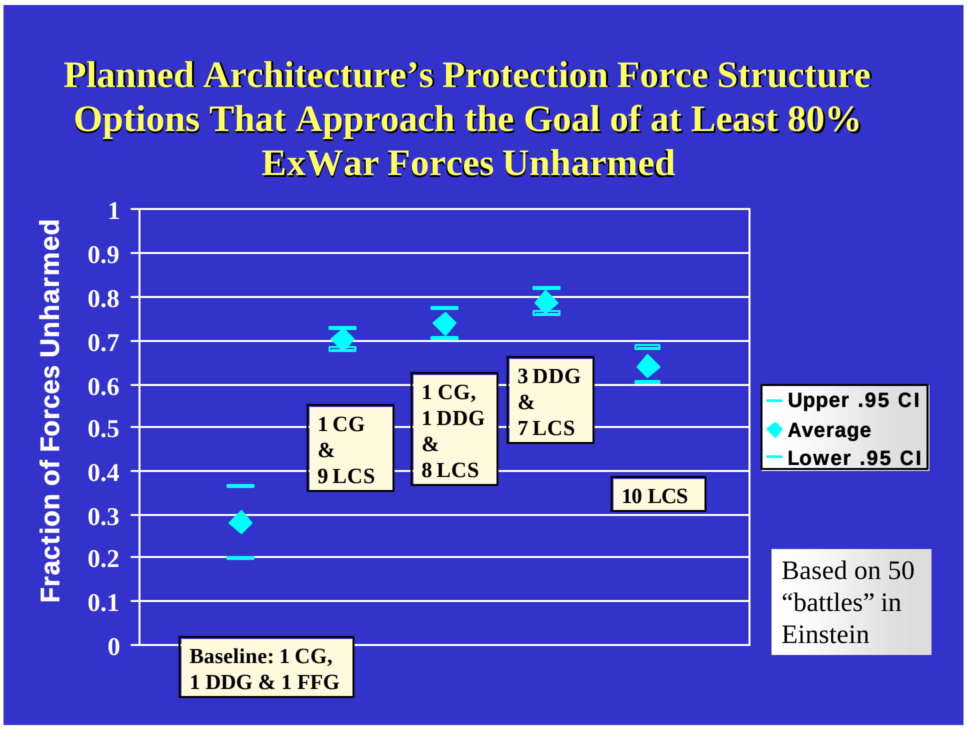



**Figure XX-23:** Results from the Planned Architecture's Protection Force Structure Options that Approach the Goal of at least 80% ExWar Forces Unharmed (Substitution by LCSs)

A similar approach of incremental step increase in protection level is applied to all the architectures being investigated. The consolidated comparison results are plotted in Figure XX-24 and Figure XX-25. The results from the Current Architecture are depicted in Red, Planned in Blue, Conceptual (Legacy) in Orange and Conceptual (New) in Green. From the plots, it appears that the Conceptual (New) Architecture consistently achieved a lower MOE as compared to the Current, Planned and Conceptual (Legacy) Architectures, except when there is inadequate level of force protection. With sufficiently higher level of escort ships, the Conceptual (New) Architecture does not appear to be performing better than the other architectures. This may first appear to be counter intuitive, but as we examine further, we will note that in the Conceptual (New) Architecture, the NESG is now concentrated over a smaller number of relatively larger ships. Basically, the two X-ships of the combat variant replace three of the Current or Planned amphibious ships, resulting in a less distributed Sea Base that has now become more vulnerable. A less distributed Sea Base provides the enemy with opportunity to concentrate fire at fewer targets.

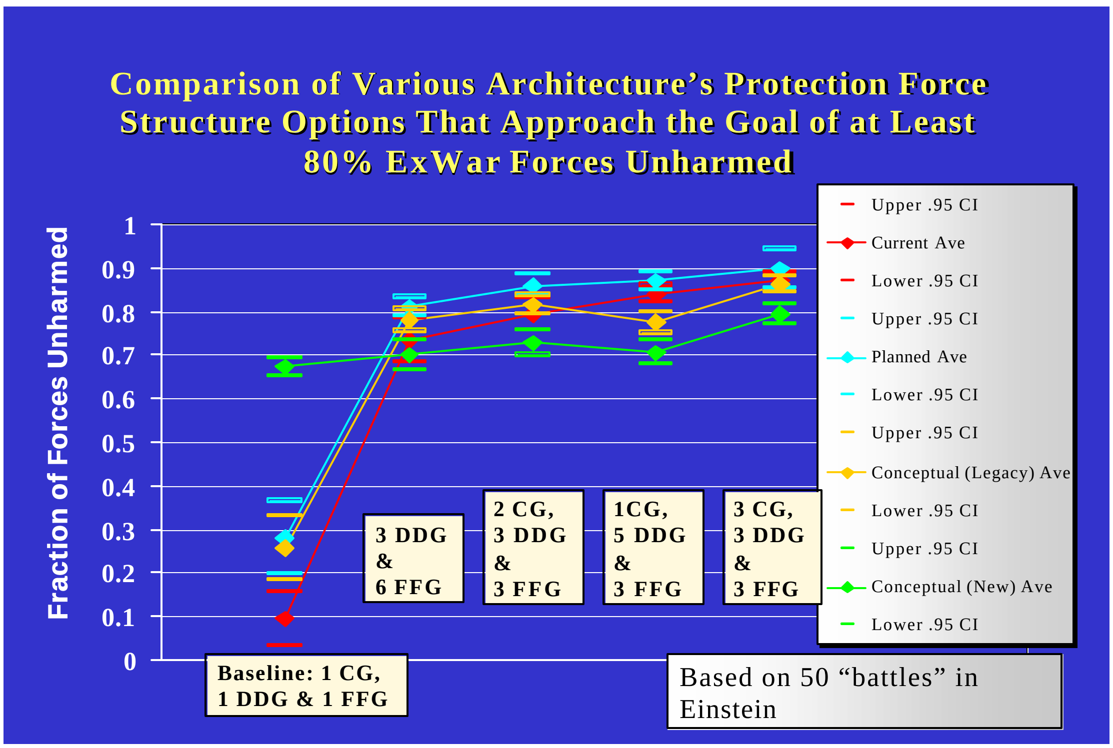



**Figure XX-24:** Comparison of Various Architectures' Protection Force Structure Options that Approach the Goal of at least 80% ExWar Forces Unharmed (I).

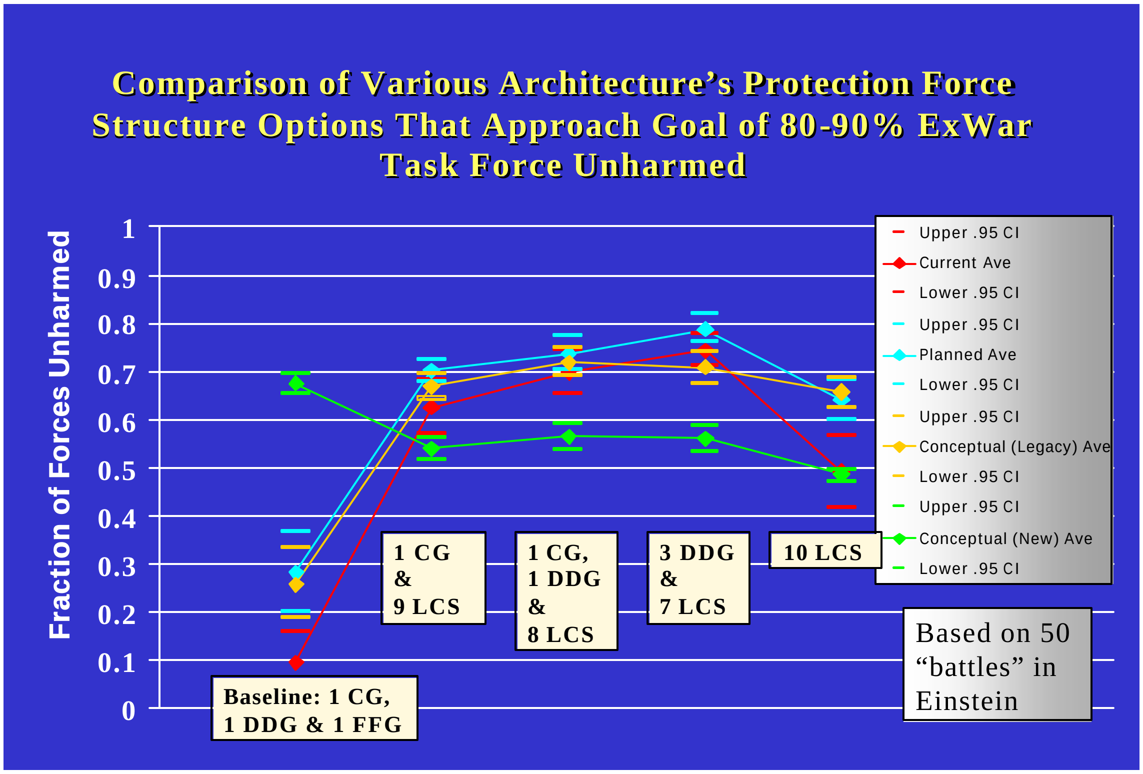



**Figure XX-25:** Comparison of the Various Architectures' Protection Force Structure Options that Approach the Goal of at least 80% ExWar Forces Unharmed (II).

### 13. Excursion Analysis on the Defensive and Offensive Capabilities of the Amphibious and Logistics Ships of the Conceptual (New) Architecture

This sub-section focuses on the varying defensive and offensive capabilities to be designed into the Conceptual (New) Architecture's X-ships for both the combat and logistics variants. The intent is to investigate f there are significant changes to the overall survivability of the NESG if the defensive and offensive capabilities of the amphibious and logistics ships are adjusted.

Three levels of settings for the amphibious and logistics ships of the Conceptual (New) Architecture to be investigated are:

a. Higher defensive and offensive capabilities (Indicated as Red on Chart).

b. Higher defensive but limited offensive capabilities (Indicated as Blue on Chart).

c. Lower defensive and offensive capabilities (Indicated as Orange on Chart).

Simulation runs with these new settings for the Conceptual (New) Architecture were conducted for the set of escort options as discussed earlier and the consolidated results are plotted in the charts as shown in Figures XX-26 and XX-27. It can be seen that in the presence of adequate protection escorts, the defensive and offensive capabilities of the X-ships do not have a significant impact on the overall survivability of the NESG. Under adequate protection, there seems to be only a very marginal improvement to the overall survivability if the X-ships are equipped with enhanced defensive and offensive capabilities. However, if there is inadequate escort, i.e., the

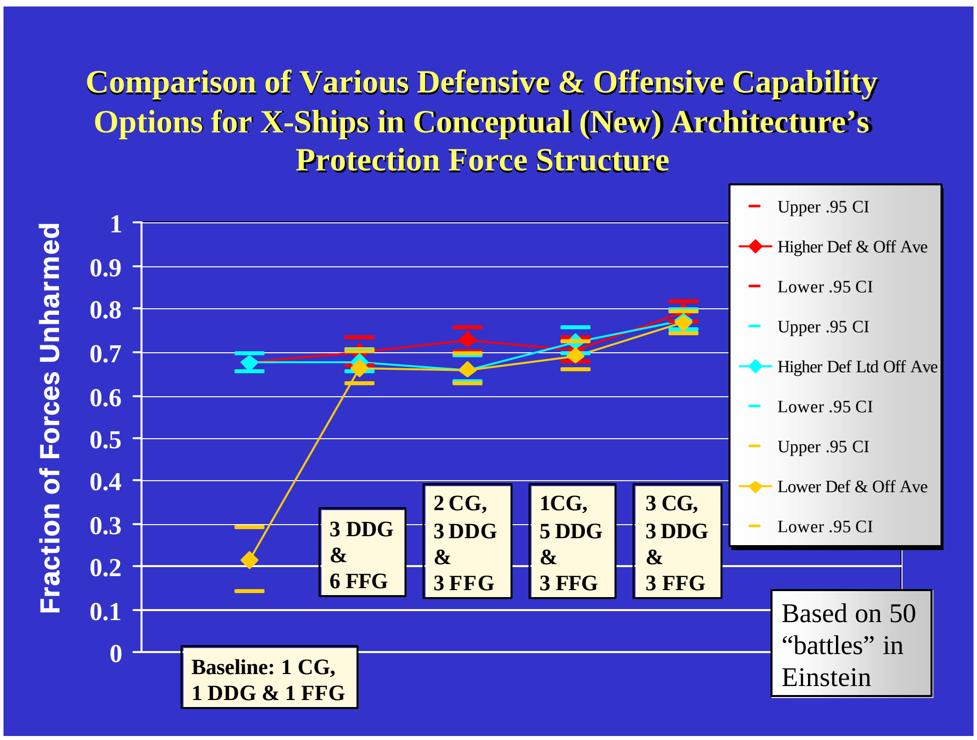



**Figure XX-26:** Comparison of the Various Defensive and Offensive Capability Options for the X-ships in the Conceptual (New) Architecture's Protection Force Structure (I)

NESG operates with limited accompanying CG, DDGs, FFGs or LCSs in the future, the organic defensive and offensive capabilities of the X-ships becomes significantly more important. This trend is clearly depicted by the lower Orange plots in Figure XX-27, which indicates the lower defensive and offensive capability options of the X-ships.

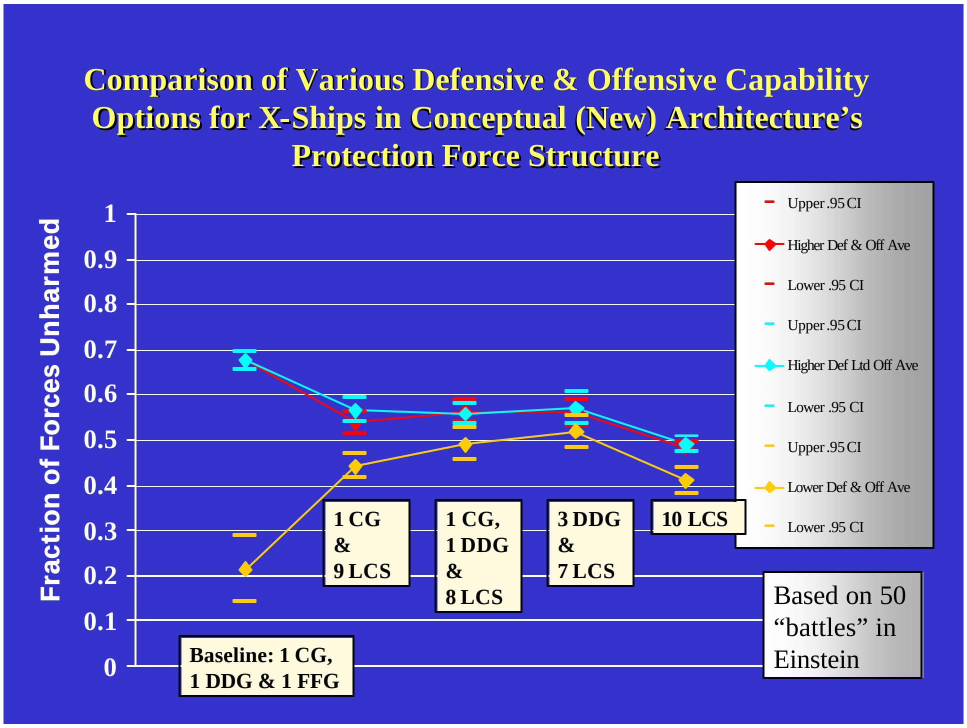



**Figure XX-27:** Comparison of the Various Defensive and Offensive Capability Options for the X-ships in the Conceptual (New) Architecture's Protection Force Structure (II).

### 14. Excursion on Impact of Anti-Ship Cruise Missile Threat

In the separate analysis on the introduction of the mobile land-based anti-ship cruise missile battery within strike range of the vicinity of the Sea Base, the results based on two earlier adequate protection level options – (1) Consisting of 3 CG, 3 DDG and 3 FFG, and (2) consisting of 16 LCSs, show that the ExWar force will suffer sizeable damages and losses as indicated in Figure XX-28. The threat of a single missile battery that escapes earlier dedicated suppression effort is something future planners cannot ignore. Either the Sea Base needs to now stand-off at a further distance, thus imposing further strains on the transit runs of the re-supply chain to support the MEB ashore or the various Sea Base ships, both amphibious and logistics ships need to have enhanced defensive capabilities, or both. In general, the Sea Base is expected to first operate at a far stand-off distance from the shore to reduce such land-based missile threats, and as operations progress and such threats are neutralized, the Sea Base can then pull closer to the shore to reduce the distance from the objectives. Specific operations to counter mobile land-based anti-ship cruise missiles must be mounted to ensure the overall survivability of the NESG even if the CSG cover is present.

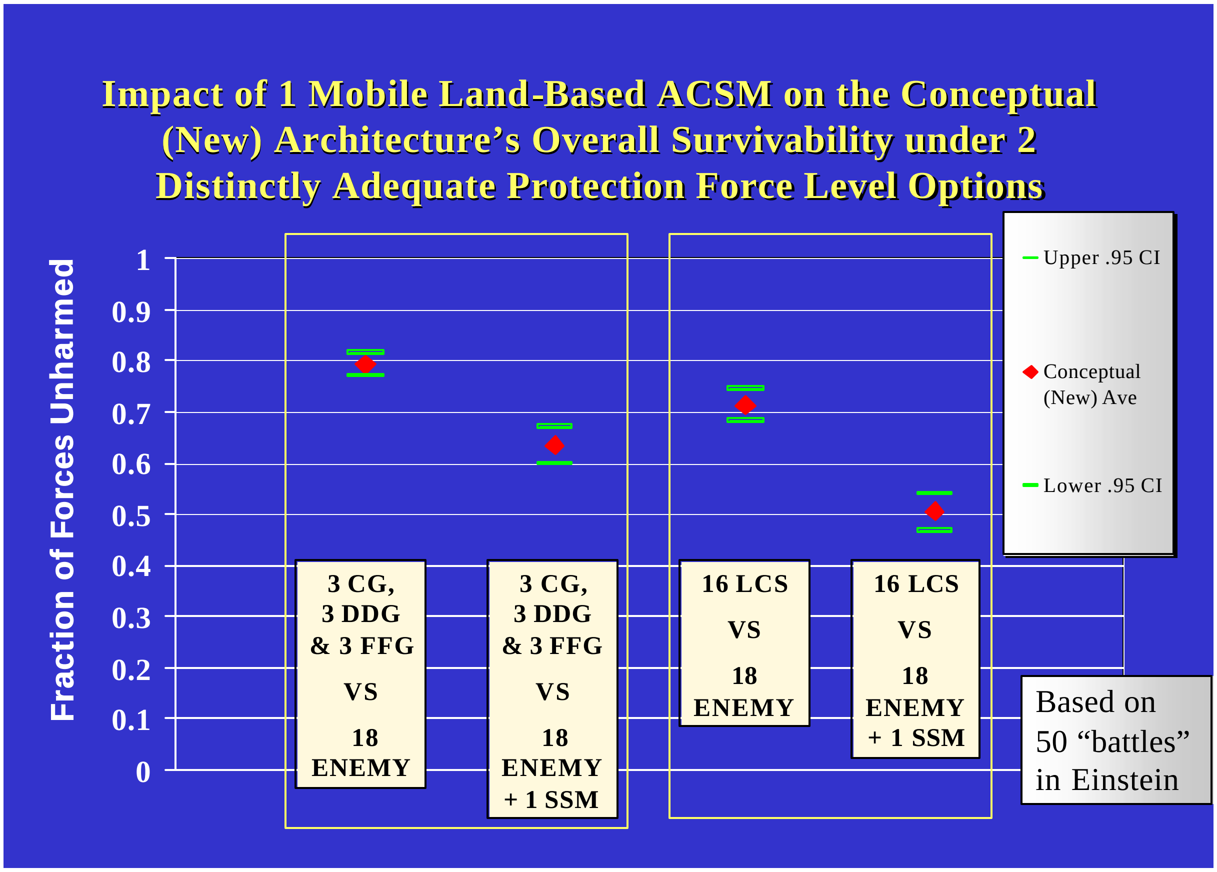



**Figure XX-28:** Impact of 1 Mobile Land-based ACSM on the Conceptual (New) Architecture's Overall Survivability under 2 Distinctly Adequate Protection Force Level Options

## 15. Summary of Significant Findings

The Conceptual Architecture is not better than the Current or the Planned in terms of survivability. Basically, we have reduced the original 15-ship MEB size NESG of the current architecture down to a 9 ship architecture consisting of 6 X-ship amphibious combatants and 3 X-ships for logistics support. This concentration of the NESG over a smaller number of much bigger ships resulted in a less distributed Sea Base that may now have become more vulnerable. To mitigate this concentration of forces on the much bigger platforms but fewer numbers, the defensive capabilities of the X-ships need to be increased (A bigger platform is associated with a more STOM friendly architecture due to the premium on the overall space and also the flight deck space which is able to support the high aerial throughput rate for the initial assault launch to capture the objective ashore). Also, the protection escort ships need to be sized adequately to provide the necessary screen. For the conceptual Architecture, the MOE of have more than 80% of the task force unharmed can be achieved by 16 LCSs; or a combined force of 3 CG, 3 DDG and 3 FFG; or 3 DDG and 12 LCSs.

The excursion on the substitution of the escort ships with LCSs for the Conceptual Architecture provides a very rough order of equal capability equation for specific anti-surface warfare scenario depicted here as:

**1 CG, 1 DDG and 1 FFG collectively = about 6 LCSs.**

Another interesting finding when we activated the communication net in the EINSTein model to simulate the Sea Base as a "perfectly" netted network centric force (with 100% accurate information shared between the ships of the various ExWar architectures), only marginal improvements to the MOE occur. While the overall percentage of forces remaining unharmed increased only marginally, a sizeable reduction in the variability of the results over the 50 EINSTein simulation battles is observed. This at first seemed counter-intuitive as a much larger effect is anticipated in the light of future Network Centric Warfare and better sharing of target data. However, this marginal improvement may be attributable to the Comms net being not adequately exploited due to the concentrated force package of the X-ships in the simulated assembly/launch area. Moreover, the focused attacks by enemy forces from one general direction did not pose a significant coordination problem. The ExWar forces in the simulation do not operate as a distributed force over a wider area and this may explain the less than anticipated benefits of "comprehensive awareness and a netted force structure".

Lastly, the option most sensitive to incremental change in the protection level appeared to be the addition of offensive and defensive capabilities to the ships. This indicates that investment on such weapon systems' capabilities as sensor and effective engagement ranges, number of simultaneous engagements, the probability of kill, the ability to soft-kill and hard kill incoming missiles are crucial to the survivability of the future ExWar force. While this excursion study on the protection needs of the Sea Base is not able to explore the options from the equal cost or cost effectiveness point of view, due to the limitation of time and manpower, a comparison across the different architectures basing of cost opportunities and trade-offs can certainly be applied to provide further insights on the appropriate defensive and offensive needs of the NESG.

### 16. Potential for Future Applications Using EINSTein.

Further agent-based simulation can be applied to explore the appropriate mix of protection force levels of the different escort ships under different threat levels to provide a quick guide to the force planners of the necessary assignment or make-up of the NESG for the given scenarios.

The NESG and the accompanying Sea Base can be viewed as a complex and dynamic collection of ship types, with individual ships, their specific weapon systems, coupled with the prevailing control measures and applicable tactical considerations. The entire architecture is a unique system-of-systems which will have some expected emergent collective behavior and combat capabilities and weaknesses that can be explored in more detailed in a simulated environment using agent-based modeling tools like EINSTein.

The unique command and control, meta-personalities, and movement constraints features offered by EINSTein make it a feasible and easily adaptable tool to better simulate the tactical movement and action of the NESG or other complex task force. In particular, the new LCS CONOPS can be explored using EINSTein whereby the subordinate UUVs and UAVs can be better modeled akin to the relationship between a battalion, company and squad, not unlike the way land forces organizes the different levels of component forces.

Another area of exploration is the offensive and defensive capabilities needed to ensure the NESG's collective survivability. The focus areas can be armament, sensors, and even considerations in tactical employment. Here, if the attributes of the weapon systems on the associated platforms can be represented appropriately and effectively, EINSTein offers a good basis for investigating the inter-related effects of improvement and introduction of new technology and weapon systems into the overall NESG and Sea Basing protection.

## I. ADVANTAGES AND DISADVANTAGES

The advantages of Sea Basing by far outweigh the disadvantages. Table XX-29 provides a list of several the advantages and disadvantages associated with Sea Basing.

| Advantages | Disadvantages |
|---|---|
| Over the Horizon Capability | Lack of Capable Air Escorts Due to Speed and Endurance |
| Oversea Access | Limited Fire Support |
| Forward Presence | Aircraft Survivability |
| Global Reach | High Cost |
| Increased Reaction Time | Limited to a MEB Size Landing Force |
| Faster Combat Power Ashore | |
| Accommodates Current Strategy & Concepts | |
| Primary Enabler for OMFTS, STOM, EMW, & SBL | |
| More Capable in Adverse Weather | |
| Selective Offload | |
| Reconstitution Capability | |
| Indefinite Sustainment | |
| Reduced Footprint Ashore | |
| Exploits Enemy Weaknesses | |

**Table XX-29:** Advantages and Disadvantages of Sea Basing

## J. RECOMMENDATIONS

The purpose of this section is to provide recommendations for follow-on studies to be conducted at NPS and to further design and develop systems that have added value to enhance future ExWar concepts.

With the future of the MV-22 in a state of uncertainty, the Marine Corps should investigate in the possibility of procuring a long-range heavy lift aircraft as well as the medium range MV-22. A long-range heavy lift aircraft would increase the throughput at longer ranges and enhance the USMC's airlift capability. Having the capability to deliver large quantities of fuel, water, and ammunition would help reduce the footprint ashore, giving the combat forces ashore more flexibility and maneuverability.

Procuring a heavy lift aircraft would require a future study in finding optimal loading plans for internal and external loads. Maximizing the aircraft payload capability would reduce the number of aircraft required to delivered the daily sustainment requirements and allow for greater flexibility in scheduling the aircraft for other operational commitments.

With a longer-range capability to move combat troops, equipment, and supplies ashore, a follow-on study needs to address the possibility of moving Joint Forces, as well as Allied Forces. The Sea Base is a resource for providing a launching pad when a host nation doesn't want U. S. Forces stationed on their soil. So having the capability to move not only the Navy and Marine Corps would definitely add a most robust capability to the Joint Force Commander.

Although not thoroughly studied by us the need for aerial and naval fire support needs to be studied in great detail. With limited range capabilities in naval gunfire support and the lack of range and endurance for aerial fire support assets, the need to figure out a way to protect the combat troops ashore and the logistics moving ashore becomes very important.

## K. CONCLUSIONS

In this study we examine the Sea Base using various tools and concluded Sea Basing is a viable option for the future of Expeditionary Warfare provided a robust aerial throughput capability and a capable force protection package exists. The following summarizes our conclusions using ENTEND, EXCEL, ARENA, and EINSTein.

### 1. Conclusions resulting from EXTEND™ analysis

- The distance from the Sea Base to the Objective is critical to the overall sustainment effort.

- Greater distances create more variability and difficulties in maintaining a desired level of days of supplies at the Objective.
- Air re-supply is more robust in adverse weather, but it is highly dependent on survivability during transit.
- Air re-supply is more responsive and expedient, but it consumes a significant amount of fuel.

## 2. Conclusions resulting from EXCEL™ and ARENA™ simulations and analysis

- Planned aviation assets cannot meet the sustainment needs of a MEB beyond 175 NM.
- Conceptual aviation assets with 24 HLAs and 96 MV-22s operating from the 6 X-ships can surge and sustain a MEB up to 275 NM from the Sea Base.
- Conceptual aerial throughput capability has a surge capacity of 4 times the daily sustainment requirements at 225 NM; 3 times at 250 NM and 2 times at 275 NM (12-Hour Operating Time).
- Conceptual Architecture can accept up to 50% attrition or diversion of assets to other missions and still sustain a MEB ashore up to 275 NM daily ($A_o$ = .75).

## 3. Conclusions resulting from EINSTein Simulations

- The Conceptual Sea Base did not perform better than Current or Planned in terms of survivability.
- A less distributed Sea Base becomes less survivable.
- Mobile land-based ASCMs (Anti-Ship Cruise Missiles) pose a threat to the Sea Base.
- The defense capabilities of the ships need to be increased.
- The simulations indicate the MOE for the Conceptual architecture can be achieved with 16 LCS; 3CG, 3DDG and 3 FFG; or 3 DDG and 12 LCS.