XIII. INTERPRETATION AND ANALYSIS OF MODELING RESULTS

A. INTRODUCTION

In order to extract and derive useful information from the data obtained through the modeling runs, it was essential that a methodology be defined. The methodology used was the Design of Experiment. However, at the same time, to allow for a common basis of comparison between the 3 different architectures, a common set of Measures of Performance (MOP) should be used. The careful analysis of these MOPs provided insights and useful information into the general performance of the various architectures as well as the significance of the various factors affecting an Expeditionary Force to project its force and sustain the operation ashore. The MOPs used to analyze the data, were therefore divided into two main categories, one for the Assault phase and the second, the Logistics sustainment phase.

B. ASSAULT PHASE

For the Assault phase, the unit for measurement is the Combat Power Ashore (CPA) index. CPA is the aggregated score to reflect the level of combat power available at any one time at a certain location. The CPA index is a summation of the Combat Power Index (CPI) contributed by individual entities that contribute combat power to the force. The CPI allocated to the individual entities are based on a RAND study, see Situational Force Scoring: Accounting for Combined Arms Effects in Aggregated Combat Models", Patrick Allen, RAND ® Strategy Assessment Center, 1992.

The entities that contribute towards combat power that were used in this analysis are:

1. M1A1 Tank
2. Light Armored Vehicle (LAV)
3. Assault Amphibious Vehicle (AAV)
4. Advanced Assault Amphibious Vehicle (AAAV)

5. M198 155 mm Howitzers
6. High Mobility Multipurpose Wheeled Vehicle (HMMWV)
7. Troops

See Appendix 13-1 for details on the computation of CPA and CPI.

Using the CPA scores, two MOPs were identified to measure the performance of the individual architectures for the Assault phase. The two MOPs are:

1. Time to Landing of Advance (TAF) Force at the Objective

TAF is the time taken from the launch of the operation to the build up of a Company level force at the Objective.

2. Time to Build Up (TBU) A Desired Level of Forces at the Objective

TBU is the time taken from the launch of the operations to the build up of a desired level of force at the Objective. There are broadly two phases when building up a force ashore. The first being the initial built-up by the Expeditionary Force projecting from the LHA/LHD to shore using their organic assault assets, such as LCAC, LCU, CH-53, CH-46 etc. After this initial assault, this force will be supplemented by the remaining force either through the arrival of the MPF at the Iron Mountain for the Current Architecture or the Sea Based MPF(F) for the Planned Architecture or lastly, by the ExWar ships for the Conceptual Architecture.

Based on the two phases, there are two distinct levels for which TBU can be determined. The first being the time taken to project the force using the organic assets, and the second being the time taken to project the force utilizing all the assets (including those carried by the MPF(F) and ExWar Logistics ships) available. Measuring the two times allows for analysis within each architecture and between the three architectures.

a. Within Architecture Analysis

The analytical objective was to find out the performance of an architecture's assault force projection capability (i.e. the first phase of the force projection capability). Hence, the desired force level that was used for this analysis is the force level that was projected based solely on the organic architecture's assault assets before the reinforcement by the Logistics ships (i.e. MPF/MPF(F)/ExWar ships). Analysis based on this reference level gives a true reflection of the performance of that particular architecture's assault assets.

b. Between Architectures Analysis

The analytical objective was to find out the performance of the overall force projection capability (i.e. both assault phases). Hence, the desired force level used for this analysis was pegged at a level that included not only the force built up by the assault assets, but the build up of the remaining force by the Logistic ships as well. This allowed a more comprehensive analysis of the performance and comparison of the total force built-up capability between the three architectures.

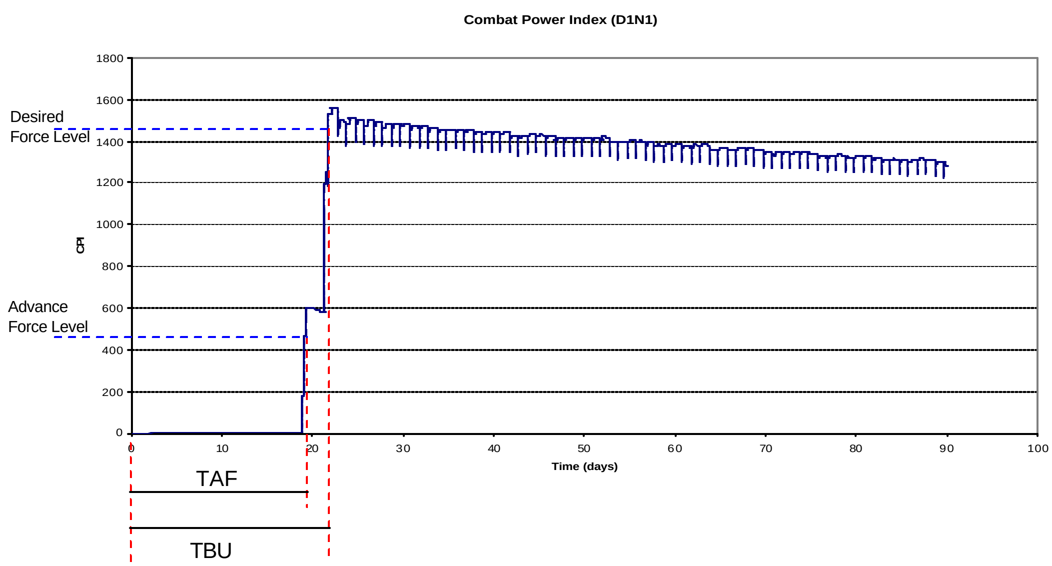

Figure XIII-1: Sample Combat Power Index Graph at the Objective

These two MOPs (TAF and TBU) were inputted into separate Design of Experiment (DOE) matrixes and were run through the Minitab program to establish the significance of the various Design and Noise factors on these two MOPs respectively.

C. LOGISTIC SUSTAINMENT PHASE

For the logistics sustainment phase, the MOP is the aggregated Mean Squared Error (MSE) of the three classes of Daily Sustainment Requirements; see An Evaluation of Sea Based Sustainment of Forces by Frey, NPS, 2002, which were required to sustain an operation ashore. The three classes of daily requirements are MREs, fuel and ammunition and they are measured at both the Iron Mountain/Sea base and the Objective. The MSE accounts for the bias and variability of the sustainment levels of the three resources from the desired level. The aggregated MSE is obtained through averaging the MSEs of the three resource levels and this MOP was inputted into the Minitab program to study the effects of the various factors on the logistical sustainment at the Iron Mountain/Sea Base as well as at the Objective.

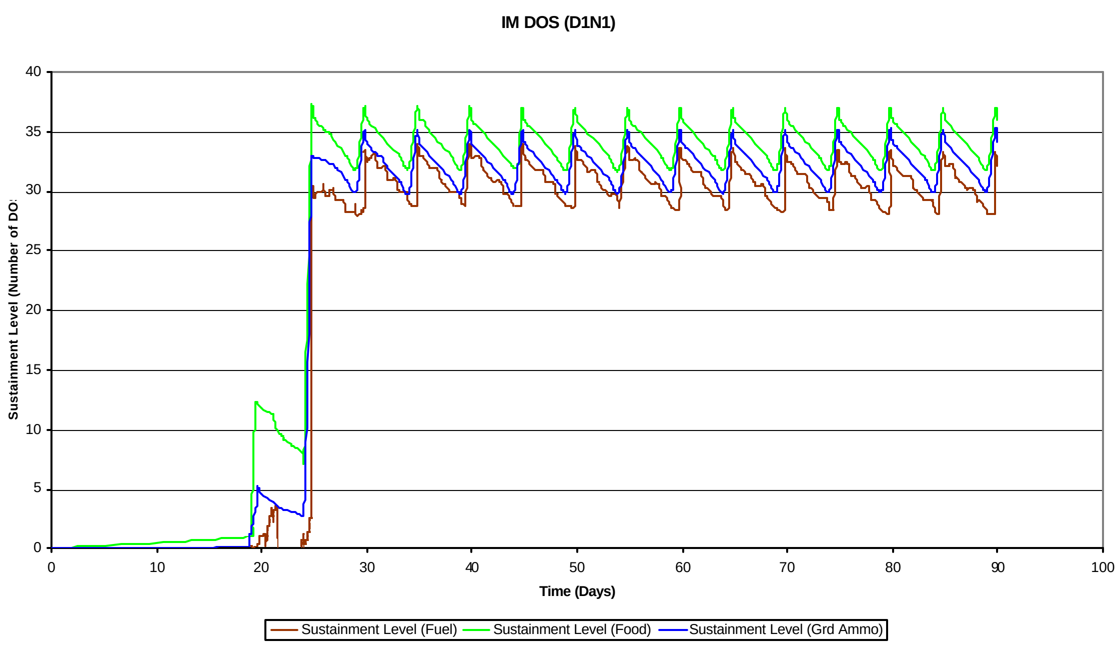

Figure XIII-2: Sample Plot Indicating Sustainment Level at the Iron Mountain

D. RESULTS OF MODELING RUNS

Upon the completion of all the 96 modeling runs based of the DOE matrix, a set of results were generated. The detail data results from the modeling runs can be found in Appendix 13-2.

E. ANALYSIS OF FACTORS AFFECTING EACH ARCHITECTURE

1. CURRENT ARCHITECTURE

The Current Architecture captures the processes that the Marines use in their present operating concept. It uses a coastal logistics depot called an Iron Mountain to sustain the operations ashore.

a. *Description*

In the Current Architecture, the MEB, using its assault elements from the LHAs, LPDs and LSDs, will launch a simultaneous assault on the Iron Mountain and the Objective. All surface assault elements are concentrated at the Iron Mountain (the one being closest to the shore, providing coastal access) while the air assault elements are directed at the Objective. Both assault elements will be sustained initially by the amphibious ships that are on station.

Once the Iron Mountain has been secured, the six MPF ships will sail into the Iron Mountain to unload the heavy combat elements and logistical supplies that they carry. From the Iron Mountain, the additional combat elements will transit to the Objective to reinforce the forces already there while the logistical elements of the Expeditionary Force will sustain the combat forces using the assets and resources that are held at the Iron Mountain. The Iron Mountain's resources are resupplied by scheduled trips of LMSR ships or HSVs coming from the Offshore Base.

b. *Initial Assault Phase*

TAF at the Objective. In the initial assault phase, the time taken for the Expeditionary Force to project one company of Marines to the Objective under the various conditions were recorded and analyzed. In the assault plan, only troops would be flown into the Objective. Hence only factors that could have an influence on the time taken for the aircraft to fly to the Objective would have an impact on the metric TAF at the Objective.

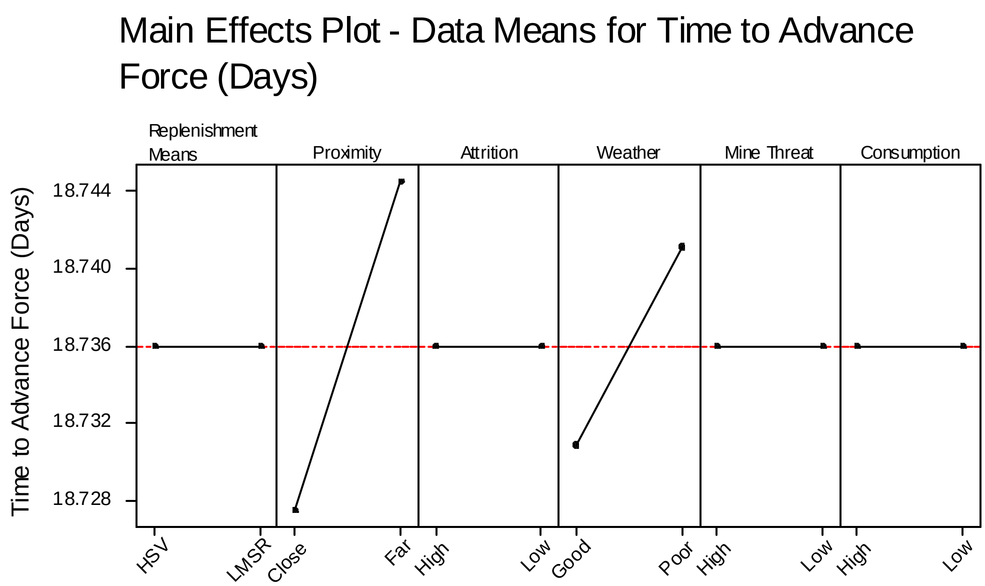

Figure XIII-3: Data Means for TAF at the Objective for Current Architecture

From the plot, it can be observed that the factors Proximity and Weather affect the time taken to project the first company of Marines ashore. Good weather and close proximity of the amphibious ships to the shore reduced the time taken to project the force ashore while bad weather and having the amphibious ships further out at sea (a difference of 50 NM) increases the time taken to land the company.

It is interesting to note, however, the effects of placing the ships further out at sea only delayed the projection of the advance force by 0.02 days or 29 minutes. This small time difference is due to the fact that the forces are flown in and the helicopters with their high transit speeds are able to cover the longer distance without sacrificing too much time. This small increase in the time to project the company ashore may be well worth the reduced risk the amphibious ships face from coastal defenses and anti-ship cruise missiles deployed against them.

TBU to Desired Level of Forces at the Objective. Once the initial company of Marines has been established, the MEB continues to build up the force at the Iron Mountain and the Objective until the entire MEB has been projected ashore. A second measure of performance indicating the time taken for the Expeditionary Force to build up a force with a CPI of 1200 at the Objective was recorded for analysis. Again, the MEB is subjected to varying conditions in order to analyze the effects that these factors have on the time to build up to a desired level of forces at the Objective.

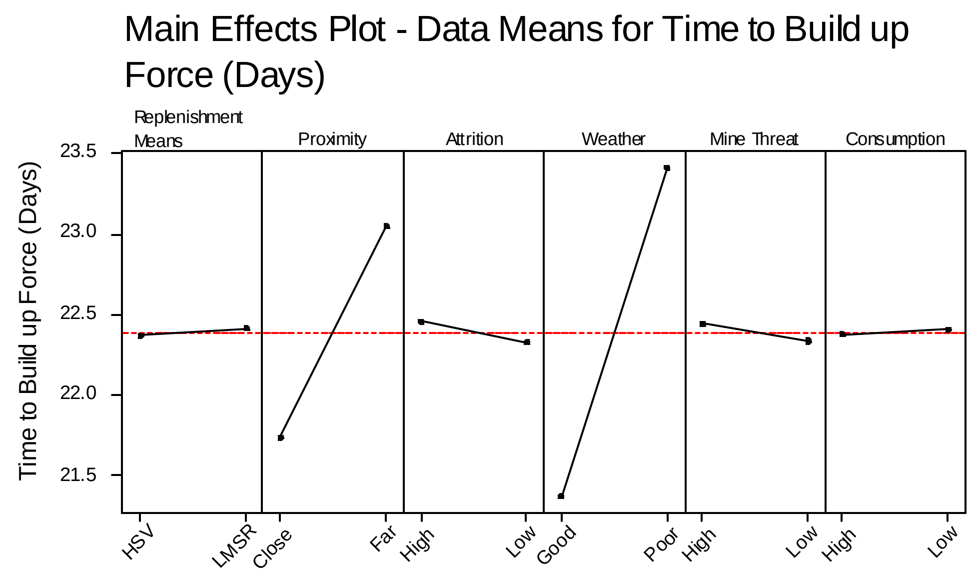

Figure XIII-4: Data Means for TBU at the Objective for Current Architecture

Once again, the factors Proximity and Weather affect the time taken to build up the desired force. In this instance, the difference in the times taken is larger as the transporters have to make several trips in order to project the force ashore. The MEB requires an additional two days to project the force ashore in poor weather conditions as compared to in good weather. Similarly, it takes the MEB on average an additional day to project the same force ashore if the amphibious ships were deployed further away from the shoreline. However, if good weather prevails, the MEB takes approximately the same time (21.5 days) to build up to a CPI of 1200 when the amphibious ships are stationed far from the shoreline. When weather conditions deteriorate, the MEB will take almost 3 more days to build up the same force if the amphibious ships were deployed further out to sea. The interaction plot for Proximity and Weather effects is depicted in the Figure XIII-5. The interaction plot indicates the extent to which the MOP changes as a result of changes in the factor levels. In this instance, the TBU at the Objective for Current Architecture only increased from 21.5 days to 22 days when the amphibious ships stayed close to the shoreline and the weather changed from good to poor; while the TBU increased from 21.5 days to 24.5 days when the amphibious ships were deployed further out to sea and the weather changed from good to poor, indicating that in good weather, it really does not matter how far the ships were deployed from the shoreline but in poor weather conditions, distance to the shoreline will have a significant effect on TBU, hence the interaction between the two factors Proximity and Weather.

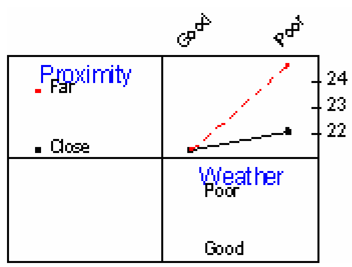

Figure XIII-5: Interaction Between Proximity and Weather for TBU for Current Architecture

High attrition rates and a significant mine threat on the landing beaches do slow the time taken to build up the desired force, but the difference is only marginal compared to the effects resulting from varying the Proximity and the impact of changing Weather.

c. Logistic Sustainment Phase

In addition to examining the combat power projected ashore, the analysis is also concerned with the process of sustaining the force that has been sent ashore.

MSE of Supply at the Iron Mountain. To investigate the effects that the factors have on the logistics supply process, a measure of performance was taken at the Iron

Mountain to determine the number of days of supply that was held throughout the 90 days duration of the mission.

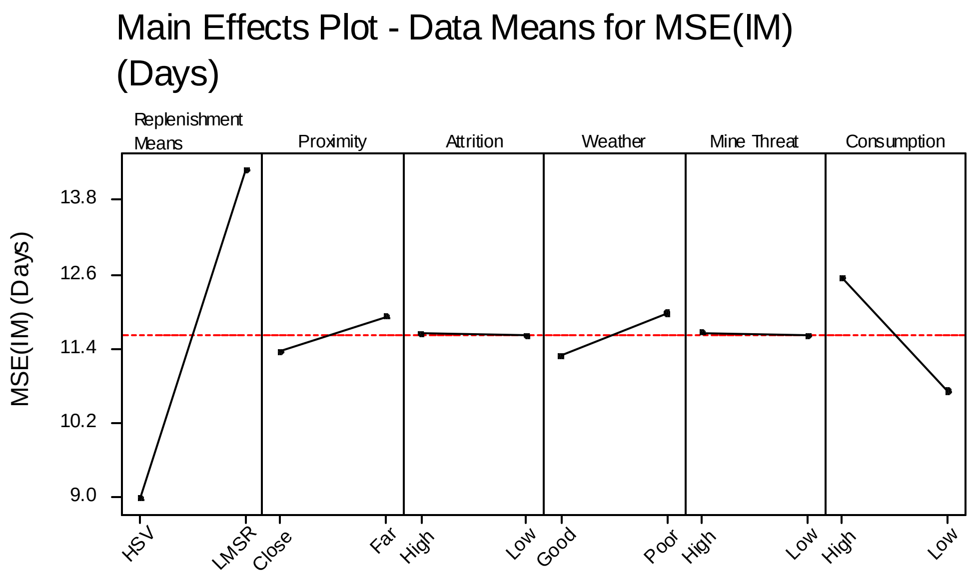

Figure XIII-6: Data Means for MSE of Supply held at the Iron Mountain for Current Architecture

From the plot, it can be observed that the replenishment means between the Iron Mountain and the Offshore Base, the rate of consumption of resources, the proximity of the amphibious ships to the shoreline and weather affect the supply process to, and the level of resources held, at the Iron Mountain.

The impact that proximity has on the MSE is relatively small because the amphibious ships only provide logistical support to the Iron Mountain up until the arrival of the six MPF ships. It should still be noted however, that having the amphibious ships further out to sea results in larger variations in the stockpile of resources at the Iron Mountain.

Similarly, the effect of weather on the MSE at the Iron Mountain is small compared to replenishment means and consumption rates because in the construct of the model weather only degrades the performance of the LCACs, LCUs and aircrafts operating between the Iron Mountain and the amphibious ships. As highlighted above, these vessels only operate for a limited time to support the logistical transfer of resources from the amphibious ships to the Iron Mountain. The variations in the stockpile held at the Iron Mountain increases as the weather conditions deteriorate.

Having a high rate of consumption of resources resulted in an average variation in the days of supply held at the Iron Mountain which is approximately two days larger than if the consumption rate was low. The increase in consumption rate meant that the resources were being depleted much quicker in the initial phase of the operation but the stockpile held at the Iron Mountain was able to sustain the increased demand, and create a buffer so that the follow on replenishment ships can make up for the increased demand if the need arises.

By using HSVs to replenish the Iron Mountain, the MEB can reduce the variation in the stockpile by an average of five days. With two HSVs carrying one day of supplies to the Iron Mountain every day, it can be expected that the resource level held at the Iron Mountain to be relatively stable as compared to using the LMSR option, which carries five days of supplies to the Iron Mountain once every five days.

MSE of Supply at the Objective. Besides the Iron Mountain, a similar measure of performance was recorded at the Objective to determine the performance of the Iron Mountain in sustaining the force at the Objective. The resource level at the Objective was measured and recorded for the entire 90 day period and the deviation from the expected holding (which was pre-determined to be five days of supply) was used to identify any factors that affect the sustainment phase of the operation.

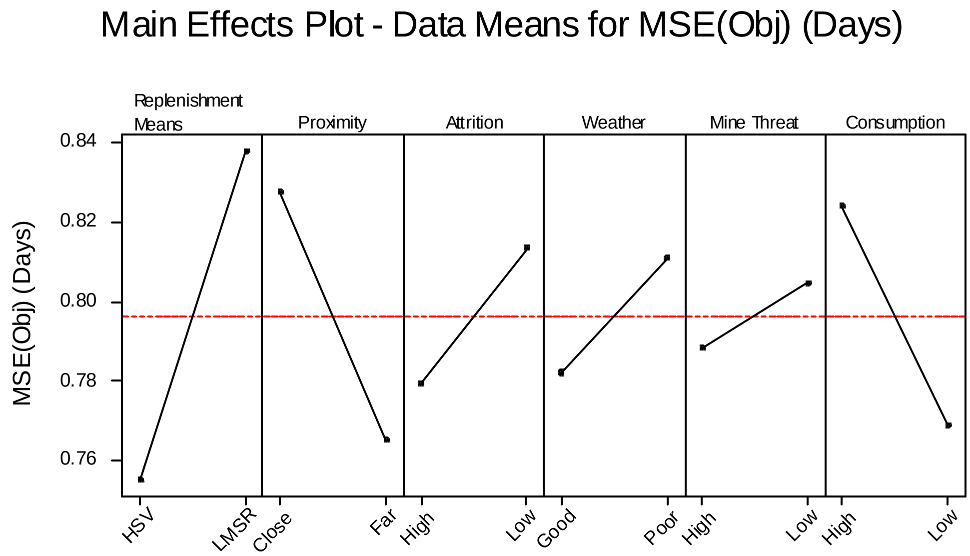

Figure XIII-7: Data Means for MSE of Supply Held at the Objective for Current Architecture

The figure shows that all factors seem to impact the MSE of supply held at the Objective. However, it is crucial to note that the variation in the resource level at the Objective as a result of the factors is at most 0.08 days, which is not significant considering that the Objective holds five days of supply. The tiny variation indicates that the sustainment process between the Iron Mountain and the Objective is not significantly impacted by any of the factors under investigation.

c. *Conclusion*

For the Current Architecture, the proximity of the amphibious ships to the shoreline and the weather in the area of operations has significant impacts on the time taken to project the combat forces ashore. Without consideration of other factors like the threat posed to the amphibious ships from coastal defensive weapons and offensive weapons, it would be best if the MEB could operate close to the shoreline in good weather conditions to achieve the shortest time needed to project its forces ashore.

Similarly, in order to sustain the force as efficiently as possible, the amphibious ships should also operate as close to the shoreline as possible prior to the arrival of the MPF ships. In choosing the replenishment means for the Iron Mountain, HSVs would perform a better job in reducing the variability of the resource held at the Iron Mountain.

2. Planned Architecture

The Planned architecture is designed to exercise the STOM concept with the presence of the Sea Base to host the logistic depot thus removing the need to build an Iron Mountain ashore for the sustainment phase as compared to the Current Architecture. This architecture utilizes a balance of air and sea crafts to project the forces ashore. Furthermore, it uses advanced platforms like MV-22 and Heavy LCAC (HLCAC) to replace the aging transporters.

a. Description

The initial operation of the Planned Architecture is quite similar to the Current Architecture with the exception of the logistical depot location. In the Planned Architecture, once the MEB has moved into the Launching Area to project the forces ashore to the Objective, the MPF (F) ships will move in and form the Sea Base at the Launching Area. With the Sea Base established, the MEB will utilize the transporters from the amphibious ships to sustain the forces at the Objective. In this architecture, 50% of the resources are transported to the Objective by air and the other 50% are sent via the sea.

b. Initial Assault Phase

TAF at the Objective. TAF is the time required to land one company of Marines as an advance force to the Objective. Since the initial forces are projected to the Objective in the first wave by aircrafts, TAF could only be affected by the speed of the platforms and the distance for projection.

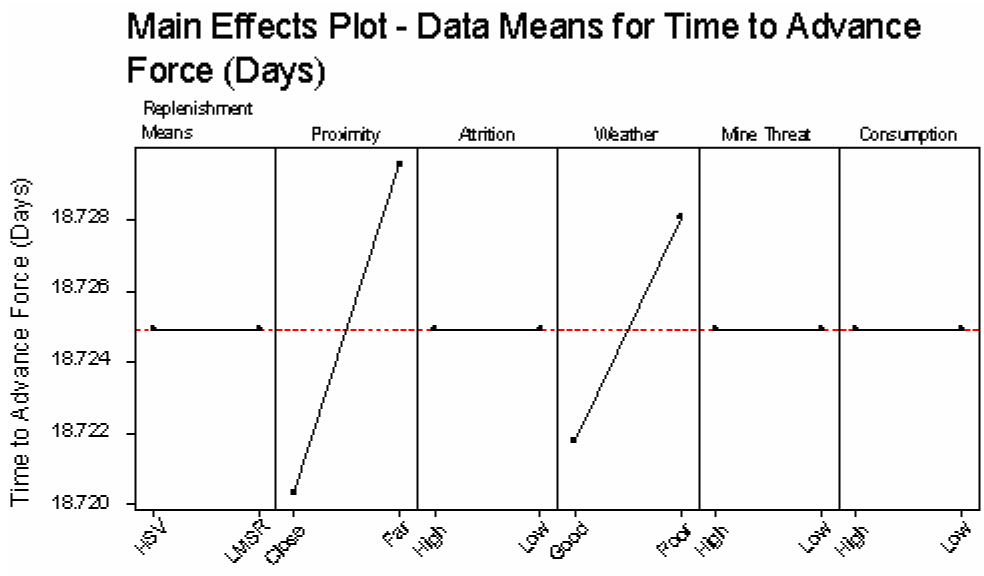

Figure XIII- 8: Data Means for TAF at the Objective for Planned Architecture

Based on Figure XIII- 8, it is observed that the Proximity and Weather are statistically significant but practically insignificant to a user, as a difference of 0.01 day is not going to affect the tempo of the operation. This is because with the employment of aircraft to transport the desired size force ashore in the first wave, the aircraft speed has made TAF to be robust to the factors. As such the study found that TAF for the Planned Architecture is robust against the design and noise factors.

TBU to Desired Levels of Force at the Objective. The desired level for TBU in this architecture is based on a CPI index of 1000. This value is derived from the force, which was projected ashore using only the organic assault elements carried by the amphibious ships. With this desired level, the study could accurately investigate the impact of design and noise factors on the build up of forces ashore by the Planned Architecture.

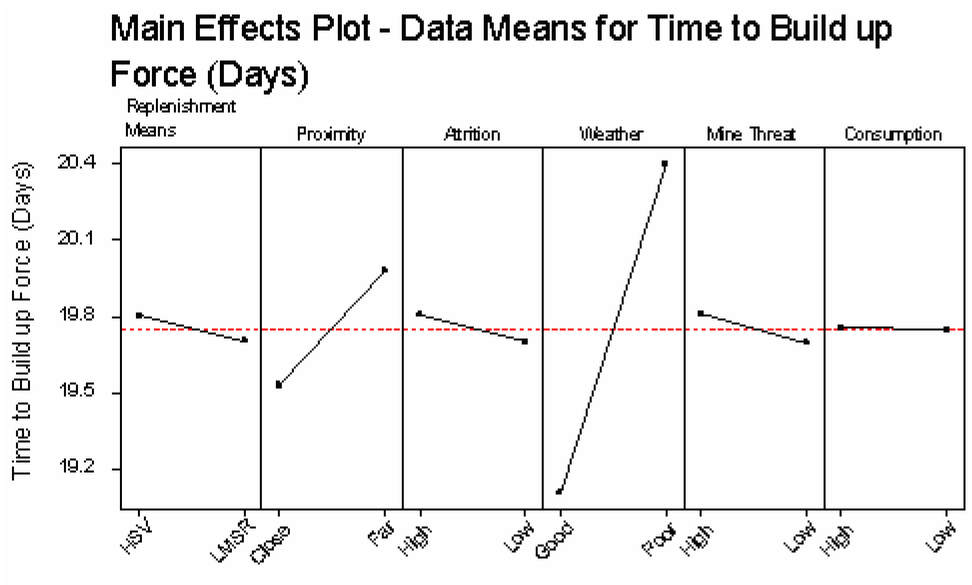

Figure XIII-9: Data Means for TBU at the Objective for Planned Architecture

Based on Figure XIII-9, it is observed that the Proximity and Weather are significant, with a difference of 0.6 days and 1.4 days for TBU. It is intuitive because reducing Proximity will reduce the turn around time for the transporters, which in turn reduces the time to achieve the desired TBU. Moreover, when the Weather toggles from Good to Poor, which causes a reduction in payload and speed for the transporters, the difference in TBU is compounded as observed from the interaction plot in Figure XIII-10.

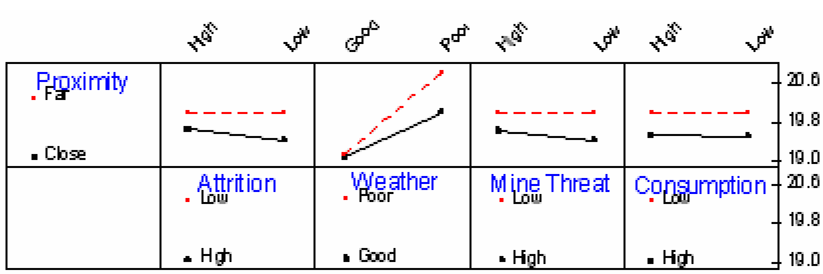

Figure XIII-10: Data Means for Interactions Between Design Factor Proximity and Noise Factors for TBU for Planned Architecture.

By studying the interactions plots in Figure XIII-10. It is noticed that operating at Far Proximity seems to be more robust against noise as compare to Close with the exception of Weather. However it is interesting to note that in Good Weather condition, TBU is about the same regardless of what is the level for Proximity. Since TBU for Far is robust against other noises, a user could choose in practice to operate at Far whenever the weather is Good, if being robust against noise factors is what concerns him even though the optimal operating condition for the Main Effects plot in Figure XIII-10 might say otherwise.

c. Logistic Sustainment Phase

TAF and TBU could only serve as MOPs to measure the performance of the architecture in projecting forces ashore. However, for the forces to operate effectively ashore, the architecture must have the capability to sustain the forces with the necessary resources. As such the MSE is used as MOP to measure the amount of deviation a resource quantity from its target value set at either the Sea Base or the Objective. With this MOP, the study could deduce the capability of the architecture in the sustainment phase.

MSE of Supply at the Sea Base. The MSE (Sea Base) measures the variability of the sustainment levels of the three resources (food, ammunition and fuel) from the desired days of supplies level at the Sea Base. This variability is affected by the ability of the Sea Base to balance between the rate of resources being delivered to and sent from the Sea Base. Since it is a deterministic demand from the Objective and the mode of resources being drawn from the Sea Base is fixed, the variability could only be affected by how resources are input to the system and the environmental conditions where the operation is conducted.

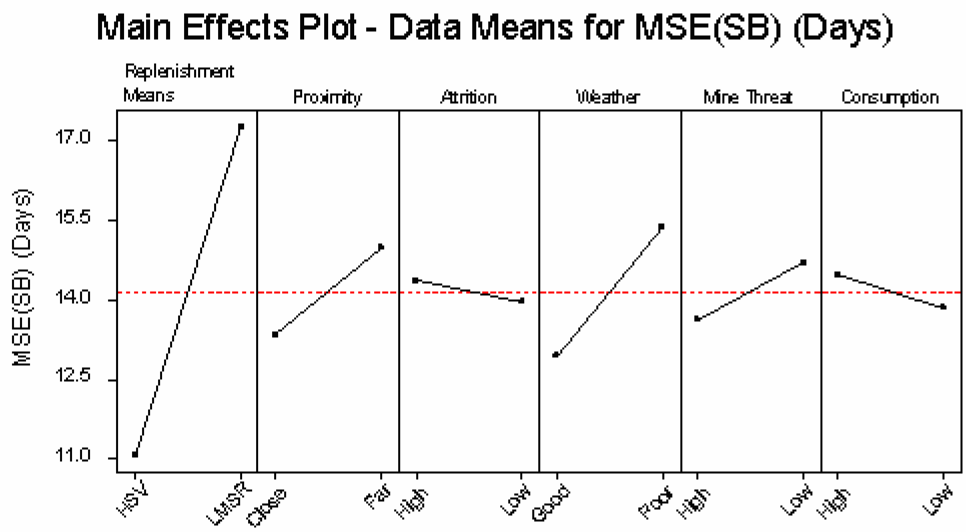

Figure XIII-11: Data Means for MSE at the Sea Base for Planned Architecture

From Figure XIII-11, it is observed that the Replenishment Means, Proximity, and Weather are statistically significant, with the maximum difference of 6 days for Replenishment Means. Thus, it is observed that using HSVs with characteristics like high frequency of replenishment, small payload and short duration for unloading as a vessel to replenish the Sea Base will provide a smaller MSE as compared to commercial ships like LMSR with low frequency, high payload and long duration for unloading. Small payload and short duration of unloading delay will have less variability due to the fact that resources are unloaded as a step function rather than real time in the simulation. High frequency will increase the ability to replenish the resources sent out from the Sea Base. However one should note that with a fixed quantity of HSVs used, and since high-speed is inversely proportional to payload with the current technology available, there might be a diminishing return on the MOP due to the fact that any increase in frequency is insufficient to replenish the Sea Base unless one of the factors is allowed to change, i.e. the user employs more HSVs in the system. Thus there might be a limit to how far speed can be increased by fixing the quantity of the HSVs in the system. This is an awkward sentence; try rewording.

While for Proximity, Close is better than Far because given the same frequency for a transporter to replenish the Objective, the level at Far will consume more fuel as compare to Close, thus resulting in a higher variability in the aggregated MSE (Sea

Base). For the factor Weather, Good is always better than Poor because the rate of the output is reduced given the same input during the initial launch phase which will result in higher variability. Furthermore, the increase in frequency for transporters to travel between the Launching Area and the Objective will increase the fuel consumption and this will further increase the value for MSE (Sea Base).

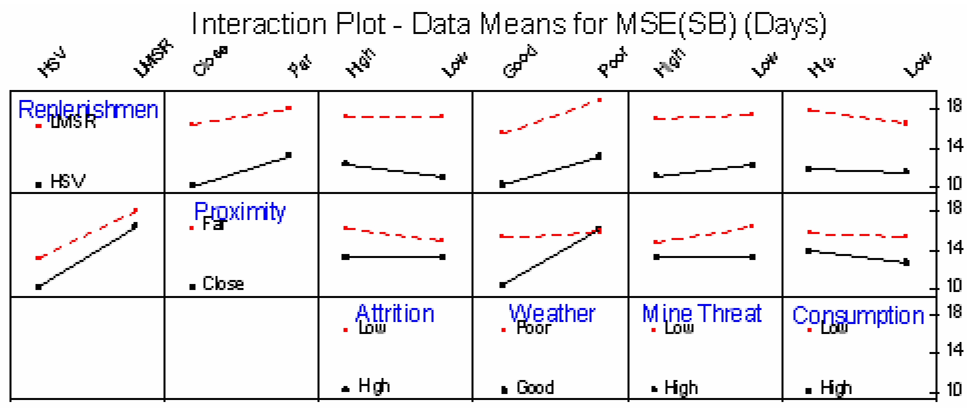

Figure XIII-12: Data Means for Interactions Between Design Factors and Noise Factors for MSE at the Sea Base for Planned Architecture.

From the interaction plots seen in Fig XIII-12, it is observed that both design factors Replenishment Means and Proximity are not so robust against the noise factors. These imply that the MSE (Sea Base) for a particular set of design is quite affected by the noise level. It is also noticed that during Poor Weather, the MSE (Sea Base) is about the same regardless of Proximity. This is because the increase in consumption for fuel by transporters due to longer transition seems to be balanced off by the reduction in the rate for the output at Sea Base. As such, if MSE (Sea Base) is what is important to a user, the user could choose to operate at any level of Proximity when Poor Weather occurs.

MSE of Supply at the Objective. With the same concept of employing MSE as an MOP for Sea Base, it is also used to measure the variability of resources at the Objective. Since the Objective generates a constant demand, what affects the variability would be the ability of the transporters to transfer resources from the Sea Base to the Objective given that these resources are available at the Sea Base.

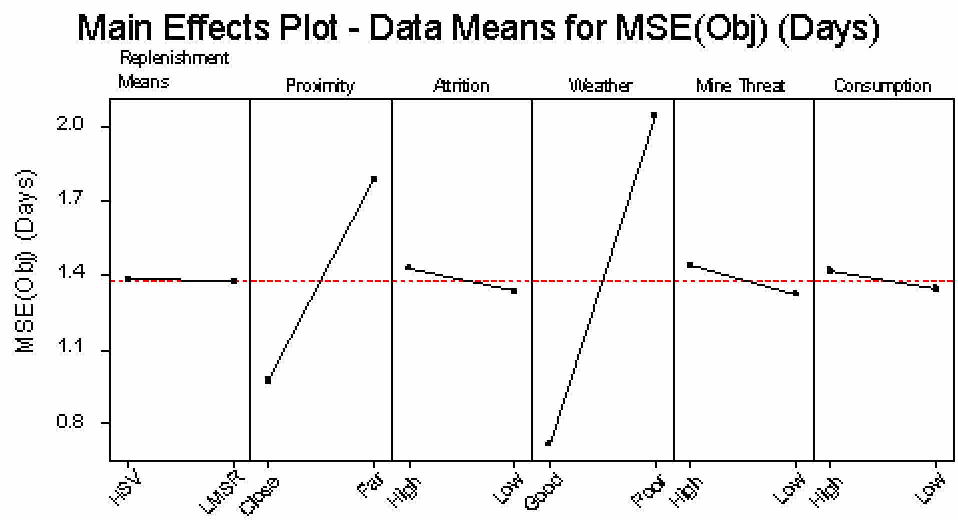

Figure XIII-13: Data Means for MSE at the Objective for Planned Architecture

From Figure XIII-13, it is observed that Proximity, Weather and Mine Threat are statistically significant with a maximum difference of about 1.5 days within the level of Weather. It is intuitive because this architecture employs 50-50 of air and sea crafts to project forces ashore, as Proximity reduces, the lead-time to replenish the Objective will also reduce. While for Weather, the reduction in speed and loading time of transporter during Poor weather will increase the lead-time for the desired quantity of resources to be transported to the Objective, thus increasing the MSE. The same rationale also explains why High Mine Threat is better than Low.

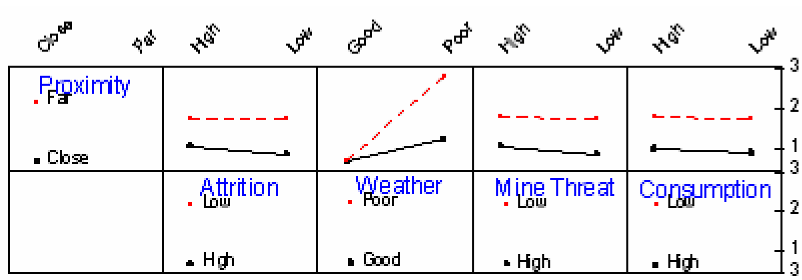

Figure XIII-14: Data Means for Interactions Between Proximity and Noise Factors for MSE at the Objective for Planned Architecture

It is interesting to note that the interactions plots in Figure XIII-14 are quite similar to the plots Figure XIII-10 for TBU, as such the same lessons are learned from the interactions of Proximity against noise factors as in the TBU. Therefore, a user has the flexibility to select any levels of Proximity given Good Weather to achieve about the same MSE at the Objective if this is what concerns him even though the optimal operating condition for the main effect plot might say otherwise.

d. Conclusion

From the study of the four MOPs used to assess the performance of the Planned Architecture, it is clear that the best policy to employ the Planned Architecture is to use HSVs as a means of replenishing the Sea Base with the amphibious ships deployed at close range to the shore. However, when the weather is Good, the user has the flexibility to deploy the amphibious ships at a further range to the shore for some other advantages if the value for MSE (Sea Base) is not a key factor in the considerations.

3. Conceptual Architecture

The Conceptual Architecture is a refinement of the Planned Architecture by the Systems Engineering and Integration group. The distinctive features of this architecture are that it employs ships with common hulls known as ExWar Ships as well as long range heavy lift aircrafts. Both of these are designs by the TSSE group and the Aero Engineering group as part of the SEI project. For details on these designs, section 4, chapters XIV and XV can be referenced.

This architecture will exploit the STOM concept in its maneuver and is therefore similar to the Planned Architecture in its concept of operations, but different in the platforms utilized.

a. Description

The model of the Conceptual Architecture uses a Sea Base module and does not have an Iron Mountain Module. As this architecture has a heavier air component as compared to the other two architectures, it will utilize a higher proportion of air replenishments than the other two architectures. In this architecture, the forces are launched from the Launching Area and subsequently the replenishments are launched from the Sea Base. This process of launching the MEB and subsequently the replenishments are purely conducted via air and sea means to the Objective.

b. Initial Assault Phase

In this phase of the operations, we measure two specific timings in order to evaluate the effectiveness of the architecture as well as to analyze how different factors affect the architecture and its design. The two timings are the TAF at the Objective and the TBU to Desired Level of Forces at the Objective. These two timings are derived from a total of 32 model runs of the Conceptual Architecture in a variety of conditions and are captured in the Combat Power Index buildup graphs (Appendix 13-7); as explained in Chapter XII.

TAF at the Objective. This timing measures the amount of time to land a company sized force at the Objective. This timing is largely affected by the speed of the amphibious ships arriving at the theater as well as the speed and loading capacity of the transportation means available to the landing force.

This MOP is also dependent on several other factors as illustrated in Figure XIII-15.

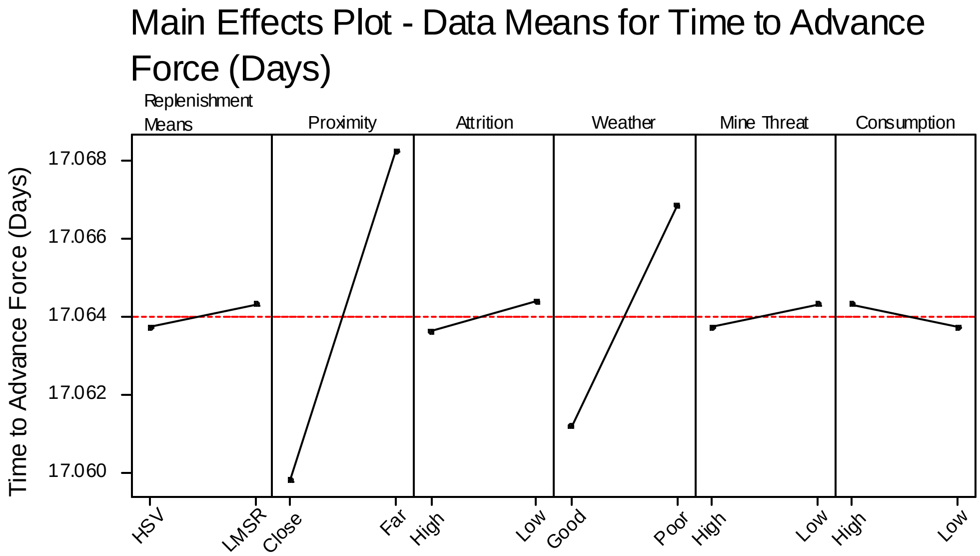

Figure XIII-15: Data Means for TAF at the Objective for Conceptual Architecture

Figure XIII-15 shows the means of the data collected from the model runs as conducted as part of the Design of Experiments Matrix. The Design of Experiments Matrix can be found in Chapter XII.

The above figure shows that the time for Landing of the Advance Force at the Objective is affected by the proximity of the Launching Area to the Objective. In other words, a closer Objective results in a shorter landing time. However the difference is only 0.008 days, which is insignificant in a practical sense albeit of statistical significance.

Weather also has the same effect on this MOP; good weather results in a shorter landing time. But this time difference of 0.004 days is again insignificant in practice.

The insight here is that in building up to the initial advance force, the factors studied in the Design Matrix have little or no practical effect on the landing time. This is largely due to the fact that the majority of the initial waves of the force are sent via air. Air transporters have a higher transit speed and are also less susceptible to inclement weather.

The other factors illustrated are statistically insignificant and are inconclusive in their effects on this MOP. Please reference Appendix 13-8 for the Analysis of Variance (ANOVA) tables illustrating the significance of each of these factors.

TBU to Desired Level of Forces at the Objective. This MOP measures the time taken for this architecture to build the forces ashore up to the desired level in order to conduct the operations at the Objective. The desired CPI level at the Objective is 1000 as the rest of the forces will be launched by the Sea Base. This timing is largely affected by the transit speed and loading capacity of the transportation means available as well as the numbers of these transportation means on the ships.

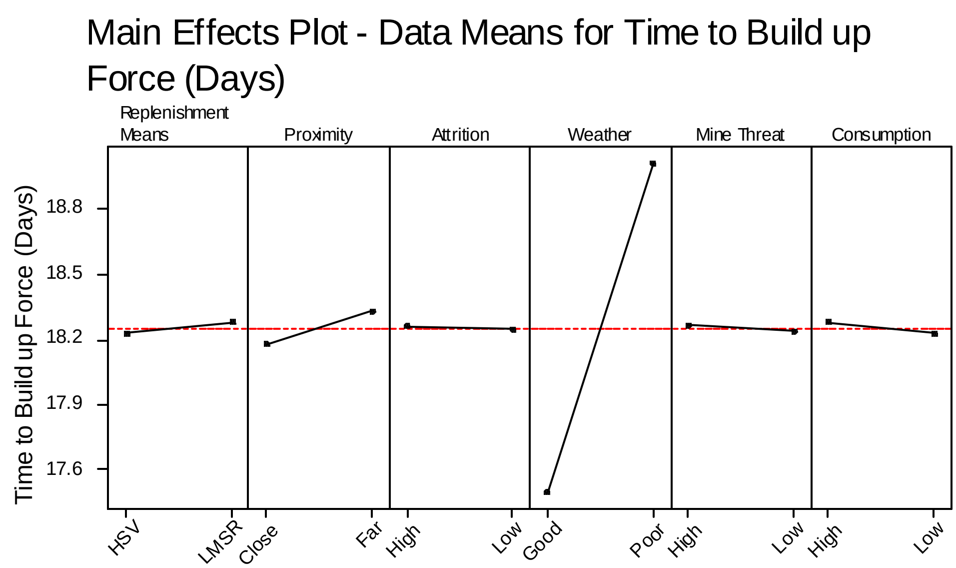

Figure XIII-16: Data Means for TBU at the Objective for Conceptual Architecture

The above figure shows that in the building of the MEB to its desired level of forces, the means of Replenishment, Proximity, Attrition, level of Mine Threat and level of Consumption does not statistically affect the TBU MOP.

Weather, however, is a major contributing factor in determining the amount of time to achieve the target level. Poorer weather results in a 1.4 days delay in sending the forces ashore. This is due to the susceptibility of surface crafts to inclement weather conditions. However, the usage of sea transportation cannot be discounted completely as heavy combat elements like the M1A1 tank cannot be transported even by the long range heavy lift aircraft designed by the Aero Engineering group.

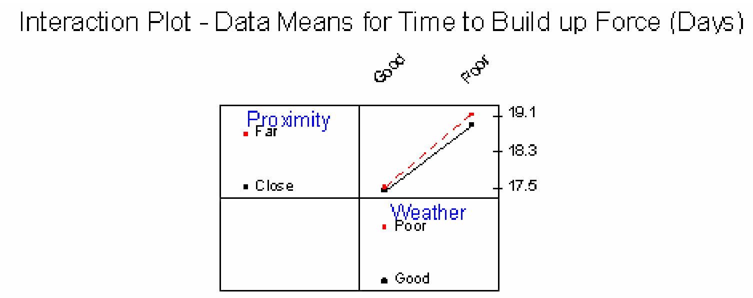

Figure XIII-17: TBU Interactions Between Proximity and Weather Factors for Conceptual Architecture

Weather has a greater effect on the architecture when the Launching Area and the Sea Base are at a further distance from the Objective. In good weather, the architecture performs similarly but in inclement weather, the architecture at far proximity is 0.4 days slower than it would be at a closer proximity. This implies that the effect of weather has a stronger influence on the architecture at farther proximities. Therefore, susceptibility to weather conditions is a critical factor for operations at OTH distances.

The solution may be to engineer more robust sea faring surface crafts or to negate the need of moving heavy combat elements ashore. Employing better and longer-range fire support from the Sea Base or using lighter and stronger composite materials in the construction of heavy tanks can achieve the latter.

c. *Logistic Sustainment Phase*

In this phase of the operations, we observe the level of resources at the Objective and the Sea Base in order to evaluate the effectiveness of the architecture as well as to analyze how different factors affect the architecture and its design. These levels of resources are benchmarked against the target level of resources that reflects the ideal supply profile of the resources at each location each day. The bias and variability of these levels from the desired levels are captured in a single number, the Mean Squared Error of Supply.

MSE of Supply at the Sea Base. This MOP benchmarks the resource levels at the Sea Base against the desired level. It is largely affected by the replenishments from the Offshore Base to the Sea Base and also the rate at which the resources from the Sea Base move to the Objective.

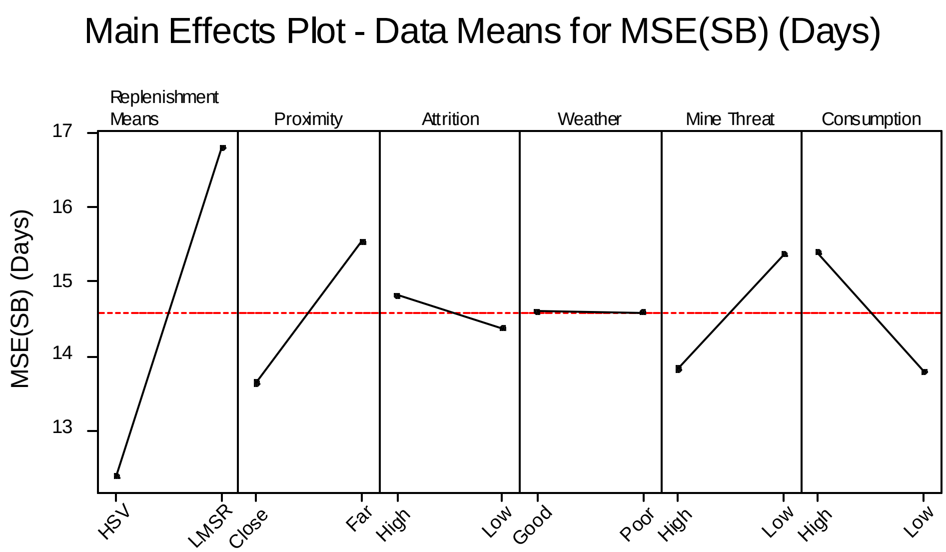

Figure XIII-18: Data Means for the MSE at the Sea Base for Conceptual Architecture

The above plot shows statistically that the means of Replenishments to the Sea Base is the largest determinant of the MSE at the Sea Base. Re-supplying the Sea Base with the HSVs, rather than with LMSR ships, results in 4.5 days less variation in the resource levels at the Sea Base. This means that by using HSVs to resupply the Sea Base, we can get more consistent levels of resources which will deviate less from the target resource levels that we want to achieve at the Sea Base.

The effects of proximity on the resource levels at the Sea Base implies that at greater distances, the throughput from the Sea Base to the Objective decreases and it generates a buildup of resources at the Sea Base. At the same time, a greater consumption of fuel due to increased replenishment sorties creates a high variability in the fuel supply.

Lower attrition entails higher numbers of surviving transporters available to conduct replenishments to the Objective. This allows a smoother throughput of resources and lesser variability.

Higher mine threat at the landing beach results in a slower rate of surface crafts reaching the Objective, which in turns creates less resources being drained from the Sea Base. This will allow the resource levels at the Sea Base to remain at more constant levels versus lower mine threat environments.

A lower consumption rate of resources at the Objective also allows a lesser demand on the replenishment process by the Sea Base. This allows the resource levels to stay at the target levels with more ease than when the Objective demands higher levels of resources due to increased consumptions.

The effects of various factors on the resource levels at the Sea Base are important to the planner of expeditionary operations. Being able to anticipate resource requirements at the Sea Base and re-supplying the Sea Base on time will create consistent levels of resources at the Sea Base and also increase the Sea Base's ability to sustain the forces ashore.

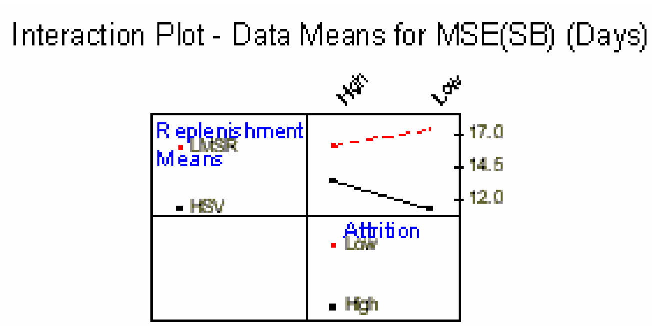

Figure XIII-19: MSE Interactions Between Replenishment Means and Weather Factors for Conceptual Architecture

Interestingly, this architecture performs differently in low and high attrition environment with LMSR ships versus with HSVs as the replenishment option from the Offshore Base. With the HSVs, the Sea Base's resource levels are more stable in lower attrition environments, which is intuitive. But with the LMSR as the replenishment option, the resource levels at the Sea Base perform better in higher attrition conditions.

This can be attributed to the infrequent runs of the LMSR coupled with its larger resource load to the Sea Base. In a lower attrition environment, more transporters are available to conduct resupply missions and this results in faster drawdowns of the Sea Base resource levels, which are only replenished every five days. Therefore, a higher variability of the resource levels results.

MSE of Supply at the Objective. This MOP benchmarks the resource levels at the Objective against the desired five days of supply. Bias from this level and variability of the resource level is captured in the MSE.

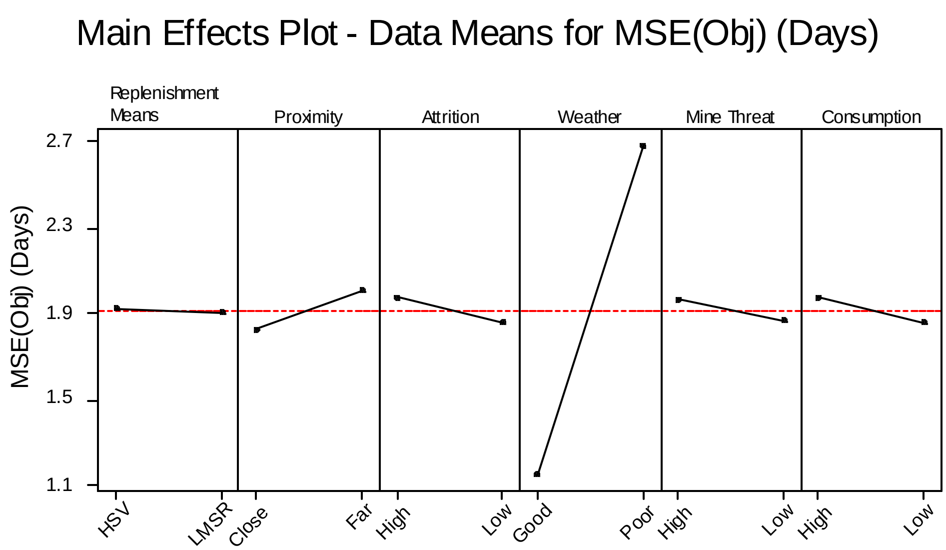

Figure XIII-20: Data Means for the MSE at the Objective for Conceptual Architecture

The above plot shows conclusively that Weather is a major factor in determining the steadfastness of the resource levels at the Objective. There is a difference of 1.6 days of variability in the resource levels between good weather environments and poorer weather conditions. Although Proximity, Attrition, Mine Threat and Consumption are statistically significant, these factors only result in differences of less than 0.3 days of variability; which are practically insignificant in relation to the overall ExWar operations.

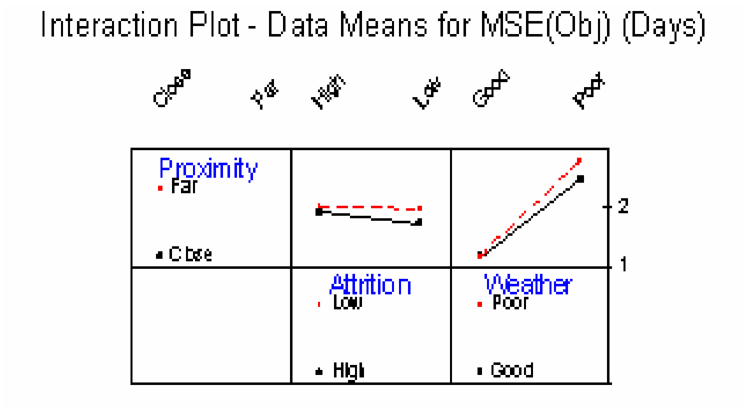

Figure XIII-21: MSE Interactions Between Proximity and Noise Factors for Conceptual Architecture

In high attrition environments, the variability of the resource levels at the Objective is similar whether the Sea Base is at far or close proximity. However in lower attrition settings, variability of the resource levels at close range is better than that at greater ranges.

Poorer weather also exacerbates the variability of the resource levels at the Objective when the Sea Base is at longer ranges versus nearer proximity.

Again this proves that the effects of uncontrollable factors like attrition affect the architecture more severely when the Sea Base is at a longer range from the Objective. Therefore to operate at OTH distances, more care must be taken to ensure a stable resource level at the Objective.

d. Conclusion

The Conceptual Architecture has an air-heavy replenishment system that attempts to avoid some of detrimental effects of bad weather conditions, as surface crafts are more susceptible to weather effects. It has also been shown conclusively that the Sea Base functions better using the HSVs as its replenishment option from the Offshore Base and that being close to the Objective results in a more stable resource levels at the Sea Base, although proximity does not significantly affect the time to build up the forces ashore. This indicates that launching the forces can be conducted from far ashore without acute delays but the process of sustaining the forces would preferably be conducted from nearer to the shoreline; after the littoral waters have been secured.

F. COMPARISON BETWEEN ARCHITECTURES

1. Examining the Four Responses.

In addition to looking within each architecture to identify any factors that will have an effect on the projection of combat power ashore and sustaining the forces in the area of operations, the SEI team also compared the performance of the three architectures in order to identify the strengths and weaknesses, if any, and any operating concepts which would allow the MEB to operate more efficiently.

TAF at the Objective. The time to initial landing of the advance force at the Objective is shown in Figure XIII-22.

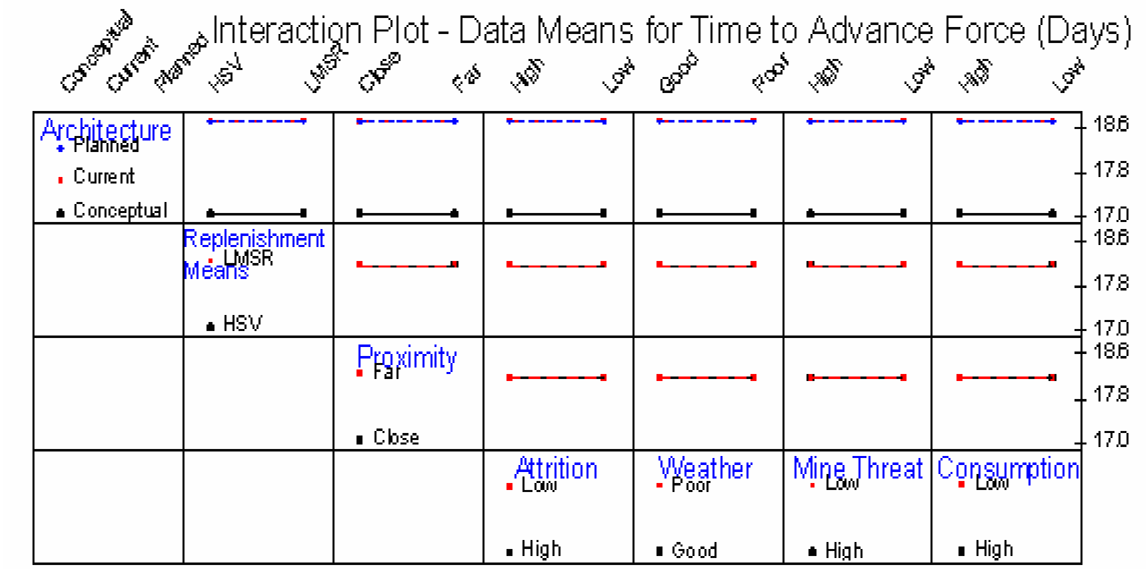

Figure XIII-22: Data Means for TAF for 3 Architectures

It is evident that the Conceptual Architecture will be able to project the first company of Marines ashore the fastest, while the Planned and Current Architectures take approximately the same time to do so. The Conceptual Architecture is able to achieve this feat due to the higher transit speeds built into the amphibious ships, which allowed them to get on station in a much shorter time. Not withstanding the need for the MEB to establish and maintain air superiority (the assumption is that air superiority would have been achieved either by the Air Force air combat elements or the air combat elements from an accompanying Carrier Task Force), the MEB would be able to commence operations to launch the advance force to the Objective in a shorter amount of time.

An observation made here is that the times taken to project the advance force in all three architectures are equally resilient against the factors of Proximity, Attrition, Weather and Mine threat. Even with changes in the level of attrition, the effects of poor weather, increased mine threats on the beaches and proximity of the amphibious ships to the shoreline, all three architectures are able to project the advance force to the Objective without a significant increase in the time needed.

TBU to 80% of Forces at the Objective. The time taken to project a force with a combat power index of 1400 on the Objective is shown in Figure XIII-23.

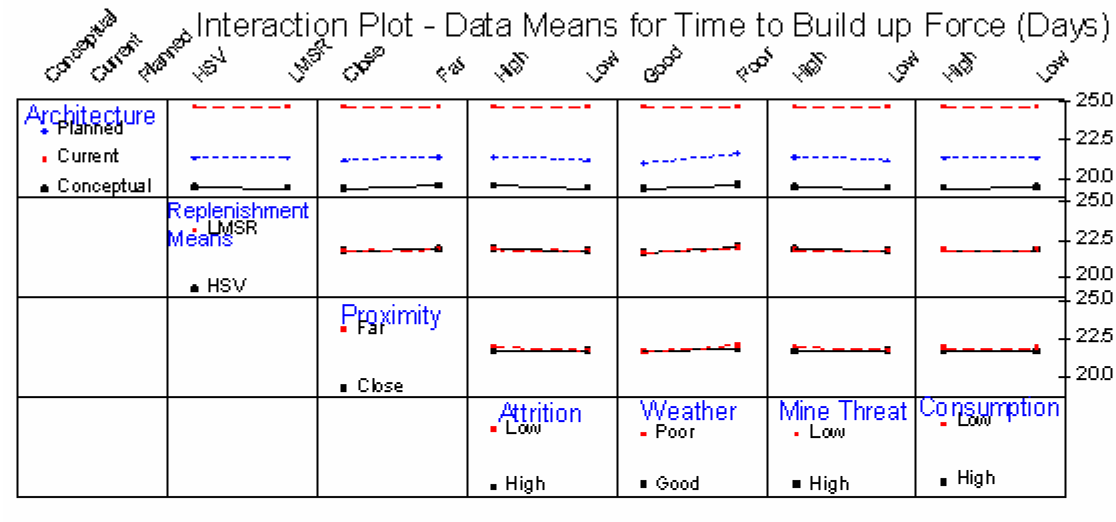

Figure XIII-23: Data Means for TBU for 3 Architectures

Again, the Conceptual Architecture is the one that will project 80% of the MEB ashore in the shortest amount of time. However, the Planned Architecture now takes a shorter time when compared to the Current Architecture to build up the force ashore.

The Conceptual Architecture is able to achieve the shortest time because the newly designed ExWar Ships were able to get on station the fastest, and their increased load out of aircraft and surface crafts coupled with increased lift capability (made possible by the newly designed Heavy Lift Aircraft) allowed the MEB to project the force ashore with fewer trips made between the ExWar Ships and the Objective.

The Current Architecture took the longest to establish the force at the Objective due to the need for part of this force to capture and establish the Iron Mountain.

The same observation is made here that for the time taken to build up to 80% of forces at the Objective, all three Architectures are once again not affected by the factors of Proximity, Attrition and Mine Threat.

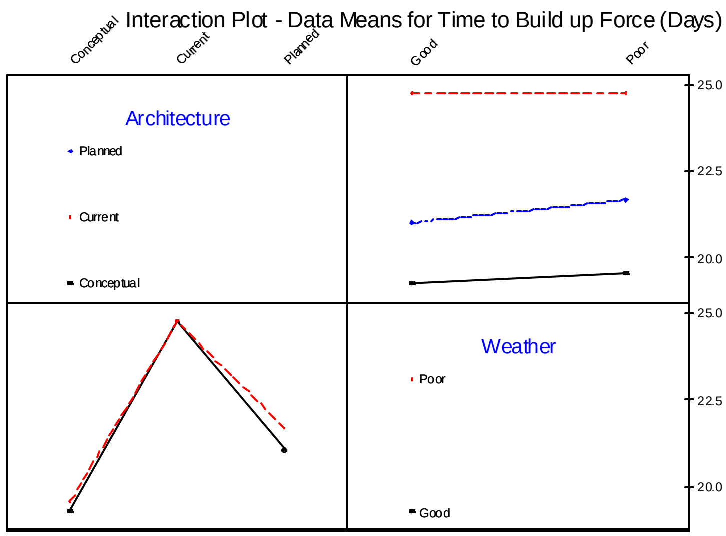

Figure XIII-24: Effects of Weather on TBU for 3 Architectures

The Planned Architecture however, is more affected by weather effects than the Current and Conceptual Architectures. The Planned Architecture uses more sea transporters to project the forces ashore while the Conceptual Architecture utilizes more aircraft to transport the forces ashore. The Current Architecture had most of its heavy combat elements delivered directly to the Iron Mountain (the MPF ships were not affected by poor weather) and the overland movement to the Objective was again not affected by inclement weather. Since the sea transporters suffered a greater degradation in performance in poor weather, the Planned Architecture was more affected by poor weather compared to the other two Architectures.

MSE of Supply at the Logistics Depot (Sea Base/Iron Mountain)

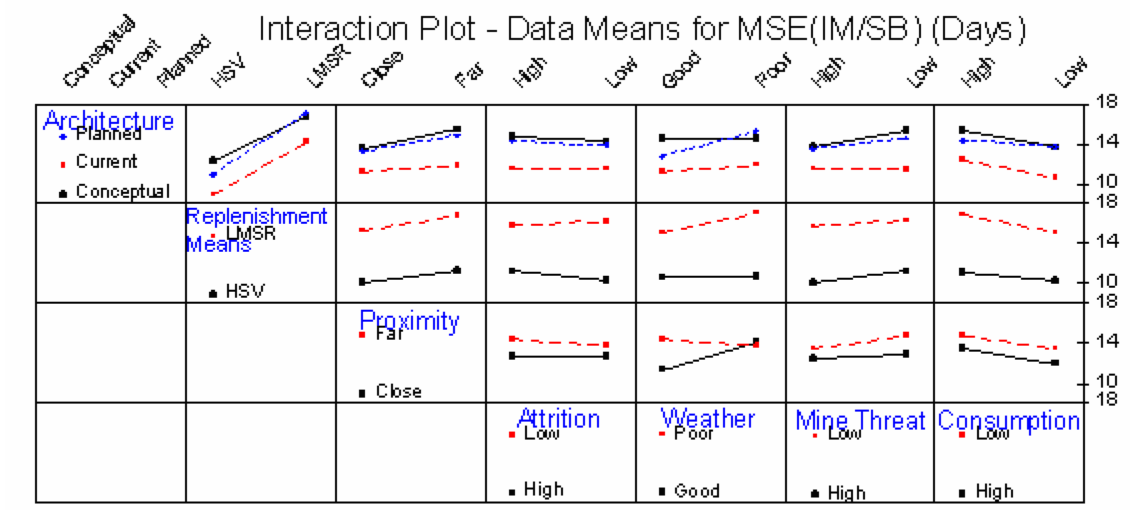

Figure XIII-25: Data Means for MSE of Supplies at Logistics Depot for 3 Architectures

It can be observed that choosing HSVs to replenish the logistics depot results in a smaller variation in the resource level as compared to replenishing using LMSR ships. This is true in all three architectures because the HSV is able to make daily trips while the LMSR ships can only make a trip once every five days.

However, the choice of the replenishment means for the logistics depot will also have to depend on other factors besides the variation in the resource level. The cost of fuel for the HSV's daily supply runs vis-à-vis that for the LMSR and the risk associated with having a huge logistics ship versus distributed platforms will have to be weighed together with the need for minimal fluctuations in the resource level when considering the replenishment method for the logistics depot.

MSE of Supply at the Objective

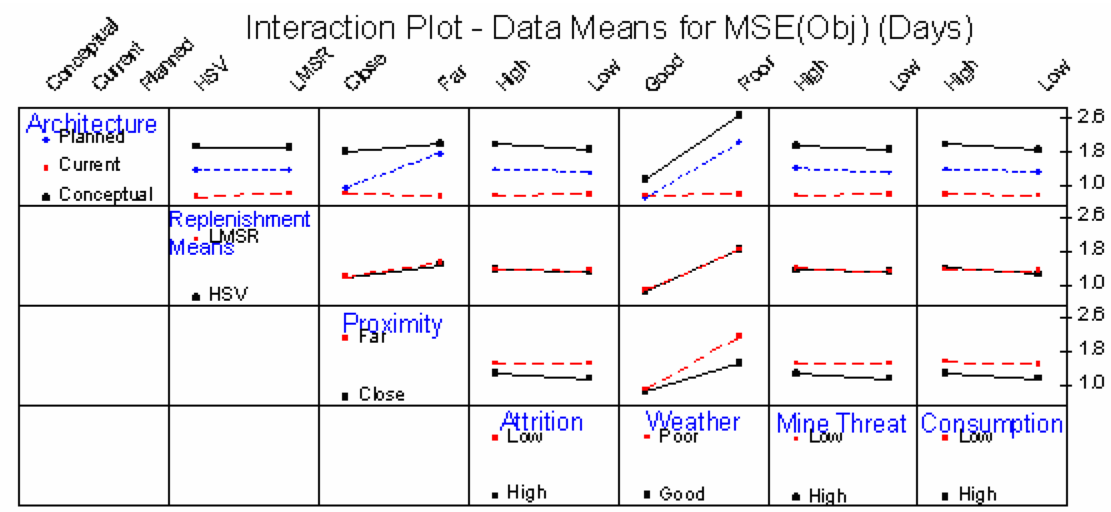

Figure XIII-26: Data Means for MSE of Supplies at the Objective for 3 Architectures

It is evident from the figure above that the Current Architecture is the best among the three Architectures in sustaining the force at the Objective. The reason for this is that the Iron Mountain has a huge capability to transport resources over land to the Objective. This capability is not in any way diminished by poor weather or attrition due to enemy action. As a result, the Objective is able to hold at least 4 days of supply regardless of any factor effects.

An interesting point to note is that the Planned Architecture using a Sea Base is also able to sustain the force at the Objective just as well as the Iron Mountain in the Current Architecture when the MEB is operating in good weather conditions. The planned Mobility Triad consisting of the LCAC, the AAAV and the MV22 does in fact have the capability to sustain the force ashore indefinitely. However, if weather conditions deteriorate, the Sea Base will have a reduced capacity to move resources to the Objective and it can be observed that the resource level decreases to an average level of 3 days of supply. If the transporters can be made more robust against the effects of weather (by having better sea keeping and transloading capabilities), the Planned Architecture can be expected to sustain the Objective just as well as the Current Architecture.

In addition, the Planned Architecture is more affected by Proximity of the Sea Base to the shoreline than the Conceptual Architecture. This is because in the Planned

Architecture the replenishment uses 50% sea transporters and 50% air transporters to sustain the Objective while in the Conceptual Architecture the replenishment uses 75% air transporters and only 25% by sea. Due to the high speeds of air transporters, the increase in distance to be covered does not have as large an impact as in the case of sea transporters. Thus in considering the use of a Sea Base to sustain the forces ashore, it might be advantageous to fly the supplies in.

In general, the Conceptual Architecture did not perform as well as the Planned Architecture in terms of sustaining the force at the Objective even though both architectures use a Sea Base to sustain the Objective. However, the Conceptual Architecture uses a Heavy Lift aircraft that has a higher fuel consumption, which resulted in diminished fuel supply at the Sea Base. In addition, there is a heavy reliance on air transporters, which are more susceptible to attrition. Both effects reduced the throughput from the Sea Base to the Objective.

2. Comparison between the best operating conditions for each architecture.

For all three architectures, it was found that it took a shorter time to project the MEB ashore if the amphibious ships were deployed closer to the shoreline. In addition, if the MEB were operating in good weather conditions, it is possible to move the amphibious ships further out to sea without significantly increasing the time needed to build up the force ashore. However, the same cannot be concluded if the weather turns poor.

Using HSVs to replenish the logistics depot proved to result in the least amount of variations in the resource level held at the logistics depot. Having the Sea Base closer to the shoreline also resulted in smaller variations in the resource levels held at the Objective.

G. CONCLUSION & RECOMMENDATION

The data collected from the series of experiments conducted on the ExWar Model indicated that in order to achieve the elements of speed, rapid power projection and infinite sustainment of the force projected ashore, it would be necessary to use more air assets to transport the light combat elements to the Objective while reducing the susceptibility of the sea transports to poor weather effects. In addition, the use of an Iron Mountain would also reduce the effects that weather has on the resupply process.

Notwithstanding, the experiments have also shown the Sea Base concept using the planned assets is indeed able to support the Objective fully without establishing another logistics depot ashore in good weather conditions. Poor weather will, however, decrease the throughput from the Sea Base to the Objective, and consequently the resource level held at the Objective will be affected. This can be overcome by either increasing the stockpile held at the Objective prior to the onset of the bad weather, by improving on the design of the transporters to make them more robust to the effects of poor weather (for example, to design sea crafts with better sea keeping ability), by moving the Sea Base closer to the Objective, by establishing a small logistics depot ashore to supplement the Sea Base or a combination of these options.

The use of HSVs to replenish the logistics depot was shown to have reduced in the variability in the resource levels. The high transit speed and relatively short loading and unloading time of the HSV allowed for multiple trips to be made in the time taken for the LMSR ships to complete one replenishment run.