XXI. FOOTPRINT

A. INTRODUCTION

Sea Basing reduces footprint ashore, but a key enabler for reducing footprint is reliability and reduction in maintenance down time. We can reduce the weight of equipment, reduce combat troops ashore, and provide a majority of firepower from the sea, but still high reliability and reduction in maintenance down time are essential ingredients for reducing footprint ashore. With a reduction of personnel, equipment, and supplies ashore, the dependability of each piece of gear is critical to carrying out the desired mission. As the Navy and Marine Corps team transitions part of its force structure to a Sea Basing concept, the reliability factor for transporters and combat equipment becomes more critical. Having the capability to sustain the troops ashore indefinitely at long ranges requires more dependable systems to ensure mission success. With poor reliability and long maintenance cycle times, the Sea Basing concept will fail because the troops ashore will be inadequately equipped and re-supplied. The main objective is to replace mass with speed, lethality, and information. This requires reliable speed and information systems that will enhance greater combat mobility and a more lethal striking capability with precision weapons. In this footprint excursion, we will concentrate on the implications of reducing the weight of equipment, reducing combat troops ashore, increasing reliability, moving the maintenance facility from the shore to the sea, and providing a majority of fire support from the sea.

B. REDUCING WEIGHT OF EQUIPMENT

The reduction of the weight of equipment and lowering the overall consumption rate of resources will help in trimming the footprint ashore. This can be achieved by leveraging technology. Key technologies include fuel- efficient generators and engines for the warfighters' vehicular platforms.

Forty five percent of the landing force daily re-supply by tonnage is fuel. More fuel efficient systems will reduce the corresponding demand on fuel, thus reducing the number of fuel supply runs and storage required to be brought ashore. The main fuel users are the heavy vehicles and combat platforms such as armored vehicles, tanks, and trucks. Aerial platforms are also recognized high fuel users. In the EXTEND^{TM} analysis on footprint reduction discussed in the later portion of this chapter, it is shown that a reduction of 25% consumption of fuel will also lead to a more robust and stable replenishment system capable of maintaining a more streamlined portion of the forces to be projected ashore.

Similarly, if the consumption of spares such as high wear component parts can be reduced, then the logistical tail to support these consumed parts can be eliminated or down-sized. Better design and more durable parts will indirectly assist in lowering the associated manpower, equipment, and spares to support these maintenance and replacement efforts ashore. The payoffs are in reducing the system processes and steps that are tied to the spares replacements and the numbers of these spares and part that need to be made available. Spares and parts that are designed for quick replacement with minimum tools or specialized tools or trained personnel will indirectly lead to a smaller footprint. The use of plug-and-play spares, Line-Replaceable-Units, fewer parts and generally lower spares usage will be crucial in achieving a force with a smaller logistical tail.

Another area that shows potential for trimming is the development of modular weapon systems that can be delivered in parts and then assembled after being delivered ashore. They will drastically reduce the demand on the limited heavy lift and delivery capacity. For example, vehicle armor can be re-designed as add-on components. Similarly, if the sub-system can be designed with plug-and-play in mind, then certain components can be removed and not delivered ashore depending on the geographical or climatic regions of the area of operations. Heating units or chemical, biological, and nuclear protection components can be removed and replaced quickly depending on the demand and anticipated threat levels, thus further reducing the overall weight of the equipment that needs to be projected ashore. Better design of efficient space-saving equipment will also help to reduce the number of delivery runs in the initial force projection and subsequent sustainment efforts. It is recognized that at times, it is not the overall weight of the equipment, but rather the volume and odd shape and bulkiness that indirectly imposes more delivery runs. Creative designs and better re-use of storage and delivery containers help minimize the overall footprint and the corresponding demands on the limited lift and delivery resources.

The use of advanced new materials such as lightweight composites in general purpose essential components such as tents, storage containers, working and protective gears like bulletproof vests, camouflage nettings, defense stores, etc., should be explored. Similarly, lightweight and longer lasting batteries, rechargeable or disposable cells or even solar cells are technologies that may reduced the load to be carried by the individual marine. When aggregated, each small reduction will enable the fighting force to be much leaner, lighter, mobile, and sustainable from a greater standoff distance.

Nearly 39% of the required tonnage is water. The key equipment for water reduction is the water purification, recycling, and harnessing kits. Instead of a better and more efficient reverse osmosis plant, we should seek a miniaturized water purification kit that is modular and able to support a smaller component force. It will be shown in the ensuing section that water consumption, its storage, and delivery are a major sustainment portion of the footprint ashore. The proposal here is to have a more scalable and flexible water support or purification system to support the forces ashore.

To achieve the reduction of footprint ashore, a multi-faceted coordinated approach is required to address the issue. The remainder of this chapter will provide other suggestions to reduce the logistical tail associated in keeping a MEB fighting ashore effectively.

C. REDUCING TROOPS ASHORE

Sea Basing can reduce the number of personnel ashore. As stated in OMFTS, “sea basing will free Marines from the need to set up facilities ashore” (Headquarters U.S. Marine Corps 1996, V-15). The Aviation Command Element (ACE) and a large portion of the Command Element (CE) and Combat Service Support Element (CSSE) will remain at sea, provided the future Sea Base can support them. NPS’s Conceptual architecture of ExWar in 2015 – 2020 has the capability to support a MEB afloat and a MEB size Landing Force ashore.

The direct effect of reducing personnel ashore is threefold. First, the logistical daily sustainment requirements ashore will significantly be reduced. Second, the warfighters will be able to move freely and rapidly to the Objective because the burden of moving logistical personnel and their supplies will be negligible. Third, the personnel protecting the "Iron Mountain" will be eliminated. The term "Iron Mountain" is used by the Marine Corps to describe the build-up of supplies and equipment at the beach during an amphibious assault. As shown in Table XXI-1, the requirement to re-supply a full MEB force requires resources capable of moving 2235 tons on a daily basis – for the Current, Planned, and Conceptual architectures this is not practical at long ranges. By reducing a full MEB to a MEB size Landing Force ashore, the daily requirement drops from 2235 tons to 490 tons per day and is practical for Conceptual aviation assets. The quickest way to reduce footprint ashore is to move the ACE from the shore to the Sea Base. This reduces the daily sustainment requirement from 2235 tons to 848 tons. Operating an ACE ashore requires an enormous number of personnel. Sea Basing a majority of the ACE at the Sea Base lightens the force ashore and gives the combat forces ashore greater flexibility and mobility.

Portion of Force Supported	Personnel	Daily Requirements (Tons)
Full MEB	17,800	2235
MEB less ACE	10,460	848
MEB less ACE and CE	9660	785
Landing Force only	6800	490

Table XXI-1: Daily Sustainment Rate (tons/day) for a MEB size Landing Force (Source: Naval Studies Board, 1999)

Reducing the personnel ashore reduces the water, food, and fuel requirements. The daily water requirement is dependent on the operational environment. Table XXI-2 shows the daily reduction of water in short tons based on personnel reductions and different operational environments. As shown in Table XXI-3, the daily water requirement is a logistical challenge. To help alleviate this logistical challenge, the

Marine Corps uses reverse osmosis water purification units, but they need to have a water source.

Water Reduction (short tons) Based On Personnel Reduction and Environment					
			Personnel Reduction		
Environment	Gallons Per Man (GPM)		1,000	5,000	10,000
Temperate Zone	Sustaining	7	28	140	280
	Minimum	4.1	16.4	82	164
Tropical Zone	Sustaining	8.9	35.6	178	356
	Minimum	5.9	23.6	118	236
Artic Zone	Sustaining	7.6	30.4	152	304
	Minimum	4.6	18.4	92	184
Arid Zone	Sustaining	14.1	56.4	282	564
	Minimum	6.4	25.6	128	256

Table XXI-2: Personnel Reduction Reduces Daily Re-Supply Water Requirements (Source for GPM: Marine Corps Combat Development Command, 2001)

Planning for the worst possible case, the assumption is that a water source is unavailable and the water has to be supplied by the Sea Base.

The daily re-supply requirement for food does not impact the logistical re-supply like the water re-supply requirement. For planning purposes assume a marine ashore eats 3 MRE’s per day. Each MRE weighs 1.86 pounds (Marine Corps Combat Development Command, 2001, 4-74). The following shows the reduction of food in short tons (ST) when the combat forces ashore are reduced by 1,000; 5,000; and 10,000: 1, 000 – 2.79 ST, 5,000 – 13.95 ST, and 10,000 – 27.9 ST.

The reduction of personnel also reduces the daily fuel requirement. A large number of personnel ashore require more transporters to move combat troops within and around the Objective.

Clearly, reducing personnel ashore reduces the logistical footprint. With the removal of the logistical tail ashore, the combat forces ashore become dependent on the Sea Base for logistics.

MEB Landing Force Daily Re-supply Requirements (ST/day)

A MEB is divided into three major elements. * Command Element (CE) * Ground Combat Element (GCE) * Combat Service Support Element (CSSE)	Personnel	Food Requirement	Water Requirement	Fuel Requirement	Ammunition Requirement	Other Cargo	Total	Percent
Command Element	365	0.8	10.18	15.9	0.53	1.42	28.84	5.9
Ground Combat Element	5,694	12.53	158.9	152.2	32.07	22.21	377.9	77.1
Headquarters Battalion	158	0.35	4.41	8.96	0.2	0.62	14.54	3
Infantry Regiment	2,993	6.58	83.5	6.53	3.76	11.67	112.1	22.9
Artillery Battalion	835	1.84	23.3	54.13	20.19	3.26	102.7	21
AAAV Battalion	521	1.15	14.54	25.86	2.28	2.03	45.86	9.4
Engineering Battalion	224	0.49	6.25	16.25	2.5	0.87	26.36	5.4
Light Armored Reconnaissance Company	138	0.3	3.85	2.59	1.44	0.54	8.72	1.8
Tank Battalion	825	1.82	23.02	37.91	1.71	3.22	67.66	13.8
Combat Service Support Element	747	1.64	20.84	56.87	0.88	2.91	83.15	17
Military Police Company (–)	89	0.2	2.48	0.71	0.1	0.35	3.84	0.8
Landing Support Battalion	360	0.79	10.04	10.67	0.23	1.4	23.13	4.7
Military Transportation Battalion	298	0.66	8.31	45.5	0.55	1.16	56.19	11.5
Total	6,806	14.97	189.9	225	33.48	26.54	489.9	100
Percent		3.1	38.8	45.9	6.8	5.4		100

(Note: Liquids account for approximately 85% of the tonnage used.)

Table XXI-3: Marine Expeditionary Brigade (MEB) Landing Force Daily Requirements (Source: Naval Studies Board, 1999)

D. ANALYSIS OF REDUCING FOOTPRINT ASHORE USING EXTEND™

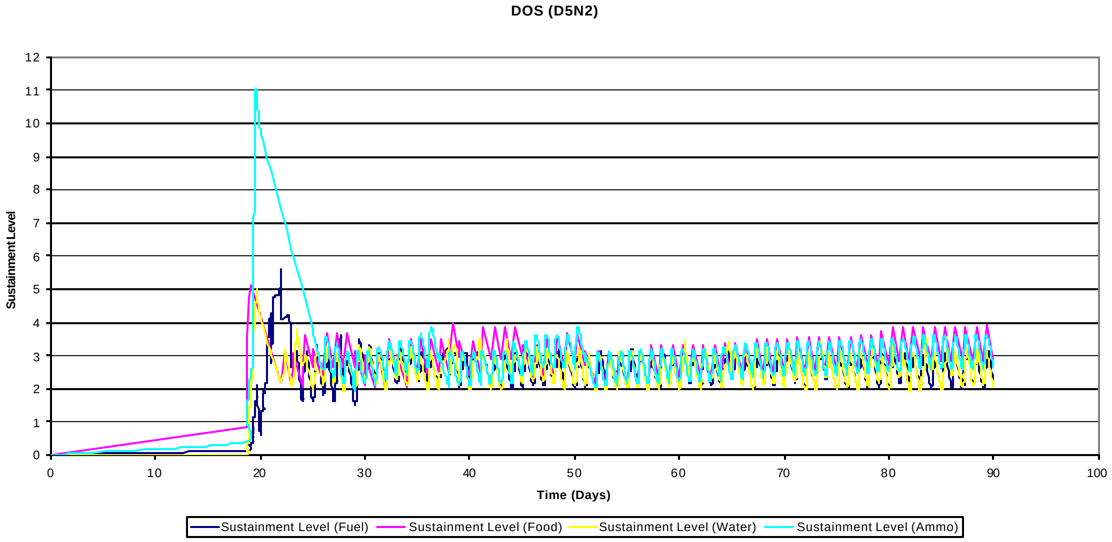
This section presents an analysis of the effects of reducing footprint ashore using the EXTEND™ Models -- specifically, the model for the ExWar Planned architecture. The analysis will describe how the resource levels at the Objective and the Sea Base are affected when the requirements for resources at the Objective are varied. The effectiveness of the system is measured using the Mean Squared Error (MSE) of Supply at both the Sea Base and the Objective. For detailed description on the workings of the model and the Measure of Performance (MOP), please refer to Chapter XII.

The main assumption used in modeling the Sea Base is that the replenishment period of the Sea Base includes a fixed quantity of resources. This assumption creates a baseline for comparison when the factors affecting the Sea Base and the Objective 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 on these factors, please refer to Chapter XII.

1. Comparisons of Different Resource Requirements by the Objective

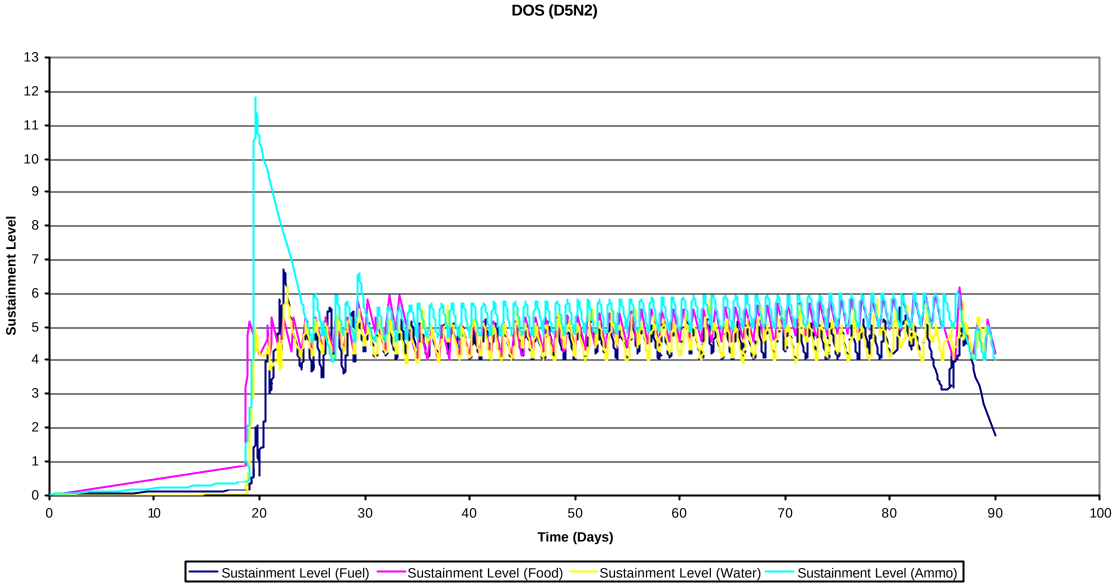
In this analysis, different resource requirements are demanded and stored by the Objective to compare the effects that each requirement will have on the replenishment system. In each model, the consumption rates remained the same as a control factor. We are investigating whether changing the resource levels demanded and stored at the Objective will have any impact on the system as a whole. Therefore, we compared 3 Days of Supply (DOS) requirement at the Objective to 5 DOS and also 10 DOS.

a. Days of Supply (DOS) at the Objective



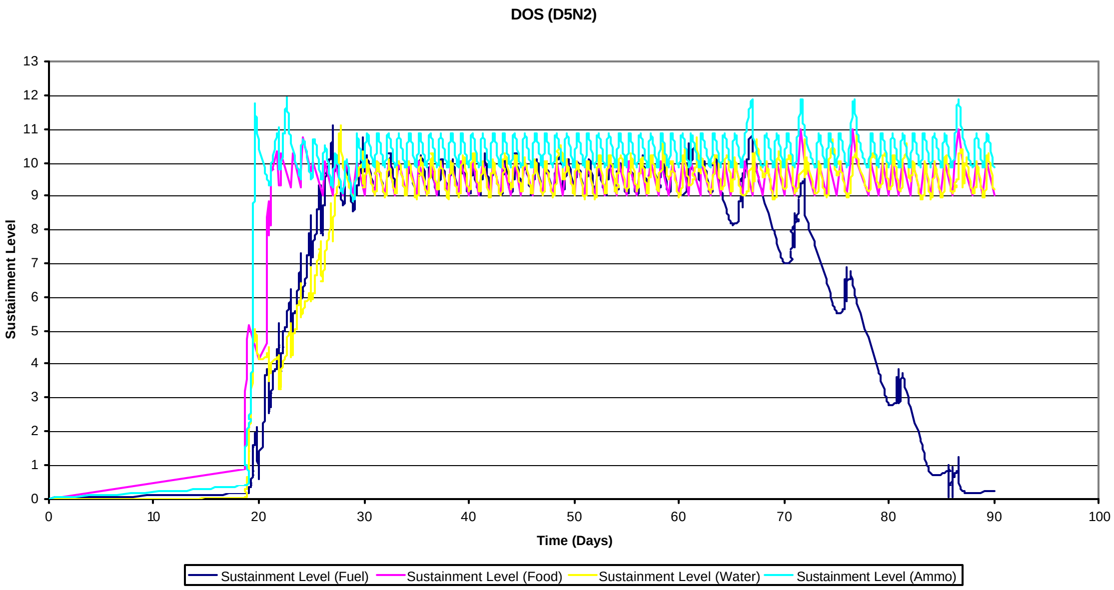
(Note: The DOS at the Objective settles around 3-DOS after the initial surge associated with the assault build-up at the Objective. Smaller variability of re-supplies means a more robust re-supply system. 3 DOS at the Objective is achievable because of the low variability.)

Figure XXI-1: DOS at Objective with 3 DOS



(Note: As the resource reserve at the Objective is increased to 5 DOS, the variability becomes larger, and the fuel re-supply causes the system to breakdown -- starting at the 87th day.)

Figure XXI-2: DOS at Objective with 5 DOS



(Note: As the resource reserve at the Objective is increased to 10 DOS, the variability increases further, and the fuel re-supply begins to collapse at the 70th day.)

Figure XXI-3: DOS at Objective with 10 DOS

	DAYS OF SUPPLY AT OBJECTIVE		
	3 DOS	5 DOS	10 DOS
MSE (days)	0.792	0.784	2.083
	26.40%	15.68%	20.83%

Table XXI-4: MSE of Resource Levels at Objective

Reducing the resource levels at the Objective to 3 days of supply does not result in any significant drawdown of the resources, as the Sea Base is able to furnish the Objective with the demands promptly. However, the variation of the resources is relatively high for this smaller level of resources held i.e. 26.40%. Increasing the resource levels to 10 DOS has several consequences. A higher variability results and a greater strain is placed on the replenishment system, as more supply missions must be launched. This drains the Sea Base of a substantial amount of fuel at the start and consequently results in a drawdown of fuel that leads to a low fuel level at the Objective.

Lowering the resource footprint at the Objective is possible without severe consequences, except for a slightly higher percentage variation. Instead, this can lead to a more streamlined replenishment system and less security demands at the Objective for the resource warehousing; albeit a higher relative variation of 26.4%.

Increasing the resource level to 10 DOS has excessive load on the replenishment system. Fuel consumption increases tremendously and this can lead to high variability in the resource levels, 20.83% variability in this case. Moreover, increasing the resource footprint will lead to higher security requirements at the Objective and large storage demands as well.

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

	DAYS OF SUPPLY AT OBJECTIVE		
	3 DOS	5 DOS	10 DOS
MSE (days)	12.568	13.354	13.825

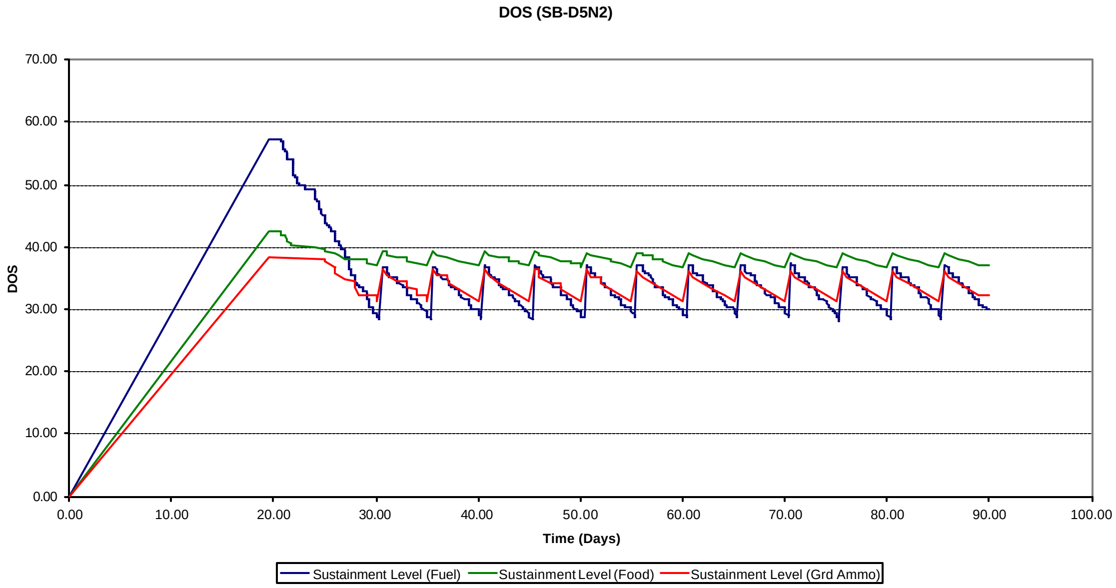
Table XXI-5: MSE of Resource Levels at Sea Base

The variability of the resource levels at the Sea Base is consistent regardless of the number of Days of Supply used. This is because the Offshore Base supplies the Sea Base with an abundance of resources, even though the quantity and schedule is fixed.

The fluctuations of the Sea Base resource levels are higher when 10 DOS is demanded by the Objective, but it is not practically significant to be of concern to the planner.

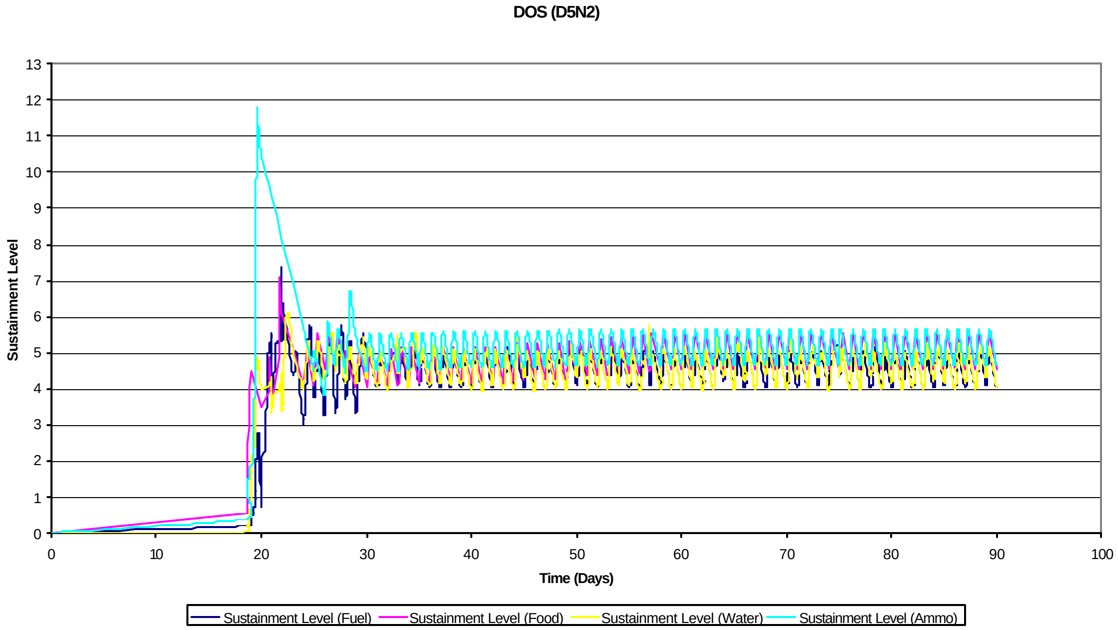
2. Investigation on Impact of Lower Footprint due to Fuel Efficiency

Fuel is one of the main requirements by the Objective. Fuel is consumed at the Objective by combat and logistic vehicles and it is also consumed at the Sea Base by air and sea transporters conducting re-supply and other missions. Lowering this requirement can lead to substantial benefits and this analysis investigates whether a 25% fuel efficiency, leading to a lower footprint ashore, have a significant impact on the Sea Base and the ExWar architecture as a whole.



(Note: 25% increase in fuel efficiency lowers the fuel consumption at the Objective and subsequently leads to a more stable resource level at the Sea Base. The 30 DOS of fuel at the Sea base is maintained. The replenishment system is not being strained by overly high numbers of re-supply missions and consequently the fuel consumption at Sea Base is also lowered. Overall, the fuel re-supply from the Sea base to the Objective did not breakdown as before (As indicated in Figure XXI-2).)

Figure XXI-4: DOS at Sea Base with 25% Increased Fuel Efficiency



(Note: With increased fuel efficiency, fuel re-supply did not breakdown at the Objective like Figure XXI-2.)

Figure XXI-5: DOS at Objective with 25% Increased Fuel Efficiency

Lowering the fuel consumption at the Objective alone leads to a more stable resource levels at both the Objective and the Sea Base. The replenishment system is not being strained by overly high numbers of re-supply missions and consequently the fuel consumption at Sea Base is also lowered. A 25% increase in fuel efficiency reduces transportation requirements by over 10%.

	MSE (days)
DAYS OF SUPPLY AT SEA BASE	10.64
DAYS OF SUPPLY AT OBJECTIVE	0.733

Table XXI-6: MSE of Resource Levels at Sea Base and Objective

The variability of the resource levels at the Objective is marginally lower than before and similarly at the Sea Base the variability is decreased. This leads to the conclusion that the replenishment system is made more robust and stable, as a direct benefit from decreased fuel consumption.

We have seen that increased fuel efficiency has significant impact on the ExWar architecture as a whole. It is an area that investments will produce results in multiple gains and should be an important consideration in the minds of today's planners.

E. INCREASING RELIABILITY

The legendary coach of the Green Bay Packers, Vince Lombardi, said "Winning isn't everything. It's the only thing." The same can be said about reliability – "Reliability isn't everything. It's the only thing" (Eaton, 2002). The key driver in reducing footprint is to ensure equipment going ashore and the transporters ferrying that equipment are highly reliable. As a key enabling factor, high reliability enhances OMFTS and STOM at long ranges.

To show the implications of poor reliability, a hypothetical scenario was modeled and simulated to show how reliability has the biggest impact towards operational availability (Ao), ultimately having a profound impact on footprint. The High Mobility Multi-Purpose Wheeled Vehicle (HMMWV) is the United States Marines Corps' versatile lightweight tactical vehicle capable of moving troops, cargo, and weapons. There are approximately 105 HMMWVs in a MEB.

Picture the following scenario (Kang, 2002): 95 Fully Mission Capable (FMC) HMMWVs with an operational availability of seventy-five percent are moved ashore to support the MEB. Normally, the operational availability for a HMMWV is much higher, but for the purpose of illustrating a point we will assume a lower mean time between maintenance (MTBM) -- reliability. The combat forces operate the HMMWVs 24 hours a day for the next 45 days. On average 71 HMMWVs are fully mission capable at any given time -- .75 times 95 equals 71 FMC. Suppose each HMMWV requires some type of maintenance or service that resembles a triangular distribution (16 hours, 20 hours, 24 hours). Next, assume that 25 percent of the time the failed HMMWV needs major service or maintenance, requiring a tow truck to take it to a mobile Combat Service Support Element (CSSE). The transit time for the tow truck towing the HMMWV to the mobile CSSE follows a uniform distribution (1 hour, 2 hours). This assumes there are only 3 tow trucks available because of the increased demand to reduce footprint ashore. After the tow truck drops the HMMWV off at the mobile CSSE, it takes 2 mechanics to conduct and perform the major service or maintenance to fix the HMMVW. The maintenance time to repair the HMMWV follows a triangle distribution (1 hour, 4 hours, 6 hours). The other 75 percent of HMMWVs do not require a tow truck and are capable of driving to the mobile CSSE for minor maintenance service. The travel time to the CSSE follows a uniform distribution (0.2 hours, 0.4 hours). It requires only 1 mechanic to service the HMMWV for minor repair. The service follows a triangle distribution (0.25 hours, 0.5 hours, 0.75 hours). After the maintenance or service is completed, the HMMWV is placed back in service. The travel time back to the combat unit follows a uniform distribution (0.2 hours, 0.4 hours). The following table represents additional assumptions.

Mechanic Rotational Cycle	Number of Mechanics
0000 – 0800	8
0800 – 1600	8
1600 – 2400	8
Assumptions: There are enough drivers to drive the HMMWVs and Tow Trucks	

Table XXI-7: Work Schedule of HMMWV Mechanics.

Using ARENA^{TM}, a modeling and simulation program, a simple model of the HMMWV maintenance was developed to show how reliability has the biggest impact on operational availability and ultimately reducing the footprint ashore. ARENA^{TM} is an excellent tool for modeling processes, simulating hypothetical or realistic scenarios, and conducting analysis. Another excellent feature of ARENA^{TM} is the graphical animation that allows the user to view the process and visually see where the "bottlenecks" are located. The basic outline of the HMMWV maintenance model is shown in Figure XXI-6.

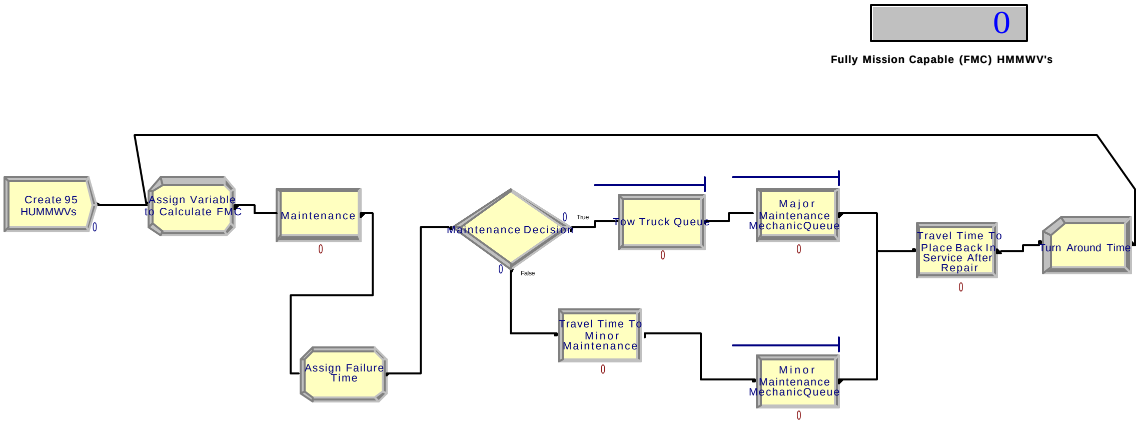


Figure XXI-6: Diagram of HMMWV Maintenance Model

1. The correlation between improved reliability and footprint

The main objective of the HMMWV model is to help determine which factor has the biggest impact on operational availability. After identifying bottlenecks in the HMMWV model, we ran four different embellishments.

a. First Embellishment

The tow truck queue was identified as one of the "bottlenecks" in the HMMWV model. Holding all parameters constant with the exception of increasing the number of tow trucks produced the following result: the number of fully mission capable HMMWVs improved from 71 to 72. With only a small gain in FMC, the operational availability remains nearly the same.

b. Second Embellishment

The minor and major maintenance queue was another "bottleneck" identified in the HMWWV model. Holding all parameters constant with the exception of increasing the number of maintenance personnel produced the following result: The number of fully mission capable HMWWVs improved from 71 to 85. With a gain of 14 HMMWVs, the operational availability increased from seventy-five percent to eighty-nine percent.

c. Third Embellishment

Increasing both the tow trucks and maintenance personnel produced the same result as the second embellishment.

d. Fourth Embellishment

We increased reliability by doubling the time between corrective and preventative maintenance. This produced the following result: The number of fully mission capable HMMWVs improved from 71 to 89, a difference of 18 FMC HMMWVs. The operational availability increased from seventy-five percent to ninety-four percent.

Operational availability equals mean time between maintenance (MTBM) divided by the quantity [MTBM plus maintenance down time]. As reliability increases the MTBM increases, resulting in a higher operational availability. A higher operational availability equates to a smaller footprint because fewer maintenance personnel and fewer spare parts are required to fix equipment. The effect of increasing reliability is three-fold. First, the smaller footprint enhances mobility and flexibility of combat troops ashore. Second, response time is much quicker. Third, the combat effectiveness is greater. As shown in the HMMWV model, increasing resources to fix equipment is not the optimum solution – investing in highly reliable equipment is a much better solution. The HMMWV model illustrates only a small portion of equipment that goes ashore, but the same concept can be applied to all equipment, including transporters with low reliability. Having higher reliability for all equipment would have a definite impact on the consumption rate, as well as on the daily re-supply requirements for forces ashore to support a MEB size Landing Force. Reducing the re-supply requirements would reduce the risk to aviation assets conducting the long re-supply from Sea Base to Objective. Table XXI-8 shows the summary of embellishments. Of special note, increasing reliability had the biggest impact on increasing the fully mission capable HMMWVs. When reliability is high, doubling or increasing the reliability will have little impact. However, if the operational availability is below 85 percent then making the system more reliable and reducing the maintenance down time will have a bigger impact than improving repair capabilities.

Scenario	Tow Truck	Maintenance Personnel	MTBM	Average FMC	Operational Availability
Baseline	3	8	(16,20,24)	71	.75
Embellishment 1	6	8	(16,20,24)	72	.76
Embellishment 2	3	16	(16,20,24)	85	.89
Embellishment 3	6	16	(16,20,24)	85	.89
Embellishment 4	3	8	(32,40,48)	89	.94
Note: Mean Time Between Maintenance (MTBM) is a triangle distribution in hours (minimum, most likely, maximum)					

Table XXI-8: Summary of Results for the HMMWV Maintenance Model Using ARENA^{TM}

F. MAINTENANCE FACILITY AT SEA

With the reduction of the Combat Service Support Element ashore, the Sea Base becomes the main hub for all maintenance actions. In order to better serve the Landing Force ashore, the Sea Base of the future will rely on a robust information system that relays vital maintenance information back to the Sea Base. A network centric information system will be linked to prognostics and diagnostics computer systems embedded in the equipment. Using real time information, the equipment requiring maintenance actions will be quickly fixed and placed back into service. Maintenance actions that once required hours will be reduced to minutes. Like reliability, reduction in the maintenance cycle time will significantly enhance mobility, response time, and combat power. A transformation in maintenance cycle time will be transformed by quick interface disconnects -- a “plug-and-play” approach -- resulting in quick maintenance turn around times. Having the capability to quickly identify maintenance actions before or when they happen, will reduce cycle time and ultimately contribute to a reduction in footprint. Operational availability equals mean time between maintenance (MTBM) divided by MTBM plus maintenance down time (MDT). Holding MTBM constant and decreasing MDT increases operational availability. Additionally, if the MTBM is increased and the MDT is decreased, then the operational availability will increase. Having a maintenance facility that has the capability to turn around maintenance actions quickly and keep equipment at high Operational Availability (A_o) will significantly contribute to a lower footprint ashore. The increased travel to and from the Sea Base for maintenance must be offset by faster maintenance at the Sea Base.

The forces ashore will be supported by mobile CSSE. The highly mobile CSSE comprise of limited personnel capable of repairing minor and major repairs within their capability. If the damaged or degraded equipment cannot be fixed, then it will be flown back to the Sea Base for repair. Having highly reliable, maintainable, and survivable equipment will reduce the number of maintenance actions and reduce the number of airlifts to and from the Sea Base. This concept parallels that of a medical evacuation. The equipment, like the medical evacuation, will be stabilized and returned to the Sea Base if the problem cannot be resolved ashore. The implications associated with moving the maintenance facility from the beach to the Sea Base are as follows: more airlifts are required, reduction in footprint ashore occurs, and the CSSE is less vulnerable. As stated previously, the more airlift required are offset by speed and increased cargo capacity capability.

G. FIRE SUPPORT FROM THE SEA

We considered shifting some fire support to the standoff Sea Base because we found difficulties in projecting and sustaining the existing fire support components of the MEB at a distance beyond 250 NM. From the earlier Table XXI-3, the current artillery battalion within the ground Combat Element of the Landing Force is shown to constitute about 21% of the total daily re-supply requirements. The three main contributing components are the fuel to support and move the artillery equipment, followed by water consumption for the 835 artillery troops, and then the associated ammunition. By shifting the fire support to the Sea Base, the trade-offs are responsive organic fire support in the form of traditional artillery but with an associated larger and more cumbersome logistical tail against precision stand-off missiles or air delivered ordnance which are less responsive and more susceptible to effects of weather. It must be noted that such a shift will not only alleviate demands on the limited lift capacity to support the 21% daily re-supply requirements of the Artillery battalion, it will also reduced the original need to project the artillery equipment, troops and ammo in the initial assault phase. The benefits that can be derived here will be substantial, particularly as the distance between the Sea Base and the Objective stretched beyond 250 NM. The fire support related footprint contributed by the artillery battalion is sizeable and any reduction will ease the strain on the lift capability to support the MEB size landing force ashore.

Fire support from the sea will require breakthroughs and technological advances in the area of targeting and cost effective precision ordnance delivery system. The technology enablers are in C4ISR, possibly unmanned systems, and precision guidance and propulsion areas. Changes in the existing fighting concepts and reliance on robust and responsive fire support at a distance will require revised doctrines. We do not proposed complete elimination of the organic field artillery support, but rather a shift in emphasis, moving towards more guided precision missiles, either standoff from the Sea Base or organic to the fighting force in the form of lightweight portable precision guided missiles. Anti-tank, anti-personnel, or anti-fortification smart munitions that are more portable and equally lethal are key to a leaner fighting force ashore. We seek to replace the volume fire of the traditional artillery with more precise and effective smart munitions that can lower overall footprint and the support logistics elements.

The idea of fire support from the sea should be viewed from a wider perspective of not only stand-off precision missile and fire support weapons in development like the Extended-Range Guided Munition and the Tactical Tomahawk Land-Attack Cruise Missile, but also to include delivery from the air assets like JSFs, attack helicopters, unmanned combat aerial vehicles, and other solutions. The challenge is in finding the appropriate mix of remote standoff and organic fire support.

The fire support related force protection issues of ExWar will be a likely subject of further investigation in the subsequent Systems Engineering and Analysis-4 integrating effort. The limited time within the Systems Engineering and Integration-3 effort restricted further investigation and more in-depth analysis on the issue. It is hope that the discussion presented here offers a basic foundation and serves as an avenue for new ideas and investigation focus and direction for further research effort.

H. RECOMMENDATIONS

To lower the footprint ashore the following areas should be studied.

- Fuel. Better fuel efficient generators and engines. Fuel-efficient generators and engines have not advanced as fast as other technologies over the past half-century. If engines and generators operating ashore were to decrease their burn rate by twenty-five percent or even fifty percent, then the biggest logistical burden -- fuel -- would lessen the re-supply requirement tremendously.
- Modularity. Development of modular weapon systems that can be delivered in parts and then assembled ashore will drastically reduce the demand on the limited heavy lift capacity.
- Water. Instead of a better and more efficient reverse osmosis plant, we should seek a miniaturized water purification kit that is modular and able to support a smaller component force. The proposal is to have a more scalable and flexible water support or purification system to support the forces ashore.
- Fire Support From the Sea Base. Shifting fire support to the Sea Base can reduce the daily re-supply requirements by up to 21%. But the more important benefits is the significant reduction of the footprint ashore associated with t he initial assault on the objective whereby the more lift assets can be freed to project the key troops and fighting equipment ashore faster.

I. CONCLUSIONS

- A reduced MEB size force with equivalent if not better collective firepower, operating with lighter and more efficient equipment, as well as lower fuel, spare parts, and ammo consumption will contribute to a flexible, more maneuverable and responsive fighting force.
- Building and developing a force with a lower footprint that will be a crucial component in making STOM at 275 NM from the Sea Base a reality.
- Water and fuel account for approximately 85% of the logistical re-supply requirement for a MEB size Landing Force.
- Reducing the number of personnel by an increment of 1,000 reduces the daily re-supply requirement by 16.4 to 56.4 tons, depending on the environment and the use of a minimum or maximum sustainment rate.
- Reliability and availability of equipment are key factors to ensuring a much leaner and more effective MEB force ashore.

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LIST OF ACRONYMS AND ABBREVIATIONS

ACE	Air Combat Element
A_o	Operational Availability
CE	Combat Element
CSSE	Combat Service Support Element
C4ISR	Command, Control, Communications and Computers, and Intelligence, Surveillance and Reconnaissance
DOS	Days of Supplies
ERGM	Extended-Range Guided Munitions
ExWar	Expeditionary Warfare
FMC	Fully Mission Capable
GCE	Ground Combat Element
HMMWV	High Mobility Multi-Purpose Wheeled Vehicle
JSF	Joint Strike Fighter
MEB	Marine Expeditionary Brigade
MTBM	Mean Time Between Maintenance
NPS	Naval Postgraduate School
OMFTS	Operational Maneuver from the Sea
STOM	Ship-to-Objective Maneuver
TLAM	Tomahawk Tactical Land-Attack Cruise Missile