XXIII. EFFECTS OF MODULARITY

A. INTRODUCTION

The term variable payload, also known as “modular payload” has been used since the early 1980s. The U.S. Navy was an active participant with other NATO allies in a multi-nation NATO frigate program known as NATO frigate replacement-90 (NFR-90). The ship was intended to include modular component groupings in the platform and combat systems to easily re-configure the ship for a specific mission or to meet a projected threat (Federation of American Scientist, Dec., 2002). However, the decision regarding eventual procurement of the NFR-90 was negative, and the program was terminated. The U.S. Navy continued to explore the modular payload concept through the Ships Systems Engineered Standards (SSES) program. Through SSES, the Navy intended to build a multi-mission modular ship to replace frigates, destroyers, and cruisers, but the first real application was on the guided missile destroyer-50 (DDG-51) program. In the SSES program method, the ship is treated as two separate entities. The first entity consists of the propulsion and hotel functions, also known as platform. The second entity consists of the combat systems functions or payloads.

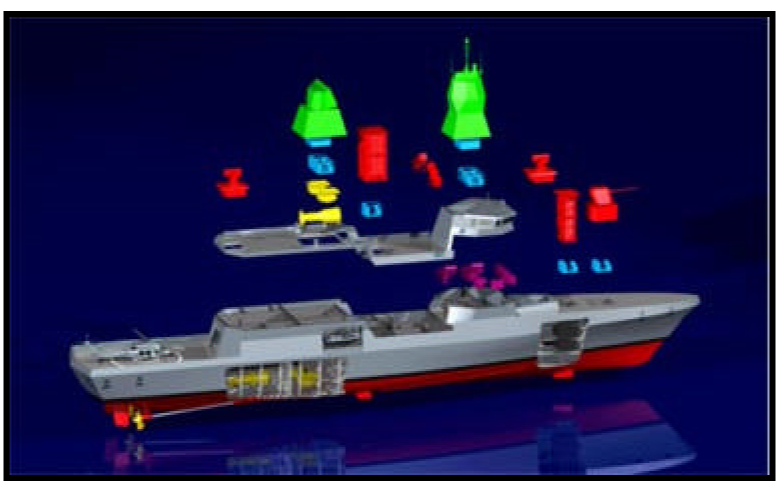

Figure XXIII-1: MEKO Class modular payload ship (Source: Blohm & Voss, 2002).

One of the most successful modular payload ship is the MEKO® class modular ship depicted in Figure XXIII-1, which was built by the German Shipyard, Blohm & Voss. These ships are designed specifically for the varied deployment of standardized modules (weapons, electronics, and ship's technical equipment). The modules are connected to the power supply, air-conditioning, ventilation system, and the data network via standardized interfaces. All the components needed to run a specific system are integrated in a single module. Containers, pallets, and mast modules are installed during the construction phase.

The TSSE Team, following the guidance of the SEI Final Requirements Document, considered modular payload to reconfigure the combat version of its concept design to a supply variant. This chapter will describe modularization and its effects on the TSSE design concept. The chapter will identify potential benefits and problems in the conclusion and recommendation sections.

B. TSSE MODULARITY

The TSSE team applied modularization in four main areas: modular combat systems, berthing, logistic systems, and power distribution systems. The variable combat systems payload would allow the ship's weapons to be interchangeable. In that manner, a combat ship that was to enter a long overhaul would be stripped of its combat systems modules and they would be reinstalled into another ship. Second, modular berthing was used to reclaim most of the Marine Corps berthing. This reconfiguration allowed the ship to reclaim large amounts of volume to store provisions, ordnance, and fuel in the reconfigured re-supply version. The third way the TSSE team implemented modularization in their design concept was in the area of logistics. By using modules, the warehouse can be reconfigure to take more pallet racks, standard 20 ft containers or quadcons, depending on the mission of the ship. Further, the motion compensated crane can be taken from the ship and installed into another ship, much the same as the combat system modules. Finally, the Integrated Power System is built upon reconfigurable power blocks. Depending on the need, power converter and inverter blocks can be connected to the main power buses allowing the electrical distribution systems to be highly flexible. The following paragraphs describe each one of these systems in more detail.

C. COMBAT SYSTEMS MODULARITY

The core of the combat systems modularity was based on the railgun modules (Figure XXIII-2). Each module is approximately 70 ft long, 40 ft tall, and 15 ft wide. There are four of these modules in the ships. The modules are located on each of the corners of the superstructure, next to the Digital Phased Array Radar antennas. Each railgun module includes a capacitor bank or pulse power module, magazine, and cooling system. The module will interphase with the IPS 4,160 volt AC bus via a step up transformer to increase the voltage to the required 15,000 volts.

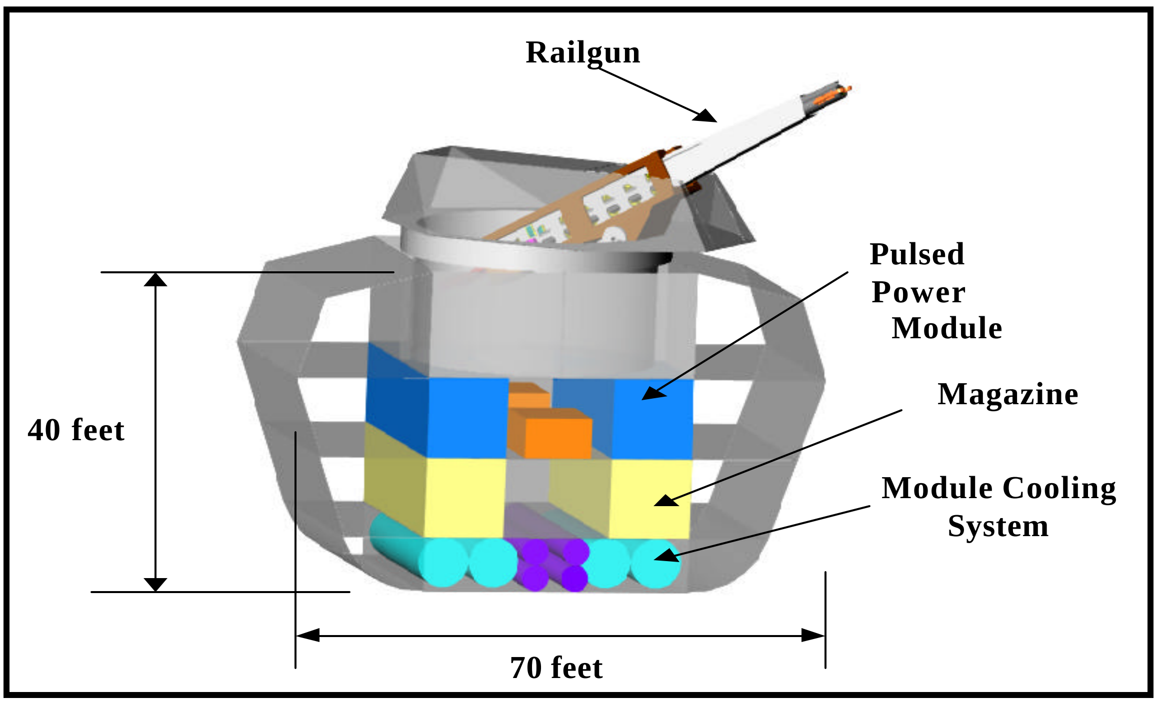

Figure XXIII-2: Railgun module

As mentioned earlier, each TSSE ship requires four railgun modules. The entire Sea Base MEB will require 24 railgun modules in total. Every module has an approximate price tag of $100 million. In the case that 18 TSSE ships were to be built to give the Marine Corps a continuous 3.0 MEB lift capability, only 24 modules (six ships on patrol) plus six spares (one for each ship on patrol) would be required. The price tag for this capability would add up to $3.0 billion. With traditional weapons systems, 72 railgun modules would have to be purchased for the entire architecture for a total price of $7.2 billion.

D. BERTHING MODULARITY

Berthing modularity was incorporated into the conceptual design to facilitate the reconfiguration of the ship from a combat to a logistic version. Figure XXIII-3 depicts the sections of the modularized Marine Corps berthing which can be removed to take in cargo. Figure XXIII-4 illustrates a two tier and a three tier modules.

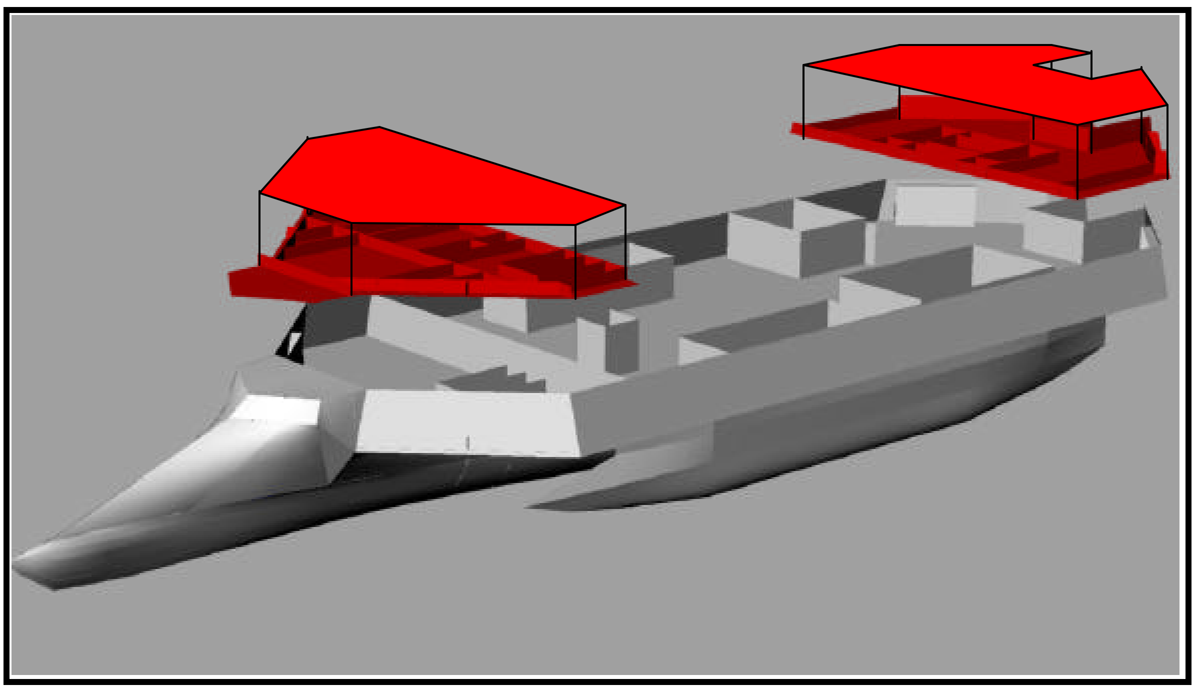

Figure XXIII-3: Berthing modularization.

The total reclaimed modularized berthing was 1,540,000 ft^3. Another 219,000 ft^3 was reclaimed from the hospital and medical facilities. In the logistic version, there will be only four MV-22 and four heavy lift aircraft embarked. Half of the hanger bay area can be reclaimed to store supplies and material. In total, 5.1 million ft^3 was reclaimed.

This translates to approximately 2,000 20 ft standard containers with a 75% volume efficiency. To place this number of containers in perspective, a Maritime Prepositioning Force (MPF) squadron composed of four ships is able to contribute approximately 2,311 (Maritime Expeditionary Force (MEF) Planner's Guide) containers to the re-supply effort.

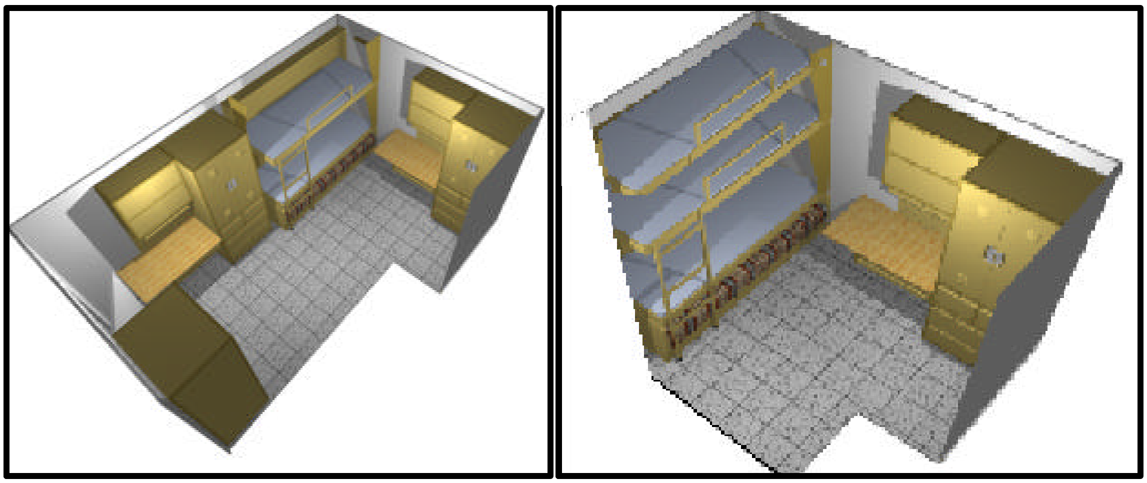

Figure XXIII-4: Berthing modules.

E. LOGISTIC SYSTEMS MODULARITY

The logistics modularization was implemented mainly in the warehouse area. The warehouse is illustrated in Figure XXIII-5. The ship's warehouse can be reconfigured to take containers, quadcons, and pallets. Pallet racks are arranged in rows of eight side by side, and staked six pallets high. These racks can be removed to make room for containerized cargo. The containerized section can hold 36 standard 20 ft containers. If the pallet racks were to be removed in this section, a total of 180 containers could be fitted. Further, the aft section of the warehouse is dedicated to modularized storerooms. If these modules were to be removed to reconfigure the warehouse, either a total of 360 containers, or 2,688 pallet racks can be stored in the warehouse.

In the logistics version of the ship, an extra module containing a motion compensated crane would be fitted on the port side of the ship. This extra capability would double the transfer rate from and to the logistic version of the TSSE design.

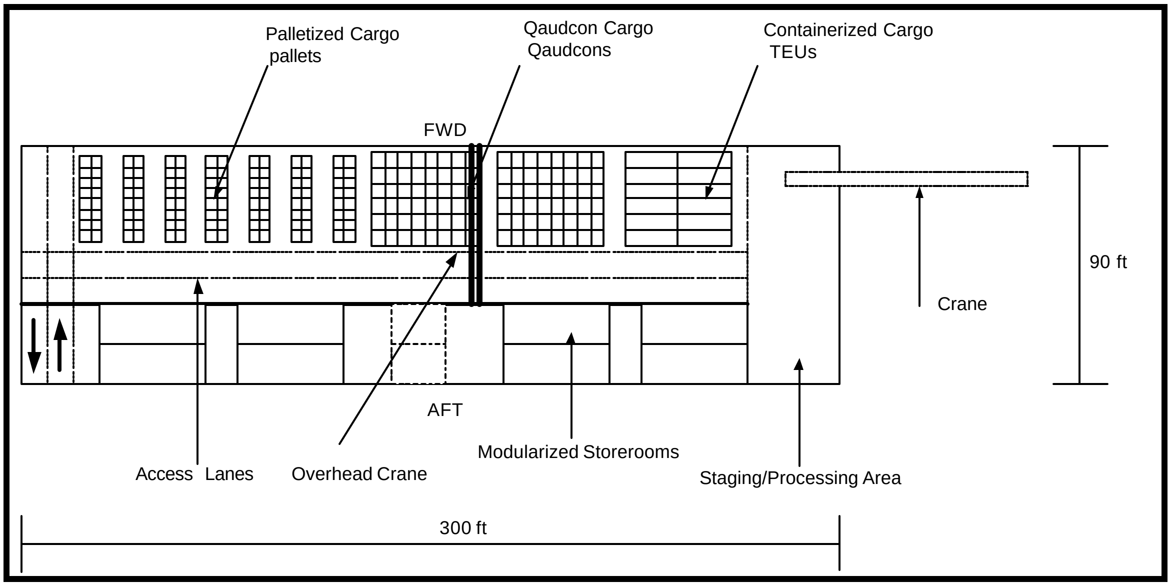

Figure XXIII-5: Modularized warehouse.

F. INTEGRATED POWER SYSTEM (IPS)

The IPS is a revolutionary electrical distribution system which is truly modular based. Figure XXIII-6 represents a generic power electrical building block (PEEB). These modules can take several functions. First, they act as ships service converter modules (SSCM) to lower the electrical bus voltage to the voltage (DC-DC) required by the load. Second, they can be ship service inverter modules (SSIM) that convert the DC voltage provided by the bus to an AC (DC-AC) voltage required by the load. For power distribution, the IPS was selected due to its flexible, modularized open architecture. Figure XXIII-7 illustrates the IPS onboard the TSSE conceptual design. The total installed electrical power is 159 MW. Most of the electrical power generation is devoted for the weapon systems with a requirement of 120 MW. This energy will be stored in capacitor banks and fly-wheels, and made available to the electromagnetic railgun and the free electron laser. The IPS architecture consists of 15 electrical zones in a combined AC and DC electrical distribution. To maximize redundancy, four buses will run along the port and starboard sides of the ship, and above and below the waterline. Two buses will carry 4,160 volts AC, and the other two will carry 1,100 volts DC.

AC buses will be connected to the zones through a step down transformer, and DC buses will be connected through a SSCM, and diode auctioneering giving as output 900 volts DC for the port side and 850 volts DC on the starboard side. Through diode auctioneering, if primary 900 volts DC power source is lost the secondary 850 volts DC power source will be ready for back up to provide power for the vital loads. All sensitive AC and DC equipment requiring a smooth waveform will be connected to the DC and AC buses through SSCM and SSIM. The sensitive vital loads such as combat system computers or lighting are tied to both buses. Non-sensitive equipment that does not require a smooth waveform is connected to the AC buses through a step down transformer and SSCM.

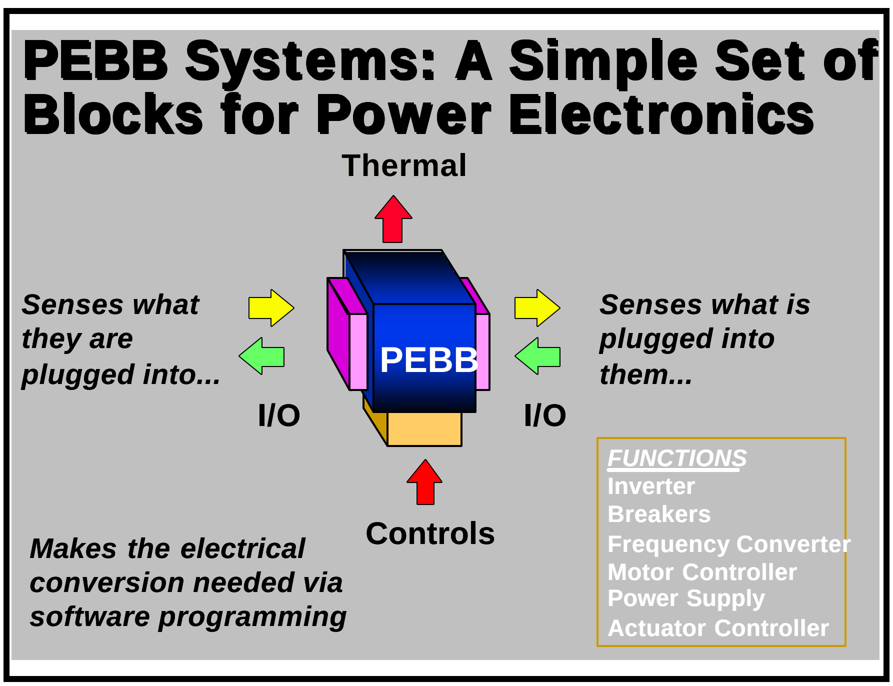

Figure XXIII-6: Power electronic building block (PEBB) (Source: Ericsen, ONR).

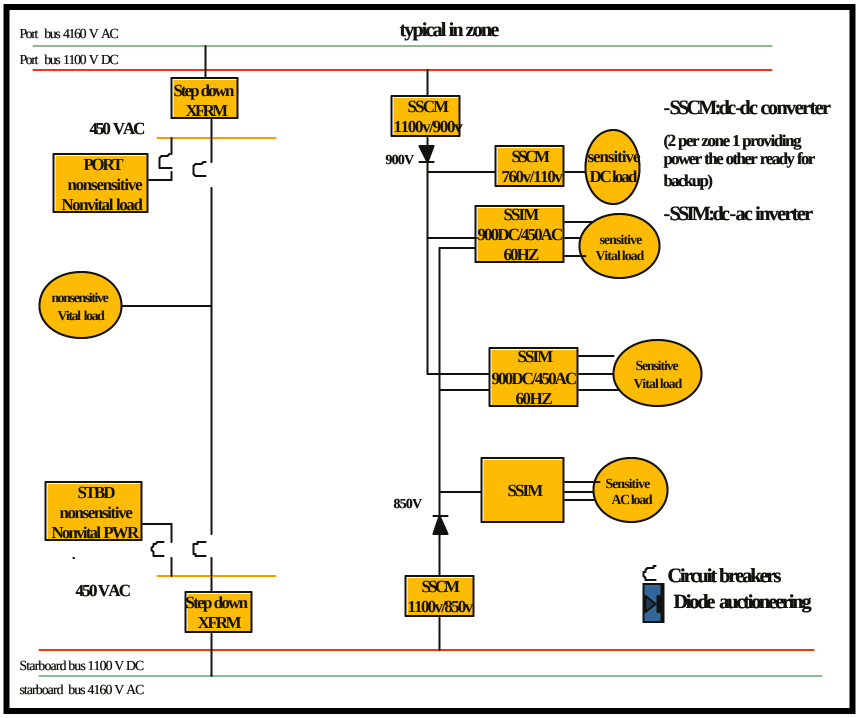

Figure XXIII-7: Integrated Power System (IPS).

G. CONCLUSIONS

Following the guidance in the SEI Final Requirements Document, the TSSE Team implemented modularization in several areas of the conceptual design. Combat systems modules were incorporated to minimize the system of systems life cycle cost. As railgun modules are interchangeable from ship to ship, only a small set of modules (24 modules for patrolling ships plus six spares) would provide the ships of the Sea Base with the capability to provide Naval Gun Fire Support to the forces ashore as well as self-defense capability. The modularized weapon systems would provide a cost benefit of $4.2 billion to the acquisition cost of the systems.

Modularization of berthing areas facilitated the conversion of the concept design from a combatant to a logistics variant taking advantage of the same hull design. The reconfiguration would allow reclamation of a total of 5.1 million ft^3 to transport provisions, ordnance, spare parts, and fuel.

Modularization of the logistic systems included a reconfigurable warehouse that will allow the ship to take different types of cargo depending on its mission. A second motion compensated crane module would allow the logistic version of the conceptual design to double its cargo transfer rate.

Finally, the IPS architecture incorporated to the design would permit the reconfiguration the system by means of PEBB. The modules can be software programmable to sense the load requirements. Other benefits of this power distribution architecture include:

a. Improved producibility
b. Use of commercial-of-the-shelf technology
c. Enhance operational flexibility
d. Maximum survivability
e. Decrease manning requirements
f. Minimum overall cost

H. RECOMMENDATIONS

Although there are great potential benefits to modularization, there are many obstacles that make its implementation difficult. Because of insufficient time, the TSSE team was unable to fully explore the feasibility of modularization in its ship design. Although modularization was part of the TSSE design philosophy, it did not have a high priority. In today's systems, and in particular ships, interphase and standardization seems to be the biggest obstacle to implement modularization. Ships are systems which are highly sensitive to changes in weight and volume. Therefore, in a design of a system, or family of ships that would encourage exploitation of modularization to the fullest, modularization would have to be at the highest place of its design priorities. A design project whose requirements force the design team to make the best use of modularization is highly recommended for future TSSE projects.