*Section 3*

# MODERNIZATION THROUGH MODULARITY

*"We need to do a better job of ensuring that our designs are modular - and that the government is in a position to control all the relevant interfaces…"*
**—Better Buying Power 3.0**

Modular approaches to design in engineering, manufacture, and sustainment have been used in many commercial sectors for years. These approaches have proven useful in reducing life cycle costs and improving the ability to quickly respond to market demands. While the Marine Corps is not driven by market forces, they are challenged with an acquisition system that struggles to keep pace with rapid proliferation of high-tech threats.

Modularity holds great promise for creating the affordability and flexibility that the Marine Corps needs in the future. More importantly, modularity provides the possibility of modernizing our force while increasing tactical agility as well as operational flexibility from the sea base.

Modernization and upgrade of critical systems is a continuing requirement that is driven by the demand to maintain technological advantage and the need to stay ahead of rapidly evolving threats. However, a variety of underlying forces affect the Services' ability to modernize, including more than a decade of continuous land-based warfighting, strategic uncertainty about the future operational environment, and the increasing cost of labor and material in a constrained funding environment that will continue to exist for the foreseeable future. There are many challenges associated with modernizing the force, and if they are to remain effective and relevant, it will be necessary to identify potential solutions that can provide the Marine Corps and the Naval services holistically modular systems that are adaptable, scalable, and interoperable.

A Holistic Modular Approach (HMA) is not just a technology concept or a strategy for developing new systems; it also provides a methodology for modernizing existing systems (see Figure 3-1). The concept relies on a set of standard interfaces, a key component of modular design that provides an opportunity to obtain required future capabilities in a cost-effective manner. Where they are feasible, modular design concepts provide a means of taking advantage of widely supported commercial interface standards to develop required capabilities. Additionally, designing a system for affordable change requires modularity - a concept that is capable of delivering combat systems that are effective, upgradable, affordable, and supportable throughout their planned life cycle. Several examples of the use of modularity exist in products that we use every day. Computers (hardware and software) rely on modular components, and many automakers are building multiple product lines on modular platforms. The auto industry is trending toward fewer chassis designs that are capable of accommodating multiple models to quickly adapt to customer needs and tastes. In regard to the Marine Corps' needs, a HMA provides a means of meeting existing requirements

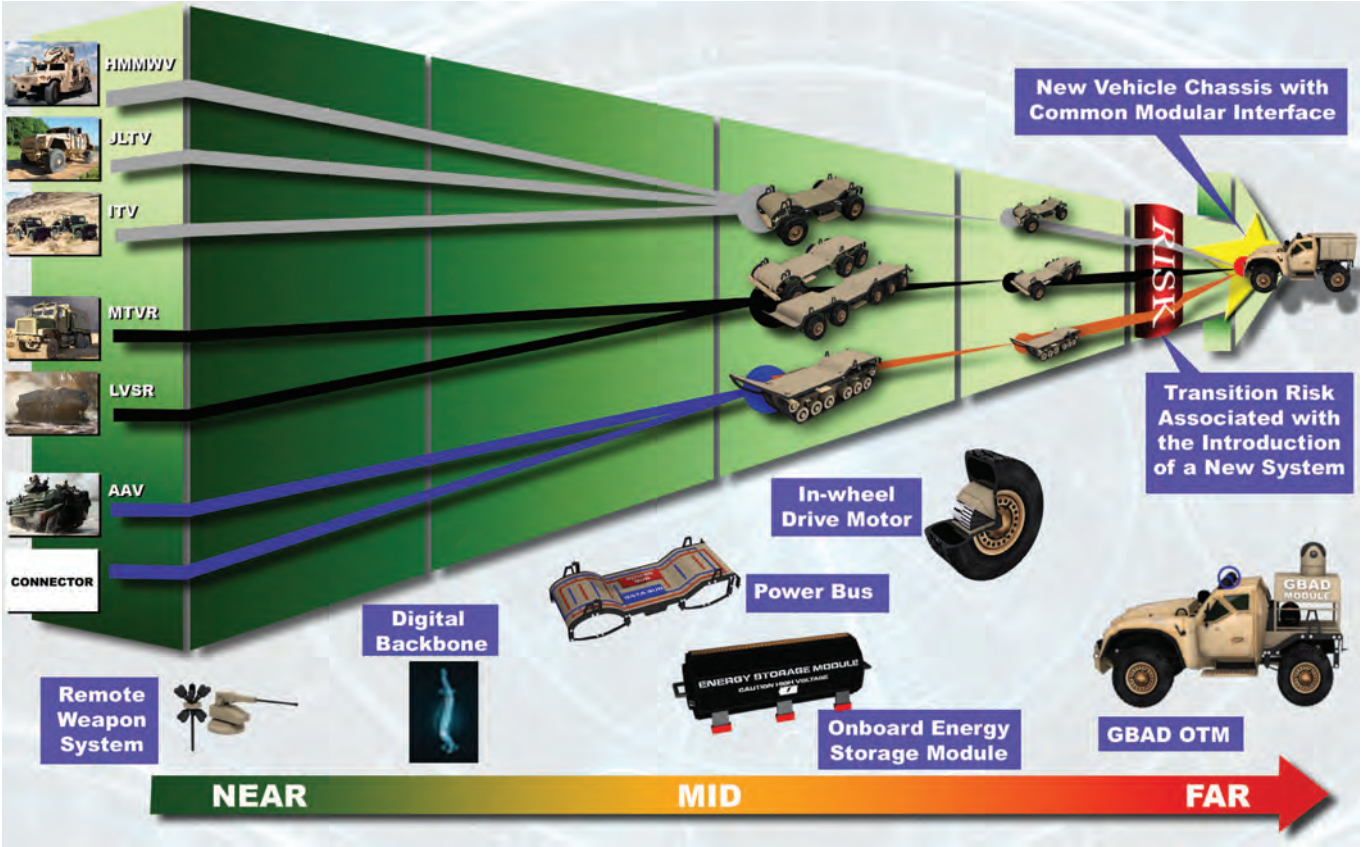


**Figure 3-1. Notional Modularity: Incrementally Increasing Modularity**

while establishing the foundation needed to meet rapidly evolving threats.

## What is Modularity and Why is it Important?

In general, modularity can be described as the development of interchangeable system components, for use with a larger complex system, that are linked together through a set of common or standard interfaces to perform a specific mission or task. A common example of modularity are LEGO® toy sets, which are composed of blocks of varying shapes and sizes that can be linked together through a common structural interface to build a complex item. In 2005 the Naval Research Advisory Committee (NRAC) defined modular as an architecture where system functions are partitioned into elements consisting of various components that have standard/defined interfaces and minimal interdependencies in the overall system (NRAC, p.19). NRAC further defined four types of modularity: capability swapping modularity (mission-package modularity), component sharing modularity, bus modularity, and construction/design modularity (NRAC, 2005).

Since 1990, many within the DoD have begun to view the concept of modularity as having great potential. As shown in Figure 3-2, when a system is "modularized," it is decomposed into manageable components that operate independently and interface with other system components through a set of standardized interfaces. From a functional perspective, modularity has three purposes: to make complexity manageable, to enable parallel work, and to accommodate future uncertainty (Baldwin and Clark, 2006). "Modularity accommodates uncertainty because the particular elements of a modular design may be changed after the fact and in unforeseen ways as long as the design rules are

obeyed. Thus, within a modular architecture, new module designs may be substituted for older ones easily and at low cost" (op. cit., p. 175).

Modularity, while not a new concept, continues to grow in its importance to industry. We have seen examples of modularity dating back to 1939, when Baldwin Locomotive Works patented a 4000-horsepower diesel engine with six generator modules (an example of functional modularity), and during World War II with the German shipbuilding industry designing and manufacturing the Type XXI Submarine in sections at various locations and shipping these modules to the Hamburg and Danzig shipyards for assembly (production modularity). A more recent example, one that has transformed logistics within the global business community, is the standard 20-foot cargo container. These containers, with their standard structural interfaces and specifically designed handling equipment, can move easily between "container ships", which are designed specifically to carry these containers, and various semi-trucks with trailers that are specifically designed to haul them.

The broad use of modular systems in industry and some military systems such as air platforms has increased interest in how to apply modularity to naval systems.

Introducing a modular concept into the DoD acquisition model can potentially provide valuable advantages in the design and acquisition of weapons systems and platforms. These advantages can range "from ease of technology refresh to decreased total ownership cost and increased readiness on the battlefield" (The Naval Strike Forum, 2005, p. 6). Numerous studies, including several ongoing studies, have been conducted to analyze modularity for military purposes. PEO LS has supported studies by ONR and Naval Surface Warfare Center Dahlgren Division (NSWCDD) that have indicated the potential for introducing a HMA. One point is clear: the success of this new modular approach is predicated on standardized interfaces and open architecture and an acquisition system that encourages open innovation. Open innovation requires modification of the existing acquisition model to one in which proprietary software/system

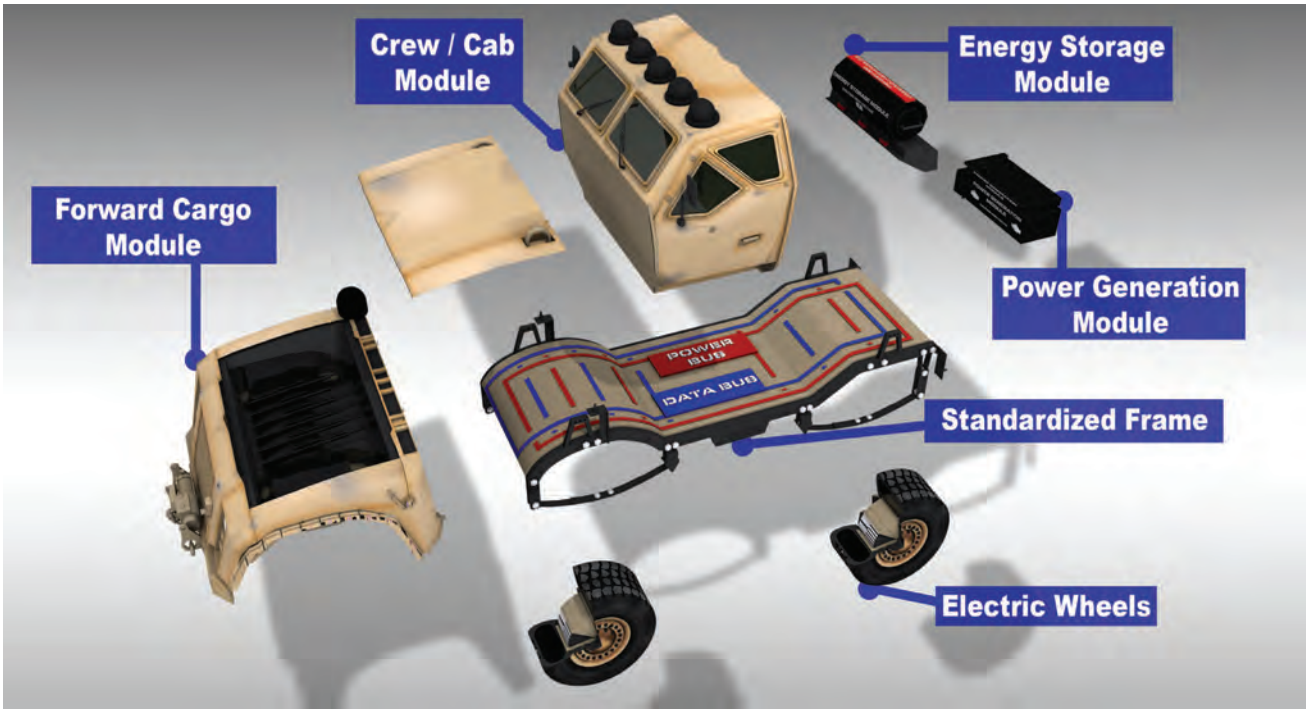


**Figure 3-2. Example of Holistic Modularity**

interfaces are no longer the norm. Lastly, and most importantly, modularity enables plug-and-play capabilities that will provide the expeditionary warfighter of the future the flexibility to adapt to the dynamic battlefield by enabling rapid reconfiguration of forces to ensure they are optimally configured for the missions at hand.

An ongoing ONR study points out the following potential advantages and disadvantages to Holistic Modularity:

## Potential Advantages

- Total structure is more comprehensible.
- Modules can be easily replaced.
- Work division is possible without all participants having an overview of the complete system.
- Effects of changes to one part a of system on other parts are minimized.
- Many different configurations of the system are possible.
- Vendor lock-in is prevented due to standardization.
- Open innovation – enabling external entity innovation input.

## Potential Disadvantages

- For very specific modules, the cost of developing interfaces can be high.
- For assemblers (integrators), it can be difficult to assess the quality and interaction of different modules.
- It can be difficult to assemble (integrate) the modules.
- The design creativity of a module designer can be limited because he needs to conform to the interface.
- Less variation in products because of overuse of the same modules.
- Total system performance may be suboptimal.
- Total module replacement costs when a cheaper sub-component has failed.

A modular design enables a system to be expanded or functionally reconfigured by incorporating new modules or replacing others with greater functionality or differing functions. A useful way to think of this concept is to visualize a desktop computer that provides basic functions such as a word processing capability, a graphics application, and spreadsheet software. In this example a modular upgrade could include the addition of a new software module such as database management software. Similarly, expanding a system's functionality can be easily achieved by installing new hardware modules such as a printer or scanner.

Applying the principles of modularity—i.e., maximum cohesiveness; grouping modules by function; low inter-modular coupling, and low intra-modular connectivity—to convert functional architectures to modular system design architectures can result in the same low cost flexibility and reliability that we have come to expect from our computers. Adding functionality is possible because the corresponding system interfaces are clearly defined, which enables designers to develop their individual modules independently.

Developing a modular design for a new system begins with the partitioning of the system into functions and identifying which elements must be designed as modules. For legacy systems, the initial steps focus on gathering information associated with the system's existing design and performing the modular partitioning and interface mapping to known functions and capabilities. Once the system design is established, the system, subsystems, and components should be prototyped to demonstrate the integration of the system utilizing the proposed

*"Holistic Modularity. This is a factory-to-fighting position concept that relies on common platforms, parts, and scalable mission modules throughout the logistics chain."*
**—Installations and Logistics Road Map 2013**

modular decomposition. There are several advantages to producing a prototype: it allows the design team to see the product assembled (an important aspect of a modular design); early design issues can be identified; it allows for the test of structure and function; and it can be used to generate interest in and discussion of the modularized system.

A HMA will provide the acquisition community with the tools and flexibility needed to maintain the capacity to field capabilities to meet the intent of EF 21 in this era of fiscal constraint. While an HMA concept with standard interfaces is closely related to the concept of designing for technology insert, the decoupled interfaces lead to independent and parallel development of modules. With an HMA, individual module independence supports an environment of open innovation, which facilitates incremental improvement. A new or upgraded module can be added to a system without affecting the system architecture. Frequently, capability and flexibility in system design are either traded away because of competing requirements (cost) or lost because the government's inability to cope with schedule slips associated with design challenges. In the current acquisition approach, capability that does not make it into the initial design may wait until a mid-life upgrade (which sometimes occurs ten years after the original system is delivered to the fleet). A modular design allows the program to move forward while the challenging modules are worked in parallel and delivered when ready without a major setback to the system's delivery schedule.

Modernizing through a modular approach can potentially provide significant benefits. However, a sizable effort will be required up front, beginning with identification or development of standardized interfaces (power, structural, data…), similar to the standardized interfaces, for example, that are found in most computers, such as USB, FireWire, or simple headphone jacks. After standardized interfaces are developed, systems undergoing modernization will require physical modification, such as adding a data bus or a power distribution bus. But once the modular design is adapted to the system, new modules can be procured or developed to ensure that the system maintains its technological advantage or that it adequately addresses the emergent threat.

The challenge will be to partition the modules correctly. Applying the appropriate interfaces as well as holistically partitioning the system will allow the Marine Corps to realize the maximum benefits from a modular design. A Holistic Modularity Approach that is focused on desired operational mission capabilities has the best potential of achieving these results.

"As the Nation meets current and future challenges, it will rely heavily on the Marine Corps to be ready, relevant, and capable. While there will be consistency in our missions, we must be willing to experiment, take risk, and implement change to overcome those challenges."
**—U.S. Marine Corps 36th Commandant's Planning Guidance 2015**