

I. *ARSENAL SHIP* CONCEPT OF OPERATIONS

A. INTRODUCTION

1. Forward ...From the Sea

Projection of power from the sea to the land, sea control and maritime supremacy, strategic deterrence, strategic sealift, and forward naval presence: these describe the fundamental and enduring roles U. S. naval forces play in providing for our nation's security. In support of these fundamental roles, naval expeditionary forces are routinely forward-deployed, designed and trained with the objectives of preventing conflicts, controlling crises, and if called upon, fighting and winning wars. Forward-deployed naval expeditionary forces are essential elements of the fundamental roles of the U. S. Navy. These naval forces normally consist of aircraft carrier battle groups and/or amphibious readiness groups. Consistent with the Navy's strategic concept paper, *Forward ...From the Sea* [1], and the Marine Corps' concept of expeditionary warfare in *Operational Maneuver From the Sea* [2], it is envisioned that these forces will increasingly be called upon to play larger and larger roles in regional conflicts.

From peacetime presence to full joint and combined operations, the power-projection capabilities of forward naval forces must increase. As described in the Navy's paper on naval warfare in the 21st century, *2020 Vision* [3], the theater commander of the future will require massive and precise firepower, long-range strike, flexible targeting, and multi-dimensional theater defense capabilities that go beyond current levels. A concept which will provide these increased capabilities is the introduction of a new weapons platform into the existing expeditionary force structure which enables the

concentration of massive firepower with netted targeting and weapons assignment. This new weapons platform, called an *Arsenal Ship*, will essentially be a massive, remote missile and fire support magazine, linked through Cooperative Engagement Capabilities (CEC) with off-board targeting and fire control platforms engaged in the battle space. Operating under the control and umbrella of Aegis surface combatants, the *Arsenal Ship* will provide the Joint Task Force (JTF) Commander with rapid response and firepower. This can be used to blunt the attack of regional aggressors and support the build-up and maneuver of coalition land-based air and ground forces through precision strike, naval surface fire support, and theater air and missile defense.

2. General Description of Mission and Threat

a. The Mission

The *Arsenal Ship* is a missile laden, forward-deployed, highly automated, optimally-manned ship that possesses a high degree of built-in protection and uses the most advanced communication networks available. In concert with traditional naval expeditionary forces, the *Arsenal Ship* provides an extremely potent forward presence in peacetime. It is used as a remote magazine, linked with the fire control and command platforms of the expeditionary forces. These *Arsenal Ship* augmented forces, operating under the concepts described in *Forward ...From the Sea* and *Operational Maneuver From the Sea*, are used by the JTF Commander for missions such as the following:

Halting Invasions. The *Arsenal Ship* provides massive quantities of advanced missiles, equipped with precision-guided munitions, used to stop attacking armored forces.

Long-Range Strike. The *Arsenal Ship* provides Tomahawk cruise missiles used to attack the enemy's center of gravity -- demolishing strategic targets, air defense sites and the enemy's military infrastructure.

Littoral Warfare. Using Standard Missile Lightweight Exoatmospheric Projectile (LEAP) or Theater Anti-Air Defense (THAAD) surface to air missiles, the *Arsenal Ship* and Aegis combatants provide tactical ballistic missile defense, defense against cruise missiles, and support to air operations. Using a naval version of the Army's Advanced Tactical Missile System (ATACMS) and an advanced naval gun system, the *Arsenal Ship* provides naval fire support to forces ashore, countering enemy artillery systems and suppressing second echelon forces and air defense sites.

Conventional Deterrence. The forward-deployed *Arsenal Ship* provides conventional deterrence against regional aggression in areas vital to U.S. national interests.

b. Threat

The *Arsenal Ship* would likely be employed in every major regional conflict and will be the primary means of delivering ordnance on target to slow and halt the advance of the enemy in all areas of the battlespace. Consequently, it will be considered an extremely high valued unit and most certainly a primary target of opposing forces. The threats posed by these opposing forces encompass all varieties of sea-, air-, and land-based weapon systems. The design and employment of the *Arsenal Ship* effectively counters the threats posed by these enemy forces.

The projected threat environment in which the mission is expected to be accomplished will range from natural environmental forces, such as heavy seas and

storms, to operations in littoral environments congested with mines, small attack surface craft and coastal submarines, to environments contaminated by chemical, biological and radiological (CBR) weapons. However, the greatest challenge will be operation of the *Arsenal Ship* and its interface with the sensor and targeting platforms in an environment where the electromagnetic spectrum has been denied or degraded. The desired mission of the system, as designed, is fully realizable in such environments.

B. CRITICAL SYSTEM CHARACTERISTICS AND CONSTRAINTS

The Defense Advanced Research Project Agency (DARPA) provided two documents, which briefly describe the Navy's concept of operations (CONOPS) [4] and general ship capabilities (SCD) [5], that should be used as guides in developing detailed concepts of operations and designs for the *Arsenal Ship*. The goals established by these two documents require the *Arsenal Ship* design to be revolutionary in nature. The operational concept gleaned from a thorough review of the CONOPS and SCD challenges existing Navy culture and tradition. Developing a ship system that attains the goals of the CONOPS and SCD requires rethinking standard practices and beliefs, and implementing labor-saving technologies. The following are critical system characteristics and constraints which drive this revolutionary concept of operations:

- The *Arsenal Ship* has a crew numbering less than 50.
- The *Arsenal Ship* supplies massive firepower in the early phases of crisis response and control and provides naval surface fire support (NSFS) in direct tactical support of ground forces.
- The *Arsenal Ship* is not a targeting or fire control platform. It does not possess the ability to employ the offensive weapons it carries.
- The *Arsenal Ship* is capable of full-time communications with ships, aircraft, satellites and shore stations via responsive, reliable, clear and secure voice, tactical

information distribution, and recorded communications. An over-the-horizon satellite link capability is provided.

- The *Arsenal Ship* possesses limited active self-defense capability. This is a function of simplicity, manning level and cost. Therefore, if unescorted, the *Arsenal Ship* would provide the enemy with a defenseless, high value target. Consequently, the *Arsenal Ship* will always be operated under the umbrella of escorts which can provide appropriate defenses.
- The *Arsenal Ship* is always available for rapid movement upon receipt of strategic warning, providing the JTF Commander flexibility in response to regional crises (total ship availability of 0.95).
- The *Arsenal Ship* is virtually unsinkable. It incorporates designs and systems which dramatically reduce susceptibility and vulnerability. These designs and systems are predominantly passive in nature and inherently make the ship difficult to detect, target and hit. In addition, if the ship is hit, it is designed to automatically, or inherently limit, and contain damage so that the ship can continue its mission.
- The *Arsenal Ship* can be fully integrated into the joint war fighting force structure, operating in both peacetime and war as an integral fleet unit within the chain of command under Joint Combatant Command (COCOM). Peacetime operational control is exercised by numbered fleet commanders. When operating under a joint task force, operational control will be exercised by the Joint Force Maritime Commander.
- A fleet of six *Arsenal Ships* will be stationed continuously forward in the SW Asia/Persian Gulf, Western Pacific and Mediterranean theaters of operation. Like the Maritime Prepositioning Force (MPF) ships, they will remain on station in support of a Unified Combatant Commander for indefinite periods without dependence on host nation support or permission. The maintenance, logistic and training concepts are consistent with the forward operating base (FOB) concept.
- The *Arsenal Ship* is designed with systems of high reliability and very low maintenance.
- The *Arsenal Ship* is able to refuel underway via connected replenishment (CONREP) and take on stores via vertical replenishment (VERTREP).
- The *Arsenal Ship* does not possess the capability to rearm vertical launch systems underway.
- The *Arsenal Ship* is capable of transiting the Panama and Suez canals.

- The *Arsenal Ship* has a minimum sustained speed of 22 knots.

C. **ARSENAL SHIP CONCEPT OF OPERATIONS**

1. **Key Employment Elements**

The discussions of mission, threats and critical ship characteristics and constraints provide the foundation for the development of a concept of operations. This concept of operations addresses the various key elements necessary to operate and maintain three squadrons of two ships, forward-deployed, with near-constant availability, capable of performing the stated missions within the constraints placed on the ship design. The requirement to remain forward-deployed for indefinite periods of time with near-constant availability and radically reduced manning demands revolutionary concepts and innovative approaches to many ship functions and operations. The CONOPS addresses the following key employment elements:

- Basing and ship movement.
- Integrated logistics support.
- Manpower, personnel and training.
- Command and Control.
- Security.
- Interoperability and integration with carrier battle groups, amphibious
- Readiness groups, and joint task forces.

2. **Basing and Ship Movement**

In order for the *Arsenal Ship* to perform its mission effectively, it must be forward deployed and continuously available for the majority of its operational life. By necessity, forward operating bases within the required geographic regions must be established. They must be capable of providing the required support services to achieve the

availability goals and response time, and also provide the strategic reach. The *Arsenal Ship* will utilize the forward operating bases already established for the three MPF squadrons: Diego Garcia, Guam and Ascension Island. Figure (I-1) illustrates the locations of these bases and the strategic reach and response times associated with the sustained speed requirement of 22 knots. The circles represent closure times of 7 and 14 days.

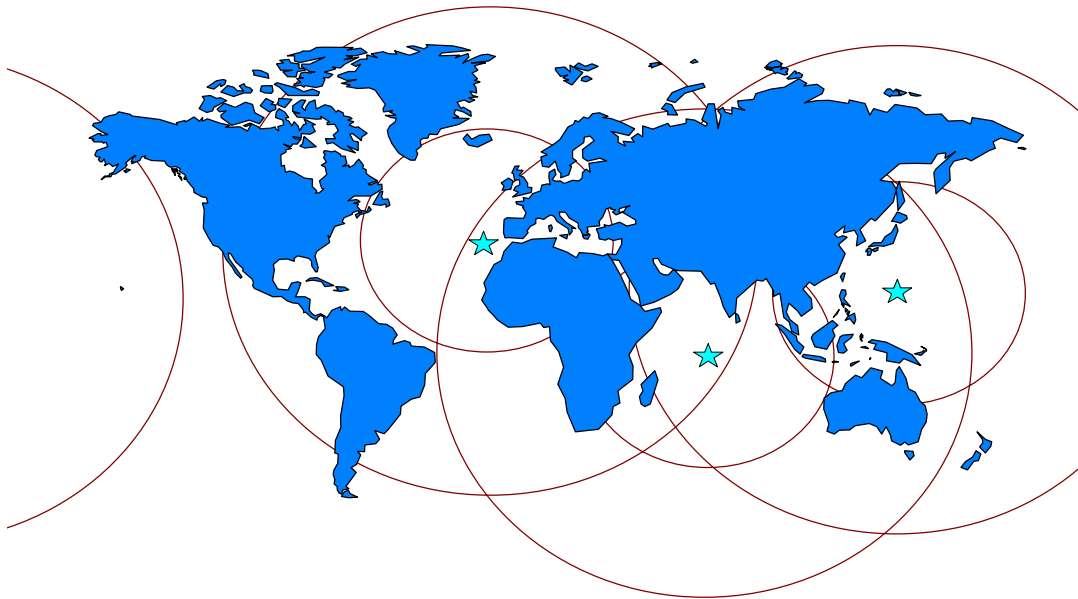


Figure I-1. *Arsenal Ship* Forward Operating Bases and Strategic Reach

The forward operating bases will have facilities for the maintenance and support of hundreds of missiles, to include lift, rearming and storage capabilities. All required inport logistics will be provided at these bases. All three bases have airlift capabilities that will facilitate the procurement, distribution, maintenance and replacement of materiel and personnel while the ships are inport. All organizational and intermediate level maintenance will be supported from these bases.

The *Arsenal Ship* will never be underway without appropriate escorts. Due to its limited self-defense capabilities and the high military value of its payload, the unescorted *Arsenal Ship* would present an irresistible target to potential foes. Consequently, the *Arsenal Ship* must be escorted by other fleet assets when it is moved into, out of, or within its area of operation.

3. Integrated Logistics Support

a. Maintenance Concept

Maintenance requirements for the entire ship system are kept to a minimum. The requirements for a near constant availability and dramatically reduced ships force demand use of radically different systems and procedures. Organizational repair capability is minimal. Shore and afloat intermediate maintenance activities (IMA) and detachments will be used to the maximum extent possible. Ship systems are redundant, and are standardized and modular in order to capitalize on the ease and speed of "unit replacement" vice "repair-in-place" maintenance concepts. The *Arsenal Ship* is designed and will be operated such that regularly scheduled depot level maintenance is infrequent. The *Arsenal Ship* will return from forward operations every five years for dry docking and depot level maintenance.

The upkeep of the weapons payload is minimal. Missile certifications will be performed during the regularly scheduled depot level maintenance availabilities. Routine maintenance and operational checks are eliminated and/or automated providing the readiness goals inherent in the mission concept.

b. Logistics Considerations

The provisioning strategy in port is much the same as for the Maritime Prepositioning Ships. The forward operating bases support airlift operations so that stores can be flown in and transported to the ship. Underway, the *Arsenal Ship* will utilize standard fleet logistic requests for provisioning via VERTREP and for underway refueling.

Storage and handling facilities for massive amounts of missiles will be required at each forward operating base. Due to the massive amount of missiles stored on both ships and the storage/handling facilities required ashore, security and safety issues are of concern.

4. Manpower, Personnel and Training

The normal crew size for the *Arsenal Ship* is less than 50 personnel. To achieve this, the *Arsenal Ship* employs a manning concept that parallels a typical Merchant Marine tanker, augmented with the personnel required for the military operations of the vessel. The ship makes maximum use of automation for monitoring and control of all ship functions. Damage control techniques are radically different, requiring minimal personnel. The *Arsenal Ship* relies on passive measures incorporated into the design to inherently reduce susceptibility and vulnerability. The *Arsenal Ship*, by design, is virtually unsinkable. Fire fighting, flooding and stability control are largely automated and centrally monitored. This allows the *Arsenal Ship* to operate in combat situations with dramatically reduced numbers of personnel.

The driving factor in crew size is the manpower surge required in certain types of operations. Although it would not be unusual for a merchant vessel the size of the *Arsenal Ship*

to be operated with a crew of about a dozen people, the *Arsenal Ship* is a warship and must be able to operate as such. Operations for extended periods at Condition 1 and Condition 3, refueling underway, precision anchoring, small boat operations and helicopter flight operations have all traditionally been manpower intensive. The *Arsenal Ship* is designed with innovative systems and will be operated with innovative procedures which will allow the ship to perform these functions safely and reliably with very few personnel.

The human element has not been discounted in the employment of the *Arsenal Ship*. A well trained, motivated, professional crew is the cornerstone of any weapons system. The general manning concept is closely tied to ship system design and to the maintenance concept. The ship is manned primarily by "operators." Since most of the maintenance functions are shore-based, a minimum number of maintenance-specific ratings are part of the crew. The crew focuses on training to operate and fight the ship. Constant readiness, intensive mission-specific training, and the constant routine of ship's business will be demanding with such a small crew. Personnel selected for duty in the *Arsenal Ship* program will require thorough screening, intense training and qualification, and a tireless work ethic.

The ships remain forward-deployed, with crew rotations normally taking place at the forward operating bases. In order to maintain a high level of readiness, and to respect the spirit of the Navy's personnel management goals, the entire crew rotates as a unit. This allows for the crew to train as a unit in the continental United States (CONUS) and then deploy as a unit. The crew cycle for the *Arsenal Ship* is approximately 18 months long. Approximately six months is spent assembling and training the crew. This detailing and training phase is followed by a twelve month deployment to one of the forward-deployed ships. Due to the intense duty, as well as the forward-deployed nature of the *Arsenal Ship*, assignment to the *Arsenal Ship* program is considered a hardship assignment. Personnel are assigned to the program for approximately 18 months. This

would allow for a single complete tour on an *Arsenal Ship*. A crew member will either voluntarily extend or be reassigned at the end of their tour in the *Arsenal Ship* program.

In order to achieve maximum readiness with a crew of less than 50, several conditions must be met. First, when personnel are assigned to the *Arsenal Ship* program, they must complete the cycle. Second, it is paramount that the crew members arrive at the *Arsenal Ship* proficient in their rating and qualifications. With a small crew, the individual crew members must arrive at the ship ready to do their job with a minimum amount of on-ship training. These needs are incorporated into a CONUS based "*Arsenal Ship* School." Ideally, this school would not be a new training pipeline, but a crew assembly and integration headquarters. Personnel arrive at the "school," are assigned to a crew, and are sent to existing service schools for rating specific training. *Arsenal Ship*-specific training is done at the "school" in order to qualify officers and enlisted personnel for duty on the *Arsenal Ship*.

As stated before, the crew is primarily composed of "operators." At the "*Arsenal Ship* School," the training is simulator and mockup intensive. This philosophy is carried over to forward ports where additional simulation-based training is integrated into the ship's routine to augment the infrequent live fire exercises with other fleet assets.

The ship remains forward-deployed. Therefore, it is not available to participate in group work-ups in preparation for deployment. However, the crew, or at least a portion of the crew, is available. Through remote connectivity and existing fleet simulators, the crew links and trains with other fleet units, as if the *Arsenal Ship* is actually with the battle group. This type of training is necessary because the *Arsenal Ship* must operate as an integral part of a battle group in order to perform her mission.

5. Command and Control

The *Arsenal Ship's* ability to interface with command and control systems, world wide, is the center of gravity for this platform. The most advanced communication systems are employed to create a network of sensor systems that link fire control information, in real time, back to the *Arsenal Ship*. When called upon by the targeting platforms, the *Arsenal Ship* will deliver overwhelming amounts of ordnance to a multitude of targets. Electromagnetic compatibility and frequency spectrum assignment issues are vital to the ship's ability to perform her mission. In addition, the communication and information security systems are impenetrable.

The level of connectivity required to enable the *Arsenal Ship* concept is revolutionary. This connectivity revolution is enabled through advances in Command and Control technologies married with intensive training and exercises with naval expeditionary forces. The Manpower, Personnel and Training section of the CONOPS addresses how the forward-deployed *Arsenal Ship* maintains its proficiency at interfacing with the Command and Control architecture of the expeditionary forces which routinely work-up and deploy as integrated groups.

6. Security

Due to the nature of the *Arsenal Ship's* mission and its cargo, maintaining physical security is a paramount concern. At sea, the ship must be protected from all threats that can endanger the ship and its payload. Escort ships, coupled with a sound shipboard security plan provide the measures necessary to safeguard the *Arsenal Ship* and its missiles.

The forward operating bases which support and maintain the *Arsenal Ships* require innovative security measures to protect the vital capability of these platforms. Opposing forces and terrorists on missions to damage U. S. warfighting capabilities and erode the resolve of forward-deployed forces will view these ships and the bases which support them as prime targets. The port facilities developed to service these missile laden ships must facilitate the enhanced levels of physical security required for such high valued assets.

7. Interoperability and Integration with Carrier Battle Groups and Amphibious Readiness Groups

The *Arsenal Ship's* interoperability and integration with the regularly deploying naval expeditionary forces is of concern due to its forward-deployed nature of employment. The following passages and figure (I-2) describe the basic operational cycle of two *Arsenal Ships*, stationed at a designated forward operating base, in six month blocks:

- Block 1 (months 1-6):
 - *Arsenal Ship "A,"* with Crew A1, is underway in her area of operation with Group A1 (the group Crew A1 trained with prior to flying out and relieving the previous crew of ship "A").
 - *Arsenal Ship "B,"* with Crew B1, is inport at the forward operating base conducting routine maintenance on redundant ship systems and preparing for crew turnover. The ship remains available to the Unified Combatant Commander for most of her time inport.
 - Back in CONUS, Crew B2 is assembled and is training with Group B2. Prior to the end of Block 1, Crew B2 will fly to the forward operating base and relieve Crew B1.
 - Detailers are writing orders and assembling members for Crew A2.
- Block 2 (months 7-12):

- *Arsenal Ship "B,"* with Crew B2, is underway in her area of operation with Group B2.
 - *Arsenal Ship "A,"* with Crew A1, is inport at the forward operating base conducting routine maintenance and preparing for crew turnover.
 - Back in CONUS, Crew A2 is assembled and is training with Group A2. Prior to the end of Block 2, Crew A2 will fly to the forward operating base and relieve Crew A1.
 - Detailers are writing orders and assembling members for Crew B3.
- Block 3 (months 12-18):
 - *Arsenal Ship "A,"* with Crew A2, is underway in her area of operation with Group A2.
 - *Arsenal Ship "B,"* with crew B2, is inport at the forward operating base conducting routine maintenance and preparing for crew turnover.
 - Back in CONUS, Crew B3 is assembled and is training with Group B3. Prior to the end of Block 3, Crew B3 will fly to the forward operating base and relieve Crew B2.
 - Detailers are writing orders and assembling members for Crew A3.

This operating cycle supports the operational concepts outlined above, providing two trained *Arsenal Ships* continuously available to integrate with regularly deploying naval expeditionary forces in each of the three operating areas.

	Block 1 (months 1-6)		Block 2 (months 7-12)		Block 3 (months 12-18)	
<i>Arsenal Ship A</i>	Underway with Crew A1 and Group A1.		Inport with Crew A1 at FOB conducting routine maintenance and preparing for crew turnover.		Crew Turn-over	Underway with Crew A2 and Group A2.
<i>Arsenal Ship B</i>	Inport with Crew B1 at FOB conducting routine maintenance and preparing for crew turnover.	Crew Turn-over	Underway with Crew B2 and Group B2.		Inport with Crew B2 at FOB conducting routine maintenance and preparing for crew turnover.	
<i>Arsenal Ship "School" (in CONUS)</i>	Crew B2 is assembled and training with Group B2.	Crew B2 Flies to FOB/Group B2 Deploys	Crew A2 is assembled and training with Group A2.	Crew A2 Flies to FOB/Group A2 Deploys	Crew B3 is assembled and training with Group B3.	
Detailing	Detailers are writing orders and assembling Crew A2		Detailers are writing orders and assembling Crew B3.		Detailers are writing orders and assembling Crew A3	

Figure I-2: Basic Operational Cycle for an *Arsenal Ship* Squadron

D. SUMMARY

In an era that now finds the majority of U. S. military might based solely in the United States, vice overseas in regions of vital national interest, the forward-deployed naval expeditionary forces will certainly play a much larger role in the early stages of future engagements. These expeditionary forces must be shaped to meet the demands of future warfare. The forward-deployed forces of today must be augmented with larger numbers of precision-guided weapons and more robust command and control systems if they are to succeed in their roles as outlined in the Navy's vision of future naval warfare. The *Arsenal Ship*, and the revolutionary warfare concept it enables, brings such capabilities to the fleet.

The CONOPS described above envisions a fleet of six *Arsenal Ships* capable and ready to integrate with regularly deploying expeditionary forces. The concept is fully consistent with the Navy and Marine Corps' strategic concepts of expeditionary warfare as described in the papers *Forward ...From the Sea* and *Operational Maneuver From the Sea*. The *Arsenal Ships*, together with traditional naval expeditionary forces, will provide the rapid, robust, combat-ready response critical to thwarting the advance of future regional aggressors and to shaping the battlefield so that follow-on forces can quickly and decisively win wars.

II. DESIGN PHILOSOPHY

A. OVERVIEW

“A top level statement of guidance, for the design team, to assist in carrying out design tradeoffs in a consistent manner”

Professor Charles N. Calvano, CAPT, USN (Ret)

This design philosophy provides a prioritized list of factors to be used by the design team throughout the duration of the project. Specific issues and systems in the *Arsenal Ship* design are considered and trade-offs made. In order to ensure this is a logical and consistent process, the following prioritized list of the major design issues is developed. This section outlines and provides justification of the issues considered important enough to be incorporated in the design philosophy and thereby incorporated into the design.

B. PRIORITY OF DESIGN CONSIDERATIONS

1. Acquisition Cost and Life Cycle Cost
2. Mission Effectiveness
3. Survivability and Self Defense
4. Reduction in Manning
5. Reliability, Maintainability and Availability
6. Commonality: Other Platforms, Commercial off the Shelf (COTS), and Exploiting DoD Investments
7. Upgradeability and Modularity
8. Minimized Maintenance
9. Environmental Impact
10. Habitability

1. Acquisition Cost and Life Cycle Cost

The acquisition cost is the only concrete requirement placed on the design team. The acquisition cost cannot exceed 550 million dollars. All other requirements are secondary and tradeable.

Cost is given the highest priority because of the “cost cap” of the program. Some may argue that placing cost ahead of military effectiveness is unimaginable, but it is the driving factor in future procurement and getting the most effective platform for the least cost.

Life cycle cost is viewed as important as acquisition cost. The life cycle cost, if not considered in early stages of design, could make operation of the vessel uneconomical in the future. For example: The number of crew is a fixed operating cost for the life of the vessel. Also, fuel economy is designed into the hull and power plant and once finalized is only a function of how many miles the ship is to be driven. Decision trade-offs are to be made considering life cycle cost in mind, to provide a less costly ship today and in the future.

2. Mission Effectiveness

The primary role of the *Arsenal Ship* is to deliver a large number of missiles for other platforms to use. The priority of mission effectiveness is considered secondary only to cost. It is a focus of the design team to provide the most mission “bang” for the 550 million dollar “buck.”

3. Survivability and Self Defense

Survivability is defined as the capability of a ship to avoid or withstand a man-made hostile environment [6]. The survivability capabilities of the *Arsenal Ship* require critical design attention. Design considerations that increase survivability should be incorporated.

The ship design should exploit the use of passive self-defense measures by reducing infrared (IR) and electromagnetic (EM) signatures and employing electronic warfare measures and decoys. Additional active weapon systems may need to be incorporated to provide additional protection. Extensive hull compartmentation, hardening and automated systems were included to help in controlling damage, keeping the ship afloat, and providing graceful degradation of systems.

These features provide a very survivable platform. However the *Arsenal Ship*, also depends on the ability of the escort ships to provide a protective umbrella and early warning of threats coming within the area of operations.

4. Reduction in Manning

The design goal of the TSSE team is to limit personnel manning to 50. Manning reduction is primarily achieved through function automation in all aspects of ship operations, including ship control, engineering plant operations, damage control and warfighting operations. Good ship designs take advantage of technological innovations which replace or assist a crew member in making decisions, thereby reducing inconsistencies and human errors.

Watchstation manning levels are greatly reduced by relying on the automated systems to carryout routine, manpower intensive, duties. Manning levels for watchstation

training are also reduced by automated systems, since fewer personnel are required. A reduction in training effort is a hidden benefit of automation. An adequately trained person should be able to operate the ship effectively and efficiently with the assistance of automated services.

Many skills cannot be replaced or done in a cost effective manner. The major effort will be to balance the two and create the best solution. Manning assignments will be addressed on a person by person basis. Every crew member will have to be justified and balanced against the cost of automation. Reductions in manning also provide hidden and intangible savings in the areas of reduced casualties.

5. Reliability, Maintainability and Availability

The requirement to operate forward-deployed, with minimal manning, for extended periods of time, make reliability, maintainability, and availability paramount in meeting the mission. Use of onboard equipment monitoring systems to provide Condition Based Maintenance (CBM) information predicts maintenance based upon need. Reliability Based Maintenance (RBM) techniques incorporated with typical Preventative Maintenance (PMS) practices cut maintenance time, reduces the number of spare parts, improves reliability, improves system performance and reduces manning. The use of easily interchangeable spares and redundant systems also help provide additional reliability and availability of the *Arsenal Ship*.

6. Commonality: Other Platforms, Commercial off the Shelf (COTS) and Exploiting other DoD investments

Systems that are already in use in the Navy or other services were selected for use on the *Arsenal Ship*. The supporting infrastructure is already in place and can be tapped without additional cost. COTS items are to be chosen where DoD systems do not exist. This provides fast procurement, of spares and replacements, easy upgrading and interoperability. Systems and equipment from Aegis platforms are to be selected, wherever possible, because of the ease of obtaining spares from these escort ships.

Other DoD programs, such as “Smart Ship” are to be relied upon for information about new systems and programs to be incorporated into the *Arsenal Ship*, to reduce the need to invest in research and development funding.

7. Upgradeability and Modularity

Future growth and entire system upgrades are to be designed into the vessel. The ship is designed to be upgraded quickly, in order to significantly cut the cost and minimize the time and effort to upgrade. Modular designs also allow quick repairs by allowing change out vice repair in place. Locations for allowing removal of large equipment were included to limit down time for maintenance, ensuring the ability to meet the design goal of 95% availability.

A design goal of the ship is to provide space for a future gun system in the near future. The ship is designed to allow for this installation and already provides the needed supporting systems to speed the installation and prevent loss of availability.

8. Minimize Maintenance

The dual challenge of increased system sophistication and decreased manning in the *Arsenal Ship* is to be accomplished by using new maintenance technology. These systems can incorporate monitoring and analysis and replace the current program of preventative and corrective maintenance. The systems identify degraded or degrading performance. Unattended embedded sensors continuously monitor the condition of all equipment. Monitoring stations record and analyze the information. Appropriate warnings and equipment shutdowns are controlled by the monitoring station. Critical maintenance items are attended to by the limited personnel onboard. Other items may be automatically scheduled for an upcoming port call and shore side technicians attend to the maintenance needs. Wherever possible all major maintenance is designed to be conducted “dockside” in short mini-availabilities, thereby lengthening the time between required drydockings to 5 + years. The reduction of longer maintenance time (drydockings) by performing needed maintenance dockside will allow the availability of the *Arsenal Ship* to remain above 95%.

It should be noted the design allows for the maintenance work to be completed by either Navy personnel or by a commercial contractor. Systems and required maintenance will be selected on their easy of use and ease of repair.

9. Environmental Impact

Environmental regulations presently in force, today and those expected to be in place in the near future, are to be adhered to in the design. Great effort should go into balancing the cost and need of creating an environmentally friendly warship as reasonably and cost effectively as possible. Systems are considered by their use of

environmentally friendly materials and processes, prevention of typical waste disposal problems (trash dumping), and prevention of negative image related incidents (oil spills, smoke generation, etc.).

10. Habitability

Sufficient habitability standards are considered as to provide adequate living space for all crew members without compromising morale. The need for higher habitability standards over conventional naval ships arises due to the smaller, mixed gender, and isolated crew of this minimally manned ship. The attention given to this area can be seen in large living quarters and recreational areas.

III. DESIGN FOR REDUCED MANNING

A. INTRODUCTION

The design of the *Arsenal Ship* must incorporate innovative measures to reduce manning. The requirements are specified as follows:

- “To meet mission goals at affordable cost, ship design will be based on commercial practices and rely extensively on automation in engineering, damage [control], ship [control] and weapon systems to achieve a crew size of no more than 50.” [4]
- “Life Cycle Considerations. The ships are to be manned, if at all, by a Navy crew to be as small as practicable, but in any event not to exceed 50 people.” [5]

The rationale for this concept is primarily based on cost. An analysis of operating and support (O&S) costs for a typical destroyer [7] reveals that personnel costs have the most significant impact on ship affordability. This is depicted in figure (III-1), where personnel costs are shown to represent 65% of O&S expenditures. Although this percentage may not be accurate for the *Arsenal Ship*, its relative proportion is considered a reasonable approximation. Therefore, to design an affordable *Arsenal Ship*, major emphasis must be placed on manning reduction.

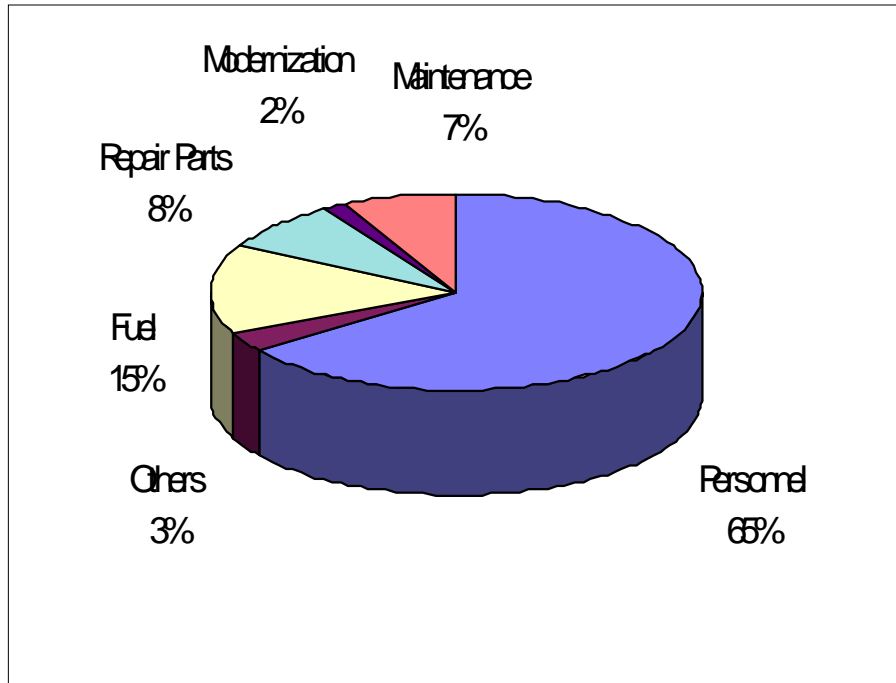


Figure III-1. O&S Costs for a Typical Destroyer

An additional benefit of reduced manning is the reduction of personnel placed in harm's way. By minimally manning the *Arsenal Ship*, personnel density is reduced and therefore, personnel loss due to casualty is lower.

This manning reduction is accomplished by extensive use of automation, electronics and computer technologies, as well as enacting concepts that challenge current Navy customs and traditions. These concepts or core themes are summarized as follows:

- Automation, Electronics and Computer Technologies
- Cross Functionality of Personnel
- Experience-- Professional Maturity
- Top Performers
- Selective Screening

In the design for reduced manning, extensive implementation of automation, electronics and computer technologies is required. The availability and affordability of advanced shipboard sensors and actuators, coupled with increased computer processor speeds, provide the means to effectively and safely reduce shipboard manning.

Secondly, personnel aboard the *Arsenal Ship* are required to be versatile. Cross-functionality is a crucial element to this concept of reduced manning. Crew members must not only demonstrate expertise in their area of specialty, but will be called upon to perform additional tasks, that may require additional training prior to deployment.

Additionally, a minimally manned ship requires a crew that is highly experienced. Personnel must report aboard fully trained, qualified and ready to perform at full capacity. Only self-motivated professionals are suitable for assignment to this ship.

Finally, discriminating medical, dental and psychological evaluations are required. In a manner similar to selection for submarine duty, *Arsenal Ship* personnel must be “hand-picked” for assignment. With a small, highly trained crew, personnel losses must be kept to a minimum. Selective screening is required to ensure that only “top-flight” sailors are assigned to the *Arsenal Ship*.

B. TRAINING CONCEPT

1. Overview

The *Arsenal Ship* reduced manning concept demands the ship be staffed with a fully mission capable crew requiring little or no onboard training. To satisfy this goal, crew members must arrive to the ship fully trained and qualified, immediately capable of performing the ship’s mission. To do this, an *Arsenal Ship* training command must be

established. This does not require a new training pipeline, but is a supplement to existing service schools with *Arsenal Ship*-specific simulator-based training.

2. The *Arsenal Ship* Training Command (ASTC)

At ASTC, crews are formed and trained, and then sent as a unit to the forward-deployed ship. This command serves as administrative headquarters for the *Arsenal Ship* program, as well as the homeport for the crews. The ASTC should be located in the vicinity of existing fleet infrastructure (i.e. Norfolk, VA). This reduces the requirement for construction of administrative and support facilities.

3. Crew Training Cycle

The *Arsenal Ship* training cycle is designed to build and deploy the crew as a cohesive unit. The *Arsenal Ship* cycle is approximately eighteen months in length. The first six months of the cycle are spent training the crew both as individuals and as a unit. During the next 12 months of the cycle, the crew is assigned to one of the forward-deployed *Arsenal Ships*.

4. Individual Training Concept

a. Rating/Designator Training

It is paramount to the reduced manning concept that each crew member on the ship is fully qualified according to billet. To accomplish this, existing service schools are used to provide initial and refresher training and qualification. This may require creation of additional *Arsenal Ship*-specific courses suited to the special needs of the program.

Additionally, existing schools may need to provide instructional and facility support to the program.

b. Cross-training

Crew cross-training is another cornerstone of the reduced manning concept. Crew members will perform numerous interdisciplinary tasks. Cross-training is performed along departmental lines. For example, a crew member reporting to the engineering department must be familiar with the operation and maintenance of every aspect of the engineering plant, not just his rating area. Service schools may need to develop courses to support cross-training personnel in out of rating area specialties.

5. Crew Training Concept

a. Special Detail Training

Like any other ship, special evolutions, such as underway refueling, boat operations, and flight quarters, are manning and training intensive. By locating the ASTC near an existing fleet infrastructure, land-based trainers and mockups can be used to perform team training for these special evolutions.

b. Fleet Integration

The *Arsenal Ship* is envisioned as a supporting platform requiring dedicated fire control support from fleet assets. Because the *Arsenal Ship* is forward-deployed and unavailable to participate in traditional battle group workups (i.e. FLEETEX, BGE), its crew must be trained in a manner similar to inport team training presently conducted at Fleet Combat Training Centers. Through remote connectivity and existing fleet simulators, the crew is able to link and train with other fleet units, as if the *Arsenal Ship*

was actually steaming with the battle group. This method of fleet integration enables the *Arsenal Ship* to remain forward-deployed while its relief crew is fully trained and integrated into the deploying battle group.

6. Effect on Manning

a. *Arsenal Ship* Manning

The concept of deploying trained people to forward-deployed equipment is not new, and is routinely performed in the U.S. Marine Corps. The *Arsenal Ship* adopts this concept in order to meet the requirements of steaming a minimally manned crew and an availability of 95%. Presently, crew members on naval warships are sent to schools when certain training requirements onboard are delinquent. The remaining crew members perform not only their own assignments, but also help take up the slack of their missing shipmate. The *Arsenal Ship* is already minimally manned and crew members will not be able to leave the ship for extra training once forward-deployed.

C. MAINTENANCE CONCEPT

The *Arsenal Ship* is designed to operate forward-deployed for extended periods of time with minimal maintenance requirements. New methods of maintenance must be developed for this to be performed by a reduced crew.

1. Depot-Level Maintenance

The *Arsenal Ship* is required to be available 95% of the time [4]. This requires no more than 18 days of unavailability for combat operations per year, or 90 days every five years. To accomplish this, most intermediate- and depot-level repairs are performed at

the forward operating bases (FOB). Access soft patches in the aft superstructure allow equipment to be easily removed and replaced requiring little more than crane service. For example, the normal lengthy overhaul of a diesel engine is reduced to a few days by removal and reinstallation of a new diesel engine, vice repair of the engine in place.

Drydocking is conducted in 90 day availabilities every five years. The driving factor for this five-year periodicity is the missile recertification requirements of the ship's payload. The *Arsenal Ship* returns to CONUS for missile offload at a Naval Weapons Station (i.e., Seal Beach, CA or Yorktown, VA) prior to entering drydock.. Upon completion of drydocking, the ship is outfitted with a fully-certified missile payload.

2. Intermediate-Level Maintenance

Each FOB must have an intermediate-level maintenance activity (IMA) capable of supporting the forward-deployed *Arsenal Ships*. These IMAs are crucial in maintaining 95% availability because the ship is far removed from depot-level maintenance activities. Additionally, IMA personnel are needed to augment ship's force in performing periodic and corrective maintenance during inport periods.

3. Organizational-Level Maintenance

Three different, but linked, maintenance systems are implemented in *Arsenal Ship*: Periodic Maintenance System (PMS), Reliability-Based Maintenance System (RBMS) and Condition-Based Maintenance System (CBMS) . These systems reduce unneeded maintenance. The PMS and RBMS determine maintenance requirements based upon known characteristics of installed equipment. The CBMS is a computer-based monitoring system integral to the Engineering Control and Monitoring System (ECMS).

Sensors are attached to major pieces of equipment and transmit status to the monitoring system. Baseline information recorded at equipment installation is used to determine required maintenance intervals. Significant time-intensive PMS items are replaced by the use of the CBMS. Maintenance is driven by need, vice a preset time interval. When used effectively, coordinated use of these three maintenance systems maximize availability of the ship and decrease maintenance man-hours and costs.

4. Redundant systems

A major consideration in the design of the *Arsenal Ship* is the use of redundant systems. These systems allow a shift to offline equipment in the event of failure vice immediate repair. The failed equipment can remain idle, pending repair. The equipment can then be repaired by ship's force, a technical assistance team, or by the IMA upon returning to port. Sufficient redundant systems are installed to prevent loss or degradation of any primary mission area.

Redundant systems also add to the overall survivability of the vessel. Multiple redundant systems give the ability to circumvent battle damage and restore lost functions quickly, greatly increasing survivability and ship availability.

5. Modularity

Modularity encompasses several concepts. This design incorporates two of them. The first is the use of commonality, interchangeable components in various systems. By pre-selecting common components (i.e., pumps and motors), the ability to use a single spare for multiple systems reduces required logistics infrastructure and parts storage. An

added advantage is that you can take a component from a non-vital system to replace a damaged vital system component in an emergency.

The second is the use of total modular systems. For example, each auxiliary system can be mounted on an individual skid. This concept supports the 90 day depot-level maintenance period by allowing entire systems to be swapped out, vice repaired in place. This creates a rotatable pool of well-maintained equipment to help maintain the required 95% availability of the *Arsenal Ship* fleet. Another benefit is the ability to perform configuration changes easily and quickly, keeping *Arsenal Ship* systems on the cutting edge of technology.

6. Industrial Coatings

Commercially available coatings are used to the fullest extent possible to prolong the time between topside paintings. These coatings include those used on industrial machinery and submarines. This is coupled with new methods of application that make underwater coating possible, thereby extending the time between drydockings for hull inspections.

D. SPECIAL EVOLUTIONS

1. Overview

Special evolutions are manpower intensive aboard naval ships. The purpose of this section is to describe how the *Arsenal Ship* is designed to reduce manning for these

evolutions when compared to current practices. *Arsenal Ship* special evolutions are listed below.¹

- Underway Replenishment (UNREP)
- Helicopter Operations
- Boat Operations
- Sea and Anchor Detail

2. Underway Replenishment

The Navy’s current methods of underway replenishment are far too manpower intensive for the *Arsenal Ship* [8]. Table III-1 shows the total number of personnel required for UNREP on a Arleigh Burke destroyer is approximately 80, depending on the number of stations involved and whether the evolution involves refueling at sea (RAS) and/or connected replenishment (CONREP) [9]. The large manpower requirement is primarily due to the need for linehandlers to pull receiving lines aboard.

1. Gunnersmate						
2. Fuel Sampler						
3-8. Phone and Distance Line						
9-22. Linehandlers for Refueling						
23-36. Linehandlers for Highline						
37-52. Rig Team						
52-62. Ready Lifeboat						

¹ NOTE: The ideas presented in this section are based on the at-sea experience of the design team, and are developed in response to the *Arsenal Ship*’s reduced manning concept. These ideas require exceptions to [8], [10] and [11].

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Table III-1. Typical Naval Combatant Manning for Underway Replenishment [8]

The *Arsenal Ship* carries enough fuel for a 90 day mission such that there is no need for RAS. If RAS becomes necessary, the *Arsenal Ship* has capstans located at each refueling station in order to reduce the number of line handlers to four (Table III-2). The primary method of stores transfer to the *Arsenal Ship* is vertical replenishment (VERTREP). Wireless communications and laser rangefinders replace the phone and distance line and station-to-station phonetalkers to further reduce the manning requirement for this evolution.

Phone and Distance Line							
1. Phone Talker							
2. Linehandler							
3. Linehandler							
4. Linehandler							
5. Linehandler							
6. Gunnersmate/Signals							
7. Fuel Sampler							
8. Winch Operator							
9. Safety Observer for Winch							
10. Linehandler							
11. Linehandler							

Table III-2. Projected *Arsenal Ship* Manning for Refueling at Sea Evolutions.

3. Helicopter Operations

Helicopter landing capabilities are critical. The helicopter is the primary means to transfer personnel (i.e., technical support personnel, medical evacuation). Since the

helicopter lands on the *Arsenal Ship*, the ship has landing deck lights, tie-downs, safety nets, and a glideslope indicator.

In order to minimize manning and maximize on-station time, the *Arsenal Ship* relies on VERTREP, vice CONREP, for rapid stores transfer. The *Arsenal Ship* has a strikedown elevator in the vicinity of the flight deck to strike below stores. The longitudinal passageways that link the fore and aft sections of the ship provide a path between the strikedown elevator and the freezer, chill box, dry provisions storeroom and ready storage spaces located forward. To move the stores from the flight deck to these storage locations, a conveyance system is installed along these longitudinal passageways.

The *Arsenal Ship* has a class-3 flight deck certification for flight deck operations [10]. Class-3 certification means the ship only provides a landing platform with no services. The decision not to carry JP-5 is based on the personnel required to maintain an additional fuel oil service and transfer system and process the fuel. Should the need arise for helicopter refueling, the escort ship or VERTREP delivery ship is responsible for providing the necessary services.

To further reduce manning during this evolution, a remotely-operated, integrated firefighting system is installed. This system includes sensors, video monitors and AFFF flight deck sprinklers. The helicopter control officer, with full visibility of the flight deck, controls activation of this system from the helicopter control station. Since this system is used to provide the initial response to a flight deck fire, the number of hose teams is reduced to one (Table III-4).

<u>Typical Naval Combatant</u>							
1-2. HIFR/Hotpump/Grounders (static discharge)							
3. Landing Signalman							
4. Helo Control Officer/comms/AFFF sprinkler operator							
5-6 Chocks/Chainmen							
7. Fire Party Scene Leader							
8. Sound Powered Phone Talker							
9-11. Plugmen/Reel Tenders							
12-17. Hosemen							
18-20. Team Leaders/Nozzlemen							
21-22. Hotsuitmen							
23-32. Ready Lifeboat Crew							
<u>Arsenal Ship</u>							
1. Landing Signalman							
2-3. Chocks/Chainmen							
4. Fire Party Scene Leader/AFFF sprinkler activator							
5. Sound Powered Phone Talker							
6. Plugman/Reel Tender							
7-8. Hosemen							
9. Team Leader/Nozzleman							
10-11. Hotsuitmen							

Table III-3. Typical Navy Combatant vs. Projected *Arsenal Ship* Manning for Helicopter Operations [10].

4. Boat Operations

The rigid-hull inflatable boat (RHIB) is essential for the *Arsenal Ship*. It provides additional flexibility to an already minimally manned ship. The RHIB not only serves to transport additional personnel to the ship for corrective maintenance, but also provides a ready lifeboat during certain evolutions. Requirements for the *Arsenal Ship*'s RHIB are as follows:

- The *Arsenal Ship* carries the smallest RHIB in the Navy’s inventory.
- The RHIB burns F-76 diesel fuel, marine (DFM). The *Arsenal Ship* does not carry aviation fuel (i.e., JP-5), onboard due to the additional storage and maintenance requirements, and does not carry gasoline due to the intolerably low flash point that presents a fire hazard to the ship.
- The RHIB is stowed on the main deck internal to the ship, to prevent an increase in radar cross-section (RCS).
- The *Arsenal Ship* reduces the manning for lowering and operating the RHIB as shown in Table III-4.

<u>Navy Combatant (lower small boat)</u>					<u>Arsenal Ship (lower small boat)</u>				
1. Safety Observer					1. Safety Observer				
2. Davit Captain					2. Davit Operator				
3. Davit Operator					3. Forward Linesman				
4. Forward Linesman					4. Aft Linesman				
5. Aft Linesman									
<u>Navy Combatant (operate boat)</u>					<u>Arsenal Ship (operate boat)</u>				
1. Coxswain					1. Coxswain/Bowhook				
2. Engineman					2. Engineman/Swimmer				
3. Bowhook									
4. Swimmer									
5. Boat Officer									
TOTAL MANNING: 10					TOTAL MANNING: 6				

Table III-4. Typical Navy Combatant vs. Projected *Arsenal Ship* Manning for Small Boat Operations [9].

During helicopter operations and underway replenishment special evolutions, the *Arsenal Ship* will not normally man a ready lifeboat. The standard procedure for these

evolutions is to use a battle group asset as the primary man overboard recovery unit. This requirement stems from the fact that the *Arsenal Ship* is minimally manned, lacking extra personnel to man special evolution watch stations and a ready lifeboat simultaneously.

5. Sea and Anchor Detail

The sea and anchor detail evolution is also a manning intensive operation due to the significant number of linehandlers required at each station. The *Arsenal Ship* reduces this number by positioning retractable capstans in close proximity to each station. This decreases the number of personnel required from ten per station to merely four. The four consist of a safety observer, capstan operator, and two linehandlers. The total number of personnel involved in this evolution is eight; two four-man teams, one fore and one aft. These teams, working in concert, make up two lines at a time until the ship is tied up.

A keel anchor is installed for several reasons. By removing topside equipment, the radar cross section, maintenance and preservation requirements are reduced. This reduction in maintenance and preservation requirements significantly reduces man-hours. The evolution watch is reduced from six personnel to one [9].

6. Maintenance

Table III-5 contains the special evolutions PMS requirements performed at a periodicity not greater than quarterly by Deck Department personnel [11].

Boat Operations	7 PMS checks
UNREP	12 PMS checks
Helo Ops	14 PMS checks
Anchoring	2 PMS checks
Other (lifeboats, lifevests etc.)	4 PMS checks

Table III-5. PMS requirements for Deck personnel on topside equipment.

The majority of these PMS checks are inspections and, by shielding the equipment from the weather, the volume of corrective maintenance based on these checks is drastically reduced. The recommended deck force personnel to accomplish topside PMS and corrective maintenance is three [11].

Figure III-2 contrasts the projected *Arsenal Ship* manning requirements for special evolutions against the current Navy combatants.

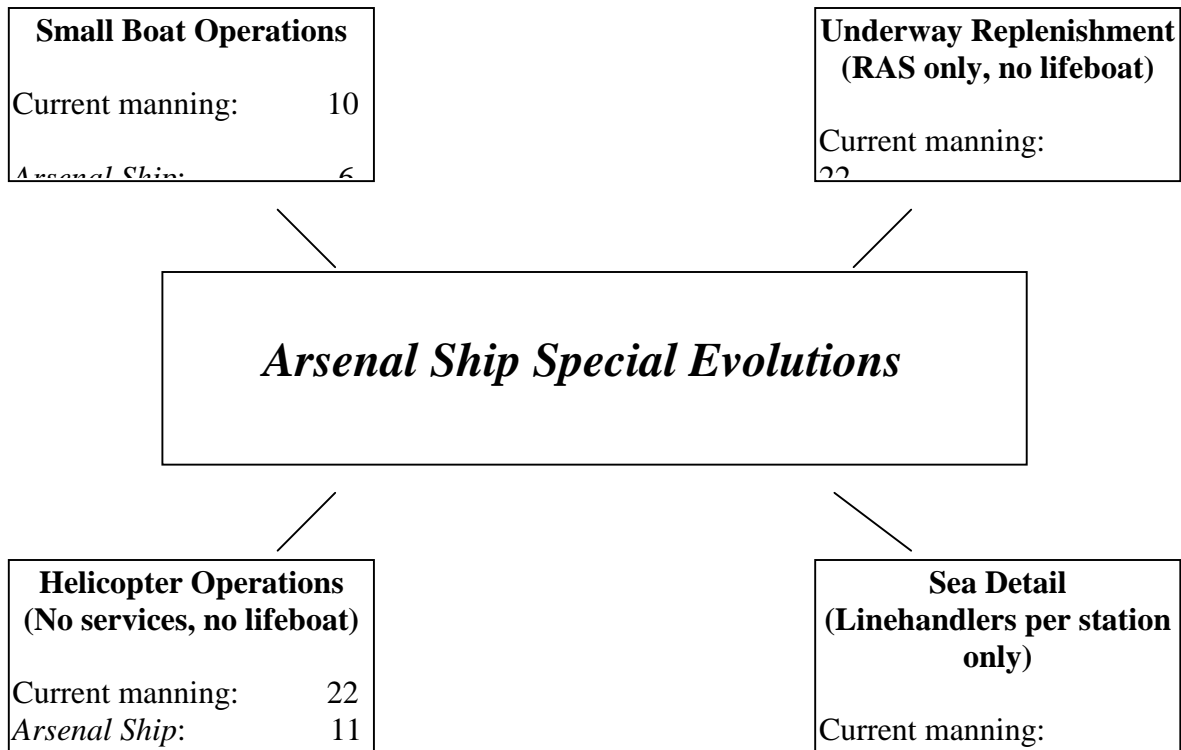


Figure III-2. Typical Navy Combatant vs. Projected *Arsenal Ship* Manning for Special Evolutions.

E. ADMINISTRATIVE CONCEPT

1. Overview

In the past, shipboard administrative functions (i.e., service records, disbursing) have had a significant impact on manning requirements. This situation has been further exacerbated each time a new program is developed. The purpose of this section is to describe how the *Arsenal Ship* is designed to reduce manning for administrative duties onboard.

2. Administrative Concept

The *Arsenal Ship* relies on computer networks to handle all administrative duties. The goal is to make the *Arsenal Ship* a “paperless” ship. The ship does not have any administrative support personnel onboard. All personnel records are maintained using the COMPASS computer program [12]. Every stateroom and berthing compartment has a computer for the ship’s crew to access the network. This allows easy exchange of fitness reports, evaluations, and training records; ordering of parts; and work order generation to all be performed on the network. A hard copy of each record is maintained at the Personnel Support Detachment (PSD) at the respective home port. All records are periodically updated via wireless transmission.

3. Postal Services

A ship’s post office and postal clerk are not assigned to the *Arsenal Ship*. This is possible because electronic mail can replace paper letters. Furthermore, each crew member has access to a personal computer located in their living quarters. Additionally, all personnel receive indoctrination training on methods of electronic financial management during their six-month pre-deployment period at the ASTC. A crew member is assigned the collateral duty of mail handling.

4. Medical and Dental Services

The ship has an Independent Duty Corpsman (IDC) assigned and sickbay facilities onboard. The IDC administers emergency care to the crew. All routine medical and dental examinations and procedures are performed inport at appropriate clinics. The

Arsenal Ship screening process discussed previously minimizes the need for medical and dental services underway.

5. Disbursing Office

In addition to being paperless, the *Arsenal Ship* is also a cashless ship. The ship does not have vending machines or a traditional ship's store. All snacks and necessary laundry items are provided for each crew member. Since the *Arsenal Ship* is not expected to visit any foreign ports due to physical security requirements, there is no need for a Disbursing Officer.

F. HABITABILITY

1. Overview

The purpose of this section is to describe how the *Arsenal Ship* is designed to maximize the size and comfort of living arrangements for a minimal crew. This section also describes the messing concept and miscellaneous crew services.

2. Messing

Two Mess Specialists (MS) are assigned to the *Arsenal Ship* to prepare and cook the meals for the entire crew. A mess attendant is assigned from the junior enlisted personnel onboard to assist the MS in preparation and cleanup of the mess and galley. The MS can use the computer in his berthing compartment to prepare the menu and automatically track the inventory of all necessary items. The entire crew pass through the buffet-style line, but dine in their own messing areas. These dining spaces include a general mess, chief petty officer' (CPO) mess, and officer's wardroom. The location of

the dining facilities and food storerooms is forward in close proximity to the primary habitability area.

3. Berthing

The berthing spaces onboard the *Arsenal Ship* are designed such that all officers have individual staterooms. CPOs are assigned to two-person quarters, and enlisted personnel (E-6 and below) are assigned to six person berthing spaces. All rooms include complete head facilities. An additional benefit of this layout is that female sailors are easily accommodated. All rooms also include a television, VCR and carpeting. This “home away from home” setup is created to provide sailors a relaxing environment for their time outside normal working hours. Mess attendants are not assigned for the officer or CPO quarters due to reduced manning. All personnel are responsible for cleanliness of their living quarters.

The forward berthing spaces are designated the primary habitability area. This area includes sufficient berthing to accommodate 12 officers, 12 CPOs, and 24 other enlisted personnel. Additional berthing accommodations are located aft. This area includes sufficient berthing for five officers, four CPOs, and 24 enlisted personnel. The additional berthing not only provides for overflow, but also provides the ability to distribute their crew during wartime operations. Distributing the crew increases their survivability mitigating the effects of a single missile strike in a berthing area.

4. Crew Services

a. Laundry

The ship is designed to have a separate laundry space that includes two washing machines and two dryers. Ship’s personnel are responsible for doing their own laundry.

In order to reduce the need for pressing services, the standard uniform underway is fire retardant coveralls [13]. Laundry detergent and dryer sheets are provided to the crew as needed.

b. Ship's Store

The *Arsenal Ship* does not have a ship's store onboard. The crew may purchase the standard ship's ball caps and collared shirts at their home port. Crew members are required to bring any necessary items that they may need underway. This concept is the standard mode of operation for the submarine community. The *Arsenal Ship* uses this mode operation due to the reduced manning concept.

c. Barber Services

The *Arsenal Ship* does not have a barber shop onboard. Underway, personnel are not required to keep their grooming standards within regulations until the week before the ship returns to port. A crew member is then assigned as the ship's barber and cuts all crew members' hair.

d. Crew Recreation/Physical Fitness

The ship is designed with a crew recreation room. This room is available during working hours for meetings and classroom training, and after working hours for socializing. The ship also has a physical fitness space onboard. The space includes all of the standard state of the art equipment (i.e., weights, bicycle and stair climbers), and any desired Nautilus equipment.

e. Divine Services

All divine services are conducted by ship's crew members assigned as lay leaders.

G. AUTOMATION

1. Overview

The *Arsenal Ship* takes advantage of the latest technology to perform routine watchstanding procedures. The installation of a central, automated system, similar to the one used in the Smart Ship Program, is the baseline for the *Arsenal Ship* [14]. Several additional subsystems are added to improve overall system performance.

2. Voyage Management System

The Sperry Marine Vision 2100 Voyage Management System (VMS), with an integrated bridge, is used for navigation [15]. It is a commercially available, Windows NT based, computer navigational system, commonly referred to as the Integrated Bridge System (IBS). This system allows only two watchstanders to safely navigate the ship. The operator has full ship control, or he can allow the system to automatically control the ship by inputting selected waypoints at the keyboard. The ADG3000 autopilot subsystem keeps the ship on track by controlling the ship's course and speed. The MK 37 Gyro, SRD-421 Doppler Radar, Global Positioning System (GPS), and depth and weather sensors provide the VMS with necessary information to automatically correct the ship's track. In autopilot, the bridge operators are only needed to monitor alarms, control casualties, establish communications, and serve as lookouts.

The VMS uses electronic charts that can be created in the chartroom using a chart digitizer, or purchased prior to deployment. Additionally, a RASCAR VT radar system

provides the autopilot with a collision avoidance feature and displays radar over-layed images on the IBS console .

Additional modules provide voyage recording (i.e., blackbox recorder), docking displays, precision anchoring, man overboard monitoring, and engineering and damage control status. These features give the two watchstanders adequate information to properly handle abnormal situations without the requirement for additional personnel on the bridge.

3. Two Wire Automatic Remote Sensing Evaluation System

The Two Wire Automatic Remote Sensing Evaluation System (TWARSES), coupled with remote television cameras, provide the bridge, engineering, and combat system watchstanders with complete all around visibility and interior space monitoring [16].

4. Standard Monitoring Control System

The Standard Monitoring Control System (SMCS) is an integrated control and monitoring system for all shipboard machinery [17,18]. Watchstanders in the engineering control station (CCS), combat information center (CIC) and the pilothouse have displays depicting the engineering plant status. The engine rooms are unmanned. The engineering watchstanders carry a personal information pad (PIP). The engineering watchstanders are free to roam throughout the ship until the PIP beeps, notifying the watchstanders of an engineering casualty.

The SMCS provides graphical interface, as well as a hardcopy printout. This allows the engineering watchstander to make quick decisions affecting the status of the

engineering plant. The SMCS, in conjunction with the ICAS (Integrated Condition Assessment System) and Damage Control System (DCS), is capable of complete control of the engineering plant including casualty control procedures [17-21]. The SMCS can shutdown and startup systems. It can also cross-connect systems and prevent loss of any vital equipment. The SMCS uses an open-architecture design that allows for future equipment upgrades and changes.

5. Damage Control System

The DCS is a computer system that monitors and initiates controlling actions in the event of a casualty. The DCS provides real-time graphical information (i.e., stability, electrical isolation) to the control stations allowing rapid decision making. In the fully-automated mode the information is passed to the SMCS. This allows the SMCS to automatically isolate the compartment and activate installed damage control systems. The DCS does not require a dedicated watchstander. The engineering watchstander are responsible for monitoring the system's displays. The bridge and CIC watchstander can also monitor the damage control status of the ship locally, via the DCS monitor on their respective consoles.

6. Integrated Condition Assessment System

The Integrated Condition Assessment System (ICAS) monitors, tracks, and provides a complete machinery-condition assessment. It is a diagnostic tool for maintenance management. By monitoring the equipment, a maintenance requirement estimate can be predicted. This reduces unneeded time-based maintenance. No

watchstander are required for this system. Pending problems are reported to the engineering watchstander for maintenance scheduling.

7. Local Area Networks

Zonal Local Area Networks (LANs) are interconnected with the ship's administrative LAN and provide engineering and ship control status to the consoles in CIC, CCS and the pilothouse. Each of these multi-purpose control centers are capable of duplicating the entire functions of the other two stations (i.e., CIC can monitor engineering plant status), thus increasing the survivability of the overall system. The control stations are also capable of displaying multiple system information on several displays

The automated systems described above provide for ship control and engineering monitoring with only three watchstanders.

H. DAMAGE CONTROL

The *Arsenal Ship* uses a combination of automated systems to drastically reduce damage control party manning. The Damage Control System (DCS), in conjunction with the Standard Machinery Control System (SMCS), control the installed engineering and damage control systems automatically. The Two Wire Automatic Remote Sensing Evaluation System (TWARSES) is the remote-sensing system that monitors all shipboard compartments.

The DCS continually monitors the TWARSES for problems. TWARSES sensors are located in every compartment, tank and void. The DCS can be monitored from CIC,

CCS, and the bridge. This removes the requirements for a dedicated damage control watchstander.

The SMCS and DCS are capable of enacting a predetermined sequence of events in response to damage. These systems isolate the damaged compartment by closing hydraulic watertight doors surrounding the damage. Electrical and electronic equipment and ventilation to the affected space are secured in accordance with preprogrammed doctrine. Depending on the damage detected, the SMCS activates installed damage control systems. The compartment is isolated within seconds of damage detection, with no crew member action.

A highly capable, six-man damage control party arrives on scene to take additional action, if required. The damage control party is comprised of personnel from the non-watchstanding maintenance force.

I. COMBAT SYSTEM MANNING REQUIREMENTS

1. Overview

The *Arsenal Ship* concept strives for functionality and simplicity with minimum required manning. Integrated sensors, computers and electronics have allowed the automation of functions that previously required human monitoring and response. At the same time, solid state and digital electronics have become more reliable, longer-lasting and require less maintenance. The assumption, based on this trend, is that electronics will only continue to improve and can be relied on for monitoring and response functions and require little intervention. The largest mechanical component of the *Arsenal Ship*'s combat suite is the Vertical Launching System (VLS). A preliminary study has been

completed to determine the minimum number of personnel required to perform preventative maintenance on the MK 41 VLS [20].

The combat system watchstanding concept is two-fold, with combat system watchstanders (CSWS) and combat system maintenance personnel (CSMP). Watchstations consist of the Combat System Officer of the Watch (CSOW), Communications (COMMS), and Ship Defense (SD) (Table III-6). CSMP consist of the combined rates of Electronics Technicians (ET) and Gunner's Mate Missile (GMM). The ET rate brings electronics expertise and the GMM rate the missile, launcher and small arms expertise.

2. Command

The Commanding Officer (CO) is ultimately responsible for the safety of the ship. He also ensures that the *Arsenal Ship* can carry out its combat mission. The CO can personally exercise his missile launch authority from the Combat Information Center (CIC). The CO is the only officer who can take the ship from the "weapons-tight" to "weapons-free" condition. Once the ship is placed in the "weapons-free" condition, the CSOW can be delegated the authority to launch all defensive weapons.

<u>COMMAND</u>					
CO					
XO					

<u>CSOW</u>		<u>COMMS</u>		<u>SD</u>	
O4	CSO	LDO	RM	E6	EW
O3	WO	E6	RM	E5	EW
<u>COMBAT SYSTEM MAINTENANCE</u>					
E6	ET	E5	GMM		
E6	ET	E4	GMM		
E5	ET	E4	GMM		
E5	ET	E4	GMM		
E6	GMM	E4	GMM		
					<u>TOTAL: 16</u>

Table III-6. Combat Systems Manning Requirements

3. Combat Systems Officer of the Watch (CSOW)

CIC and the Communications Center are fully manned with a CSOW, COMMS and SD when the *Arsenal Ship* is in a combat area. The CSOW operates from the Advanced Tactical Weapons Control System Console (ATWCS), monitoring system and weapon statuses, selection requests, and post-fire assessment. Combat system maintenance and damage control parameters are monitored in CIC on the combat system control console. This console is identical to the SMCS in CCS and the IBS on the bridge. The CSOW may be thought of as a Local Area Network (LAN) manager, monitoring the entire combat system with the capability to access it to respond to individual casualties. The CSOW uses the system and determines the required level of casualty control. He can task maintenance personnel remotely via the personal information pad (PIP). The CSOWs stand a six-hour watch during combat operations. During peacetime operations,

the CSOWs conduct system diagnostics and review prioritized maintenance work lists, and are not required to remain in CIC.

4. Communications (COMMS)

The COMMS watchstander is responsible for ship connectivity. The COMMS watchstander ensures the proper communications plan is established, setting up and monitoring long-haul, tactical and link communications through the SACCS (Ships Automated Communications Control System). He conducts message delivery and communications system diagnostics. The COMMS watchstander stands a six-hour watch for one week, rotating with CSMP ETs to maintain a proficient operator/maintainer force. Since the COMMS watch is automated, the watchstander mainly monitors the system, such that a typical six-hour watch is not physically or mentally demanding.

5. Self Defense (SD)

The SD operator controls the ship's self-defense system. SD watchstanders stand a six-hour watch as required for ship self-defense. When manning of the self-defense system is not required, the SD watchstanders augment the CSMP. Similar to the COMMS watchbill, two CSMP ETs are also trained to stand the SD watch. The self-defense system includes the Advanced Integrated Electronic Warfare System (AIEWS), Decoy Launcher Control and the Rolling Airframe Missile (RAM) Weapon Control Panel. The SD operator receives engagement orders from the CSOW.

6. Combat System Maintenance Personnel (CSMP)

CSMP have day work hours and prioritized maintenance schedules, repairing out of commission equipment first and then completing preventative maintenance. CSMP are

on call 24 hours for emergent work or emergency response to casualties. CSMP are contacted by the PIP. The PIP notifies the CSMP of the system casualty and location or the need to contact with Officer of the Deck (OOD) or CSOW. CSMP receive damage control and security force training as a ready response force for ship damage and protection.

J. ENGINEERING MANNING REQUIREMENTS

1. Overview

In support of reducing manning, the engineering spaces are unmanned during normal steaming. The *Arsenal Ship* has an Engineering Officer of the Watch (EOOW) and an Engineering Operator (EO) in a four-section watch rotation (Table III-7). These watchstanders are not required to remain in the engineering spaces. The watchstanders carry a personal information pad (PIP). The watchstander is free to roam throughout the ship until the PIP beeps, thus notifying the watchstander of an engineering casualty. Four additional personnel are available for troubleshooting and repair of engineering casualties.

Maintenance Officer			

<u>EOOW</u>		<u>EO</u>	
E7	EN	E6	EN
E7	EN	E6	EN
E7	EM	E5	EN
E7	EM	E5	EM
<u>ENGINEERING MAINTENANCE</u>			
E6	DC	E5	EM
E6	EN	E5	DC
			<u>TOTAL: 13</u>

Table III-7. Engineering Manning Requirements

2. Engineering Watchstanders

The EOOW operates from the Standard Monitoring Control System (SMCS) console in the engineering control station (CCS) during engineering casualties. The EOOW uses the system to determine the required level of casualty control. He can task the EO and maintenance personnel remotely via the PIP. The EOOW may be thought of as a Local Area Network (LAN) manager, monitoring the entire engineering system with the capability to access it to respond to individual casualties. The SMCS allows the entire engineering plant to be monitored and controlled from any of the consoles in CIC, CCS, the pilothouse; all Local Operating Panels (LOP); and all Control and Collection Units (CCU). The digital monitor and control capability of this system is the primary justification for leaving all engineering spaces unmanned. The EO is primarily an assistant to the EOOW, and is available to provide local casualty control on engineering equipment in case the SMCS fails to take the proper controlling action.

3. Engineering Maintenance Personnel (EMP)

EMP have day work hours and prioritized maintenance schedules, fixing broken equipment first and then completing preventative maintenance. EMP are on call 24 hours for emergent work or emergency response to casualties. EMP are contacted by the PIP. The PIP notifies the EMP of the system casualty and location or the need to contact the EOOW. EMP comprise the damage control party, and are involved in all special evolution details.

K. PHYSICAL SECURITY

1. Overview

The *Arsenal Ship* is a truly high value asset, thereby making physical security a significant concern with a reduced crew size. The *Arsenal Ship* relies mainly on passive design characteristics, augmenting traditional security practices, in the protection of the ship and its payload.²

2. Threat Assessment

- At Sea Physical Security Threat
 - Hostile boarding and small boat attacks from terrorist organizations or special operations forces.

- Inport Physical Security Threat
 - Sabotage and deliberate attack from terrorist organizations or special operations forces.

² Note: A comprehensive analysis of these threats is beyond the scope of this report.

3. Passive Design Measures

The central feature in the design for passive security is limited and controlled access. This is accomplished by minimizing the number of access points between the weatherdecks and the interior of the ship. The fore and aft superstructures each have two accesses. The doors can be remotely closed and locked from the bridge. The internal watertight doors are also remotely actuated and lockable, thus providing enhanced security and compartmentalization. The fore and aft armories are located in close proximity to the starboard accesses.

4. At Sea Security Concept and Tactics

The *Arsenal Ship* relies on tactical evasion, high freeboard, and the formation of the security alert team (SAT) to combat at sea security threats. The SAT is comprised of the non-watchstanding maintenance personnel. They immediately man the armories during security alert, and arm themselves with small arms and stinger missiles. The escort ship's five inch and 50 caliber guns provide the first layer of defense against potential small boat and helicopter attacks. The *Arsenal Ship's* rolling airframe missiles (RAM) are the second layer of attack against helicopter attacks. The final layer of defense against incoming boat and helicopter attacks is the SAT.

5. Inport Security Concept and Tactics

Inport, the *Arsenal Ship* is protected by existing shore-based security forces. TWARESES assists the security forces by monitoring interior spaces using infrared (IR) sensors. There are existing security forces in place to provide pierside and port security

at the three forward operating bases. It is beyond the scope of this report to estimate the effect of basing *Arsenal Ships* at these locations.

6. Active Design Explorations

The design team explored additional active security measures. They are used to give the SAT sufficient time to obtain weapons from the armories, and provide additional protection to support the reduced manning concept. The systems **were not** included in this overall design because they are drastically different from current security alert procedures and are untested.

a. Weapons Positions

Armored gun tubs are placed on the weatherdecks surrounding the fore and aft superstructures. The SAT mans the tubs with small arms, 50-caliber machine guns, and stinger missiles. These tubs are positioned to place grazing fire over the weatherdeck of the ship and to provide close-in fields of fire around the superstructures.

b. Border Suppression System (BSS)

A systems of command-detonated anti-personnel mines (i.e., naval variants of the M18A1 and M14 anti-personnel land mines) are placed flush with the weatherdecks (M14) and recessed into the superstructure (M18A1). These mines are positioned to cover the weatherdecks with overlapping casualty producing zones. The mines are controlled from the bridge and provide immediate response to a hostile boarding, giving the SAT time to react to the threat.

c. Intruder Detection System (IDS)

A key feature to the physical security system inside the ship is an IDS [22]. The IDS is integrated with TWARSES. An intruder is sensed by the TWARSES IR sensors. A signal is sent to the IDS. The IDS signals the damage control system (DCS) to flood the selected space with a damage control agent (i.e., CO₂).

L. WATCHSTANDING CONCEPT

The *Arsenal Ship* operates with a reduced manning concept. The crew is divided into operational watchstanders and a maintenance force. The maintenance personnel augment the normal watchstanders for all special evolution stations, and serve on damage control parties and security alert teams. Tables III-8 and III-9 show that 44 personnel are needed to man the *Arsenal Ship*. This manning reduction is accomplished by extensive use of automation, electronics and computer technologies, as well as enacting concepts that challenge current Navy customs and traditions. The crew must be highly experienced and versatile. Selected screening is required to ensure that only “top-flight” sailors are assigned to the *Arsenal Ship* program.

