IDA RESEARCH SUMMARIES

IDA STUDIES & ANALYSES FFRDC VOLUME 10, NUMBER 1, WINTER 2003

Small Combatants:

Implications for Effectiveness and Cost of Navy Surface Forces

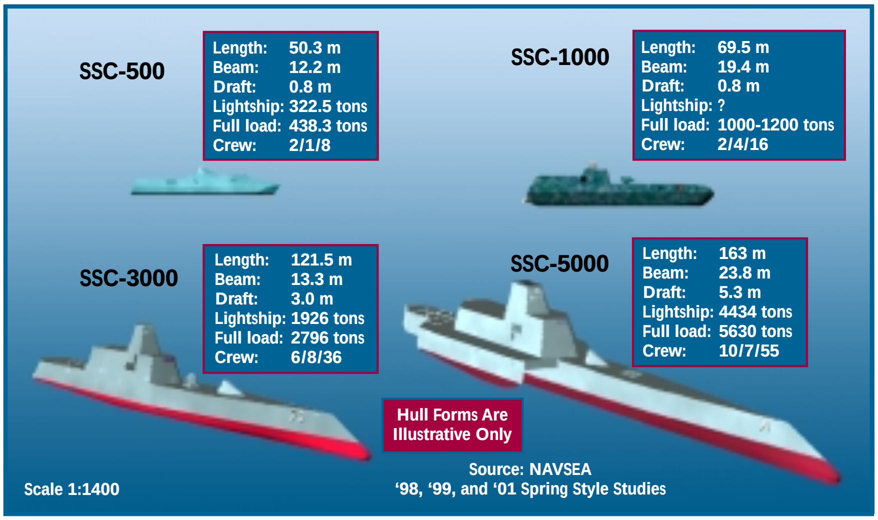
Current Navy surface combatant forces consist of a mix of relatively new highly capable ships (DDG-51 *Arleigh Burke* class destroyers and CG-52 *Ticonderoga* class cruisers) and older, less capable ships (DD-963 *Spruance* class destroyers and FFG-7 *Oliver Hazard Perry* class frigates). In anticipation of future naval surface combatant force needs, the Navy is procuring additional DDG-51s and developing the new DDX class of destroyers. The Department's recent Quadrennial Defense Review questioned whether even more ships might be required in the future and proposed considering smaller, lower-cost ships as a way to meet those needs at affordable cost. In response, the Navy developed a new class of small combatants designated the Littoral Combat Ship (LCS), which will be much smaller than the new DDX destroyer but will take advantage of many of the technologies and systems being developed for the larger ship.

While early development of the LCS is now under way, only limited assessments have been made of the costs and potential combat capabilities of such ships or of the mixed surface combatant forces that would result from their use. OSD therefore asked IDA to assess the potential effectiveness, in both combat and presence missions, and the costs of alternative mixes of smaller, lower-cost surface combatants and existing and planned surface combatants, the DDG-51, CG-52, and DDX class ships.

Study Approach

IDA's study first reviewed the characteristics and employment concepts for a variety of small combatants employed by the Navy, the Coast Guard, or selected foreign navies. The study team also examined a diverse set of conceptual small combatant designs developed by the Naval Sea Systems Command. Based on this review, IDA identified a set of alternative small-ship designs (Figure 1), configured them with combat payloads (both multi-mission and modularized), characterized their performance, and estimated their costs. Equal-cost mixes of DDXs and small combatants were then developed by reducing the planned DDX force by 5, 10, or 15 ships and using the funds intended for those ships to buy small combatants instead. The number of small ships bought varied with the number of DDXs foregone and the relative costs of the two ships (i.e., the DDX and the specific small combatant design under consideration). These ships were then assigned to standard naval formations and the effectiveness of those formations estimated using assessment tools appropriate for the warfare task under consideration.

The study considered all of the principal warfare tasks likely to be assigned to surface combatants, including the anti-access threats of sea mines, submarines, and surface ships, as well as theater and antiship missiles. The study also assessed the relative effectiveness of the ship alternatives when used for precision strike and fire support, presence, and homeland security. The effectiveness assessments took into account the relevant warfare capabilities of the ships included in the mix as well as those of the threat systems encountered. The results of these assessments were then used to establish the relative cost-effectiveness of the alternative forces.



Source: NAVSEA
'98, '99, and '01 Spring Style Studies

Figure 1. Ship Sizes Considered.

Small Combatant Options

The study considered a range of small combatant sizes (Figure 1), from a 5,000-ton frigate-sized ship to a 500-ton patrol-boat-sized ship. Configurations with full load displacements of 1,000 and 3,000 metric tons served as intermediate points. To distinguish between the Navy's LCS and the notional small combatants examined in this assessment, IDA identified its small surface combatant designs as SSC-X where X denotes the ship's full load displacement. As indicated in the figure, the hull forms shown for the designs are illustrative and correspond to Navy designs of the approximate size. A range of hull forms would be possible for a small combatant at each of the sizes indicated, with the preferred choice depending on such factors as desired speed, seakeeping capabilities, endurance, and combat payload. While determining the exact size, shape, and layout of the small combatant was considered beyond the scope of this study, that task will obviously be the focus of considerable effort in the Navy's development of its LCS design.

Key Results

The study's effectiveness assessments showed that the addition of small combatants to the Navy's standard combat formations reduced ship losses versus diesel submarines, small boats, sea

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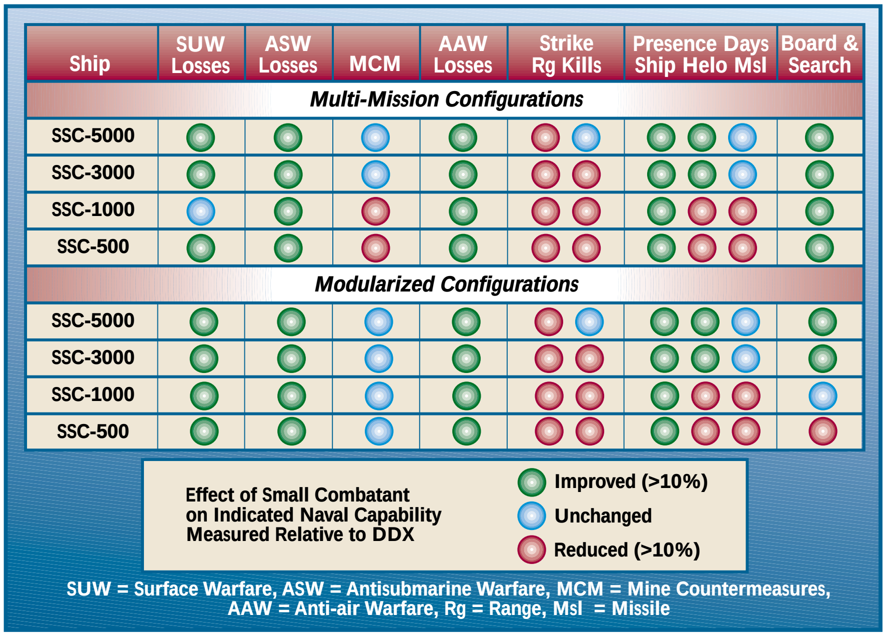


Ship	SUW Losses	ASW Losses	MCM	AAW Losses	Strike Rg Kills	Presence Days Ship Helo Msl	Board & Search
Multi-Mission Configurations							
SSC-5000	🟢	🟢	🔵	🟢	🔴 🔵	🟢 🟢 🔵	🟢
SSC-3000	🟢	🟢	🔵	🟢	🔴 🔴	🟢 🟢 🔵	🟢
SSC-1000	🔵	🟢	🔴	🟢	🔴 🔴	🟢 🔴 🔴	🟢
SSC-500	🟢	🟢	🔴	🟢	🔴 🔴	🟢 🔴 🔴	🟢
Modularized Configurations							
SSC-5000	🟢	🟢	🔵	🟢	🔴 🔵	🟢 🟢 🔵	🟢
SSC-3000	🟢	🟢	🔵	🟢	🔴 🔴	🟢 🟢 🔵	🟢
SSC-1000	🟢	🟢	🔵	🟢	🔴 🔴	🟢 🔴 🔴	🔵
SSC-500	🟢	🟢	🔵	🟢	🔴 🔴	🟢 🔴 🔴	🔴

Effect of Small Combatant on Indicated Naval Capability Measured Relative to DDX

🟢 Improved (>10%)
🔵 Unchanged
🔴 Reduced (>10%)

SUW = Surface Warfare, ASW = Antisubmarine Warfare, MCM = Mine Countermeasures, AAW = Anti-air Warfare, Rg = Range, Msl = Missile

Figure 2. Overall Assessment

mines, and anti-ship missiles. However, because these ships are too small to accommodate the new 155-mm Advanced Gun System planned for the DDX, replacing some DDXs with small combatants would diminish the Navy's precision strike and fire support capabilities. To the extent that such capabilities are considered essential, the study concluded that the most effective overall force would have to include DDXs as well as small combatants. Although the study results depend on the specific combat systems assumed to be available to the small combatants and thus cannot be broadly applied, they do suggest that the addition of appropriately configured small combatant designs could yield improvements in effectiveness, with the amount of improvement depending on the specific combat systems included on those ships and the missions performed.

The assessment also showed that equipping the small combatants with modularized sensor and weapon payloads with enhanced capabilities in a specific warfare area was more effective than the multi-mission configuration that included less extensive capability in several warfare areas. Realizing such a benefit in practice, however, was considered problematical since it would require Navy strike group commanders to have sufficient advance knowledge of the specific threats to be encountered that the small combatants could be configured with the appropriate combat module.

From a more detailed perspective, we found that the two smallest small combatant configurations—those at 500 and 1,000 tons—provided less capability than the larger versions (see Figure 2). Because these ships lacked both gun and helicopter, they provided reduced capability in mine countermeasures and presence as well as precision strike. The 500- and 1,000-ton small combatants would have to be modularized with a helicopter flight deck to improving their mine countermeasure capability. However, since ships of this size would be too small to accommodate even a 5-inch gun and its magazine, they could only provide limited precision-strike capability. And, although small combatants of these sizes offer the possibility of a larger fleet, their small combat payloads would likely limit their presence contribution.

In contrast, the 3,000- and 5,000-ton small combatant were found to provide greater warfare, presence, and homeland defense capabilities than were available from equal-cost forces of the DDX or the other small combatant configurations considered. Formations that included the 3,000- or 5,000-ton small combatant in lieu of the DDX provided greater surface-warfare, antisubmarine-warfare, antiship-missile-defense, and homeland-defense capabilities than did formations that employed the DDX. Mine countermeasure and presence capabilities with the 3,000- and 5,000-ton small combatant were at least equal to the levels attained by formations that included the DDX. However, because these ships lack the 155-mm Advanced Gun System available on the DDX, they provide less precision strike and fire support capability. Thus, the most effective overall force would include DDXs as well as small combatants.

Testing the Navy Marine Corps Intranet

The Navy Marine Corps Intranet (NMCI) is an initiative to purchase industry standard information technology (IT) services via a commercial contract and create a single unified network where many disparate systems now exist. In particular, the NMCI is intended to consolidate over 300 separate, shore-based Navy and Marine Corps computer systems involving some 400,000 desktop machines spread across the United States, Puerto Rico, Iceland, Cuba, and Japan. The cost of the NMCI contract is estimated at $4 billion over 5 years ($7 billion with an additional 3-year option), which makes it the largest IT program in the Department of Defense's history.

The existing shore-based IT infrastructure has a network infrastructure developed with few enterprise-wide standards, so network and system characteristics vary widely from one installation to another. It also has approximately 100,000 DoN legacy applications, many of which are either redundant or obsolete, and has a multiplicity of commercial contractors that provide information transfer between these many sites. These factors have made it extremely difficult for Department of the Navy (DoN) to manage its IT infrastructure efficiently and to maintain the level of interoperability and security necessary to conduct operations. The NMCI will address these problems and provide the Navy and Marine Corps secure, universal access to integrated voice, video, and data communications and information services (Figures 1 and 2).

IDA's Role

The testing approach to the initial phase of the NMCI differs from a traditional acquisition in that developmental testing, normally performed when DoD procures a new system, has been replaced by Contractor Test and Evaluation (CT&E), which in addition to government oversight also requires an independent party to assess the process. The Assistant Secretary of Defense for Command, Control, Communications, and Intelligence (ASD (C3I)) asked IDA to assess the NMCI test and evaluation activities. IDA was specifically tasked to assess the adequacy of the testing, to include operational as well as business process testing, and to identify areas of risk. This phase was completed in late Spring 2002. Throughout the period, DoN staff worked with the IDA team providing information necessary for the assessment.

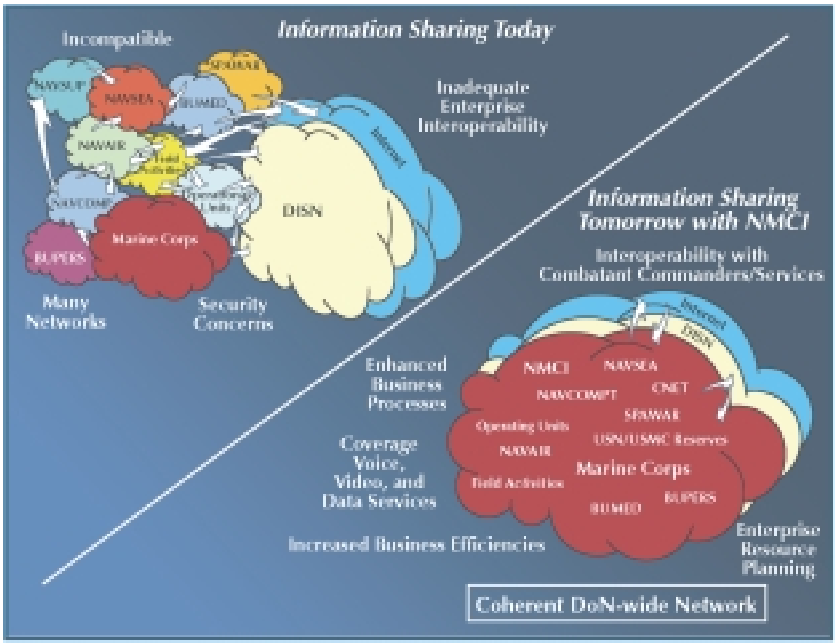


Figure 1. Navy-Marine Corps Information Sharing before and after NMCI

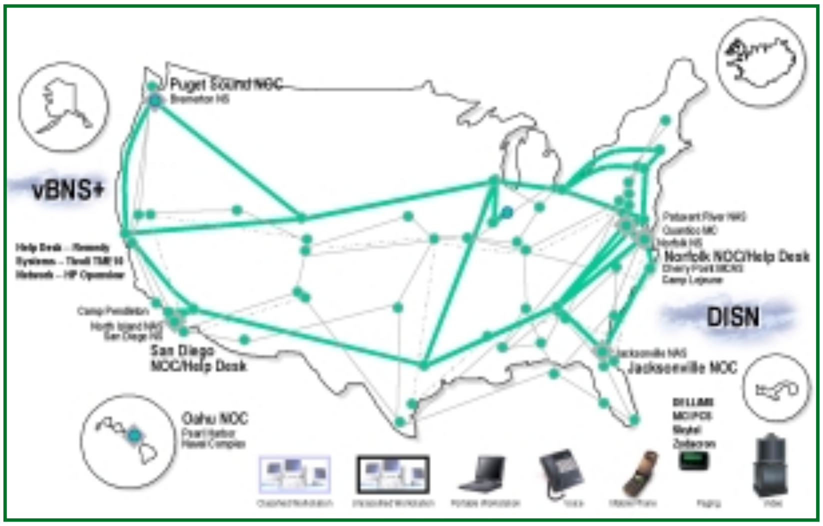


Figure 2. NMCI Network Infrastructure

An Innovative Acquisition Approach

Unlike a traditional DoD acquisition program in which a system is purchased and the government assumes configuration control and life cycle maintenance responsibility, the NMCI contract is for IT services and is based on a commercial model of service level agreements (SLAs). The contractor, not the government, owns and manages the IT infrastructure. Hardware, software, and connectivity are provided as part of the purchased service. Additionally, the services provided can be changed to meet the changing needs of the Navy and Marine Corps and take full advantage of technology advancements over the life of the contract.

SLAs define the services and performance thresholds necessary to support DoN operational requirements, and each SLA is linked to critical operational effectiveness and suitability requirements. For this contract, the approximately 190 SLA performance categories refer to such items as information assurance, network performance, customer service and support, interoperability, and operational availability. These categories are monitored throughout the life of the contract, and the vendor is provided incentives to meet them and to optimize network performance, and is penalized if they are not met.

NMCI Implementation and Testing Approach

Implementation of the NMCI follows an event-driven schedule that ties meeting performance thresholds to releasing blocks of seat orders, where seats are various configurations of user workstations with supporting infrastructure. The ASD (C3I), in his role as the DoD Chief Information Office, and the Principle Deputy Undersecretary of Defense (Acquisition, Technology & Logistics) are the decision-making authorities that oversee the following major test decision points:

- Decision Point 1 (May 2002). If adequate performance is demonstrated during CT&E, DoN will be authorized to order an additional 100,000 seats beyond the originally authorized 60,000 seats.
- Decision Point 2 (estimated November 2002). If 20,000 NMCI seats meet SLA performance levels, DoN will be authorized to order an additional 150,000 seats.
- Decision Point 3 (estimated June 2003). A successful operational evaluation will provide an opportunity to assess and refine the network and services.
- Decision Point 4 (estimated June 2004). A successful stress test, performed when 85 percent of the planned NMCI is in place, will provide an opportunity to assess and refine the network and services.

The test concept is to first build and test a small portion of the planned system that represents that system in terms of geographical coverage, seat technology, and operational communities. Tests attempt to represent the entirety of business processes, including multiple users and numerous applications (e.g., administrative, maintenance, operations), and to evaluate NMCI's ability to meet the performance specified by SLAs, as well as verify that SLAs are being measured correctly. The testing covered by this article included CT&E and independent testing at three DoN sites (Naval Air Facility Washington, Naval Air Station Lemoore, CA, and Naval Air Systems Command, Patuxent River, MD). Later testing will include operational evaluations, stress testing, and related independent testing, and will involve additional test sites.

IDA's assessment team consisted of experts in a number of information systems and telecommunications disciplines. Over several months, the team interviewed DoD personnel and the NMCI contractor, visited Navy test sites and locations where the contractor implemented similar systems in the past, and exhaustively evaluated test plans and results.

Results of IDA's Work

To support Decision Point 1, IDA identified the areas of risk following the CT&E period. Eleven areas were identified and their risk levels assessed (Table 1). Because procurement decisions were being based on test results from a much smaller version of the planned NMCI, it was important that the test system be representative of the planned system and that results could be interpreted to scale to the larger system. Consequently, many of the risks identified below relate to representativeness and scalability of the test results. Many of the recommendations derived from Table 1 were accepted by the DoN leadership and implemented during the continuing testing.

We found that for such a large and complex system, the most critical program risks relate to its implementation process.

Significant Risk Areas

Accommodating Legacy Applications: DoN needs to reduce the application population size from 100,000 to a much smaller number on the order of 20,000 or less, and bring this remainder under configuration control. Many of these applications are duplicative versions or disparate applications of the same functionality. Additionally, all applications have to be certified to ensure they do

Risk Area	Risk Issue	Risk Level
1. User Mission Support	*Inadequate functional support to allow users to accomplish their missions.*	*Low-Moderate*
2. Interaction with Operational Forces	*Inability of deployed forces to utilize shore-based NMCI capabilities.*	*Low-Moderate*
3. Interoperability	*Inability to exchange information among users and applications.*	*Low-Moderate*
4. SLA Measurement	*Inability to fully monitor the performance of the NMCI.*	*Low*
5. Accommodating Legacy Applications	*Inadequate rate of rationalization/certification of legacy applications to meet NMCI deployment schedule.*	*High*
6. Enterprise Management System	*Inability to achieve the necessary automated management of the NMCI system.*	*Moderate*
7. Help Desk Procedures	*Inability to handle the large number of NMCI users.*	*Low*
8. Network Performance	*Inability to accommodate the network traffic of the full set of NMCI users.*	*Low*
9. Active Directory Performance	*Inability to adequately provide directory services to users.*	*Low*
10 Information Assurance	*Inability to protect and maintain uninhibited access to information.*	*Low-Moderate*
11. Roll-Out Process	*Process will be inadequate for deploying a system of NMCI's size and complexity.*	*Moderate-High*

Table 1. IDA Risk Assessment of the NMCI, May 2002

not interfere with other applications and that they operate in accordance with accepted security policies. During the CT&E test period, it was not clear the demonstrated rate of certification could support the NMCI deployment schedule. Non-certified applications would continue to be supported, but on separate systems isolated from the NMCI network. This would cause duplication of network infrastructure and increase the vendor's costs. For risk management, IDA recommended that the rationalization process continue to be matured, the adequacy of the rationalization and certification enhancements be assessed to meet the schedule proposed for the next 100,000 seats, and senior-level Navy commitment be maintained.

Enterprise Management System: An effective Enterprise Management System (EMS) enables the contractor to manage a large and complex network such as NMCI, and to automatically capture and report SLA performance data to the government. It provides a single, integrated system-of-systems that facilitates strong, centralized configuration management and change control, and allows help desk and network operations personnel to troubleshoot problems and respond quickly to customer requirements. During testing, the delivery and integration of EMS was continually delayed, and as the network grew, many of the management functions remained manual or semi-automated. To manage risk, IDA therefore recommended that this area be given increased leadership attention and monitoring by the Navy. IDA also recommended that the performance data being gathered by EMS and reported by the contractor to the government be independently verified throughout the life of the contract.

Seat Roll-Out Process: For a system of NMCI's size and complexity, the seat roll-out process is critical to meeting the schedule for the system's deployment. During the earlier portion of the test period the process lacked proper management oversight and, as a result, suffered numerous problems. For example, ineffective coordination of customers for delivery of desktops caused high unavailability rates (25-50 percent), and lack of a product assurance process caused significant rework. As a result, the seat roll-out rate remained well below the desired 100 seat-per-day-per-site rate. For risk management, IDA recommended that the Navy quantitatively track the effectiveness of its roll-out procedures as NMCI deployment proceeds and quantitatively monitor quality assurance enhancements brought about by the contractor's enterprise testing strategy.

Continuing Work

The finding at Decision Point 1 was that adequate progress had been made and that the risks were well enough understood to authorize DoN to order an additional 150,000 seats. Since then, the contractor has been deploying additional seats and supporting infrastructure. The DoN has been continuing with program oversight and developing more extensive tests in preparation for Decision Point 2. IDA will continue its work, and for the period leading to Decision Point 2 will focus its assessment in the following areas:

- Review the results of the SLA measurements on the 20,000-seat configuration to assess the NMCI performance demonstrated.
- Continue to characterize the scalability of the NMCI technical solution demonstrated through test, fielding, and performance measurements.
- Assess the NMCI test plan being developed and its execution as applied to NMCI installation and maintenance.
- Assess preliminary plans for the NMCI stress test developed by the Navy and the contractor.

It will be interesting to see what new issues emerge as the deployed NMCI grows in size, and whether implementation issues continue to dominate risk or if performance factors become more prominent.

Cost Analysis for the Airborne Electronic Attack Analysis of Alternatives

Today, the Airborne Electronic Attack mission is being conducted primarily by one aircraft, the EA-6B Prowler, which is used jointly by the Navy, Marine Corps, and Air Force. The EA-6B has evolved to its present capabilities over three decades of improvements, from its Initial Operational Capability in 1971 to the upgrade it is currently undergoing to an Improved Capability III, which is scheduled to be available in FY2005. This latest modification will improve certain receiver, connectivity, communications and countermeasures features of the aircraft – which will result in a significant increase in warfighting capabilities.

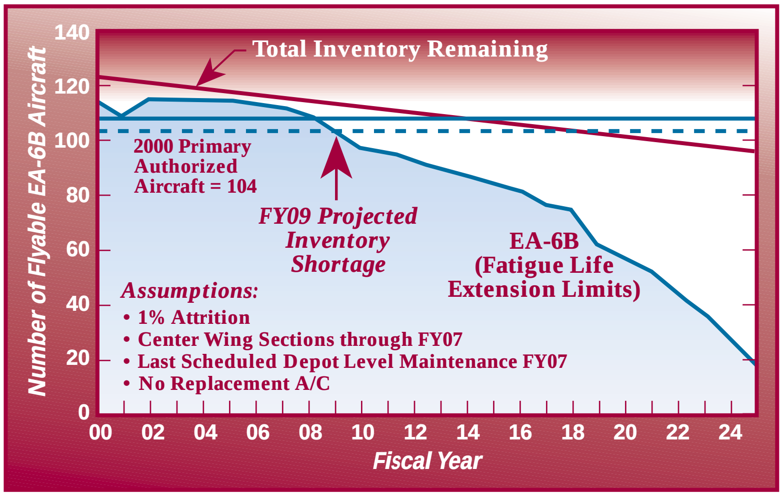


Figure 1. Current EA-6B Fleet

The Problem

EA-6B aircraft are flown a great deal in operational missions around the world, and are exceeding the originally planned usage rates. Thus, the aircraft are wearing out more rapidly than predicted and will need to be replaced sooner than previously planned. Figure†1 shows the FY2002 snapshot of the fleet falling below the planned operational number (primary aircraft authorized) before FY2010.

The Department of Defense therefore initiated the Airborne Electronic Attack Analysis of Alternatives (AEA AoA) to examine potential options for replacing the aging EA-6B fleet beginning in 2010. The AEA AoA was begun in February 2000, and delivered its report in December 2001.

Organization of the AEA AoA

An independent study team was formed, specific working integrated product teams (WIPT) were established, and membership selected from the OSD, the Joint Staff, the Services, and Federally Funded Research and Development Centers (Figure 2). Over 180 people participated in the analysis. IDA co-led the Cost WIPT with Naval Air Systems Command and was represented on the Technical WIPT. The Cost WIPT also received counsel and oversight from an Independent Senior Review Group that comprised members from cost analysis organizations in the Navy, Air Force, and at IDA's Cost Analysis and Research Division.

Analysis Process

The Services submitted operational assumptions, vignettes, and mission plans that were used within the context of major theater war

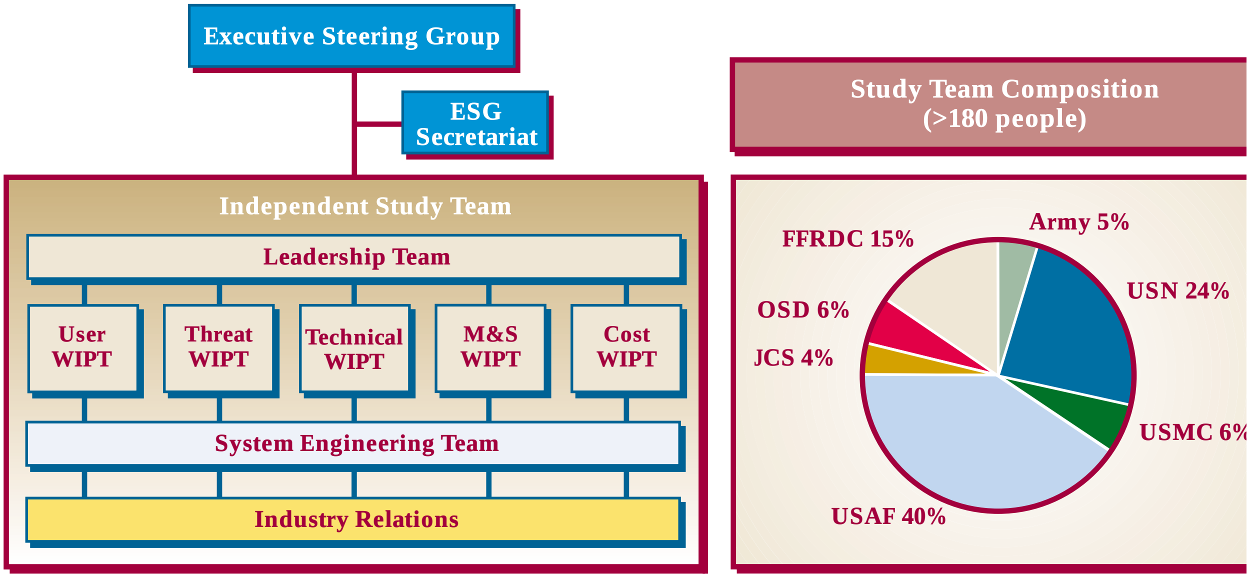


Figure 2. Airborne Electronic Attack Analysis of Alternatives Study Team Organization and Oversight

scenarios to assess AEA contributions in denying and / or degrading enemy air defenses. After developing the tradespace, the AEA AoA team applied physics and engineering analyses to examine how the requisite AEA capabilities could be hosted on the various alternatives and then modeling and simulation to assess their warfighting capabilities. The team then developed alternative life-cycle cost comparisons for a significant number of alternative forces (Figure 3).

Through the execution of this process, the study concluded that two components; a recoverable core component and a recoverable or expendable stand-in component, are needed to provide complete AEA capabilities against the evolving air defense threat in the broad range of missions identified by the Services (Figure 4).

Cost Analysis Options

The wide variety of system alternatives examined (Figure 5) – including fighters, bombers, and commercial aircraft – required that the Cost WIPT set up a detailed set of ground rules and assumptions for each grouping of systems. At the outset, the team determined that the cost

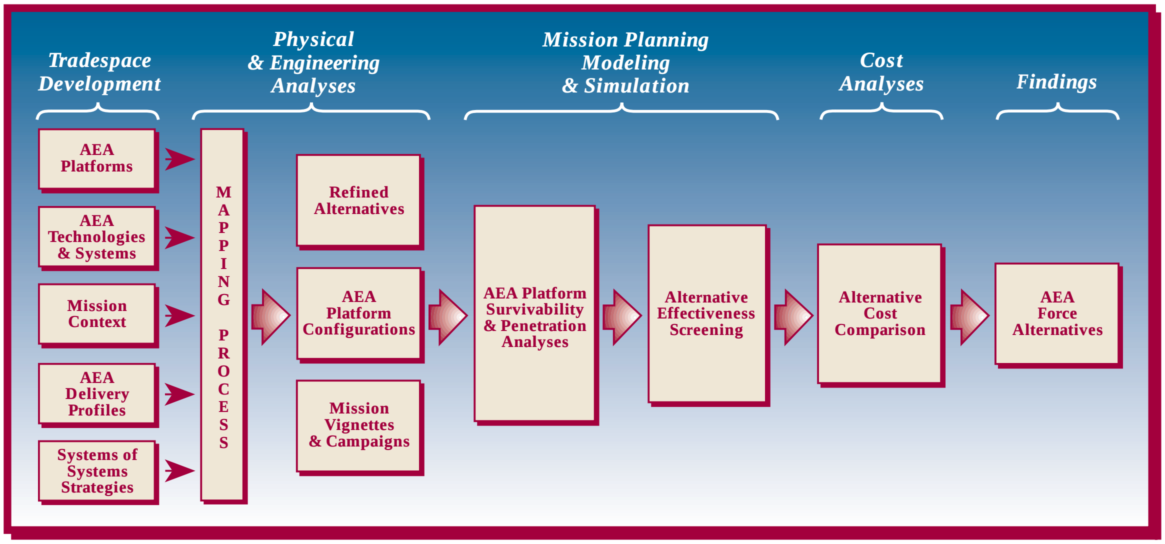


Figure 3. Airborne Electronic Attack Analysis of Alternatives Analysis Flow

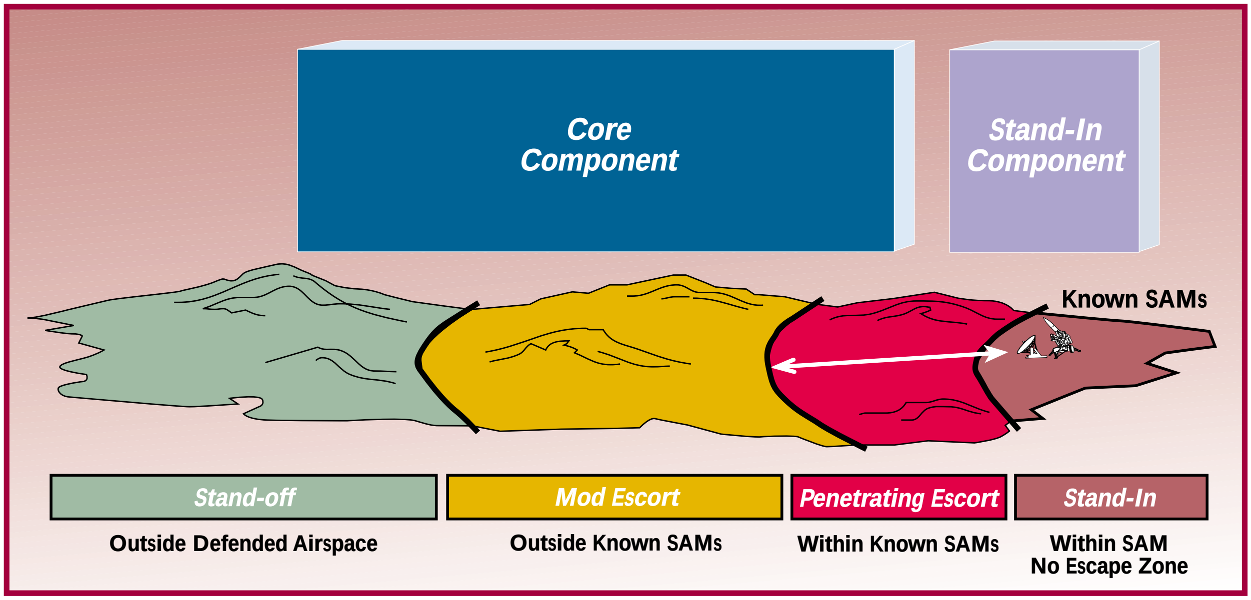


Figure 4. Airborne Electronic Attack Components

estimating process would provide relative cost estimates and that projections of total costs should not be viewed as "budget-quality" cost estimates.

For each alternative, a lifecycle cost estimate was prepared that consisted of system development and demonstration, procurement, and operations and support cost elements as required for each system viewed as a stand-alone program.

Results

The study's proposed solutions were organized into six broad alternatives; for each, several vehicle or system options could provide the

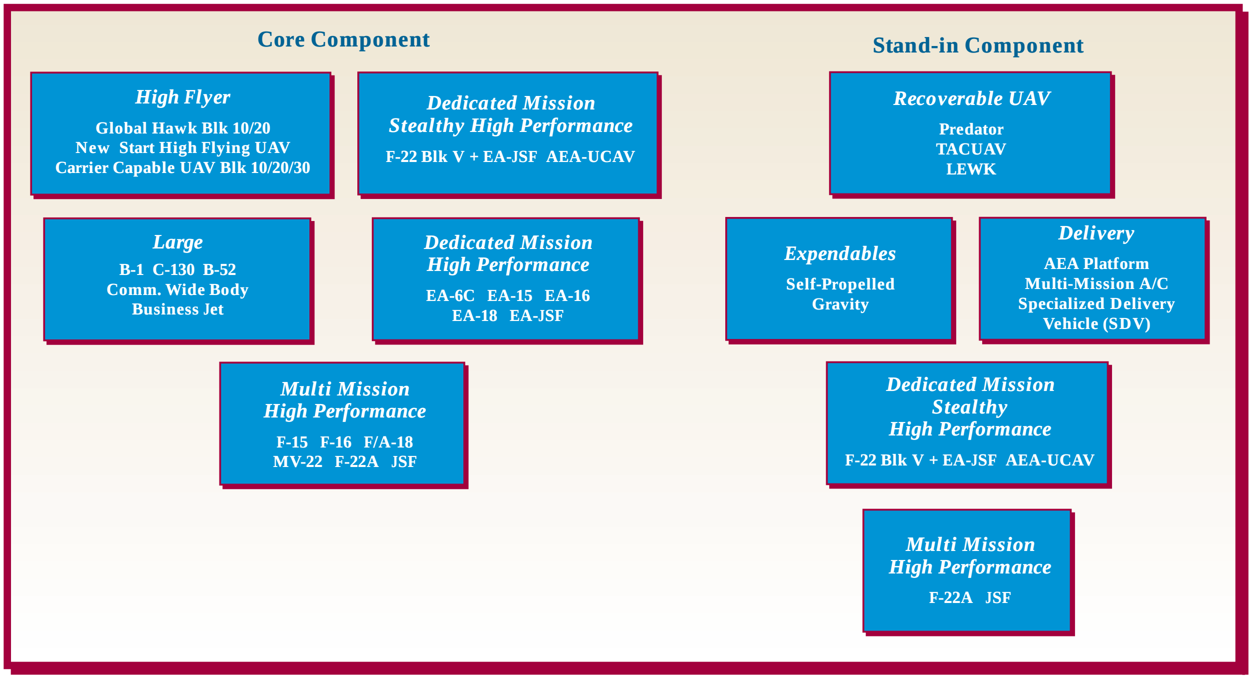
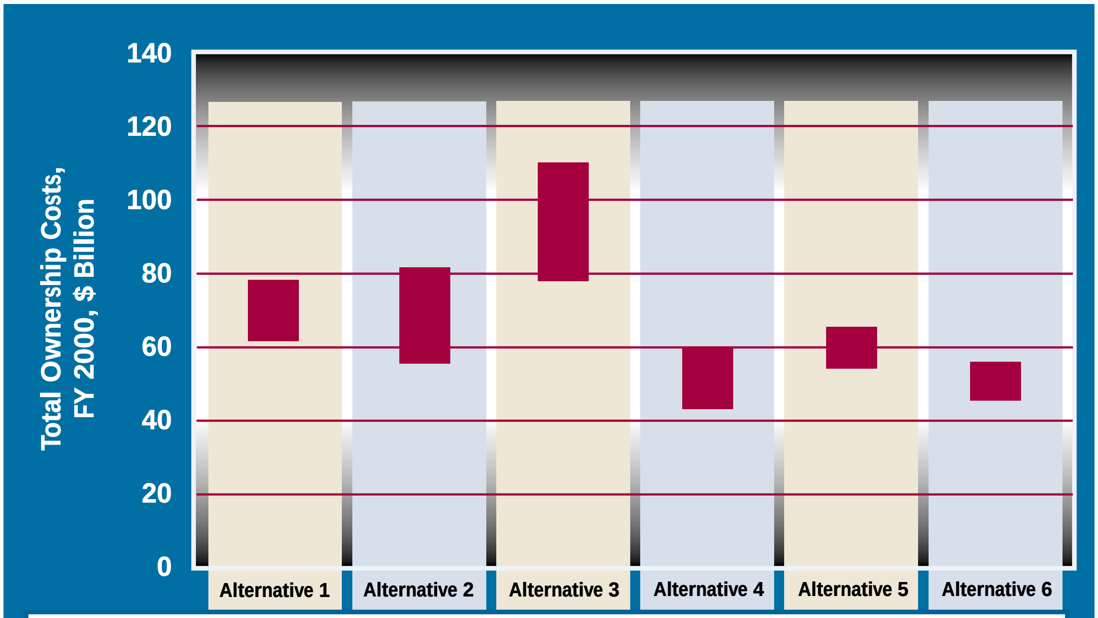


Figure 5. Airborne Electronic Attack Systems Examined



	Capabality	Platform/System Combinations					
Core	Modified Escort	Dedicated High Performance	Large Aircraft	Legacy Bomber	High Flyer	High Flyer	New Start A/C High Flyer
Stand-in	Penetrating Escort			Stealthy High Performance	Stand-in Delivery Platform	Multi-mission A/C	
	Non-escort Stand-in	Expendable/ Recoverable	Expendable/ Recoverable	Expendable/ Recoverable	Expendable/ Recoverable		New Start A/C High Flyer

Figure 6. Costs of Alternative Airborne Electronic Attack Forces

warfighting capability thresholds specified in the OSD guidance. Total ownership costs, however, were estimated for combinations of specific weapons systems, with resulting costs of sub-options presented as a range for each alternative

The costs of alternative AEA forces were presented as ranges defined by sub-alternatives consisting of specific platform and system combinations. For example, in Alternative 1 in Figure 6 above, dedicated high performance aircraft employed for modified escort could be "dedicated" EA derivatives of F/A-18, F-16, Joint Strike Fighter, or newly built EA-6 aircraft, each manned, trained, and equipped to perform AEA as their primary mission with specialized aircraft. These possibilities are reflected in the range of costs for Alternative 1.

Based on IDA and Naval Air Systems Command cost estimates and the study team's effectiveness calculations, the study recommended that the all multi-mission solutions and all expendable alternatives be dropped from consideration. The study recommended a small number of acceptable solutions, with preferred alternatives split into combinations of proposed vehicles and electronic warfare systems.

The study concluded that AEA will be required for the foreseeable future and will contribute significantly to providing dominant air superiority against projected enemy air defenses when used in concert with complementary capabilities such as air vehicle electronic self protection, threat physical destruction, low observable technology, information operations, and lethal suppression/ destruction of enemy air defenses. The study team assessed that no combinations of new technologies, systems, or concept(s) of operations could substitute effectively for AEA capabilities.

Surface Ship Radars

Surface ship radars provide situation awareness and targeting for Navy anti-air warfare (AAW) operations. With many Naval missions today focused in littoral waters, the environment for radar operations is more stressful than in the open ocean. Close to shore there are often more objects to detect, identify, and track, and the presence of land produces high levels of clutter. Moreover, the littoral battle space is compressed, and radars must support responsive actions against threats that include short- and long-range ballistic missiles, and low flying, low radar-cross-section, highly maneuverable anti-ship missiles. To address these challenges, the Navy plans to improve radars on existing ships and incorporate new radar technologies into next generation ships.

The Office of the Secretary of Defense asked IDA to examine the Navy's plans for modernizing surface ship radars – to compare the cost-effectiveness of alternative systems, to assess critical radar mission requirements, and to evaluate advanced radar technologies. Also, we were asked to identify key decision points on the radar development-to-procurement timeline and assess whether new radars will be ready in time to meet planned ship construction schedules.

Of current interest to DoD is the choice of radar systems for the CVN-77 aircraft carrier. CVN-77 is the 10th and final ship of the *Nimitz* class and will serve as the transition ship to a new class of aircraft carriers. CVN-77 was designed to be equipped with a new integrated warfare system, including a new radar suite. The original plan was to install a state-of-the-art radar system consisting of the SPY-3 Multi-Function Radar (MFR) and Volume Search Radar (VSR) for ship self-defense and air control (Figures 1 and 2).

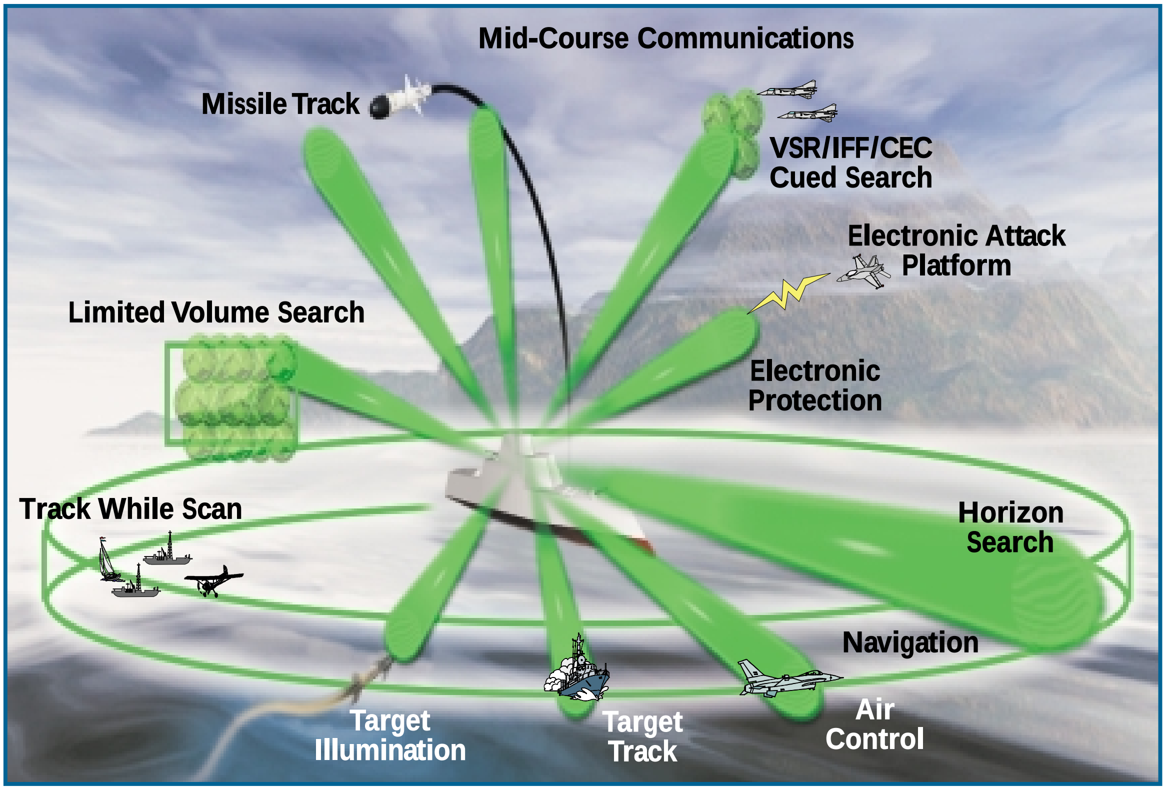


Figure 1. Multi-Function Radar (SPY-3)

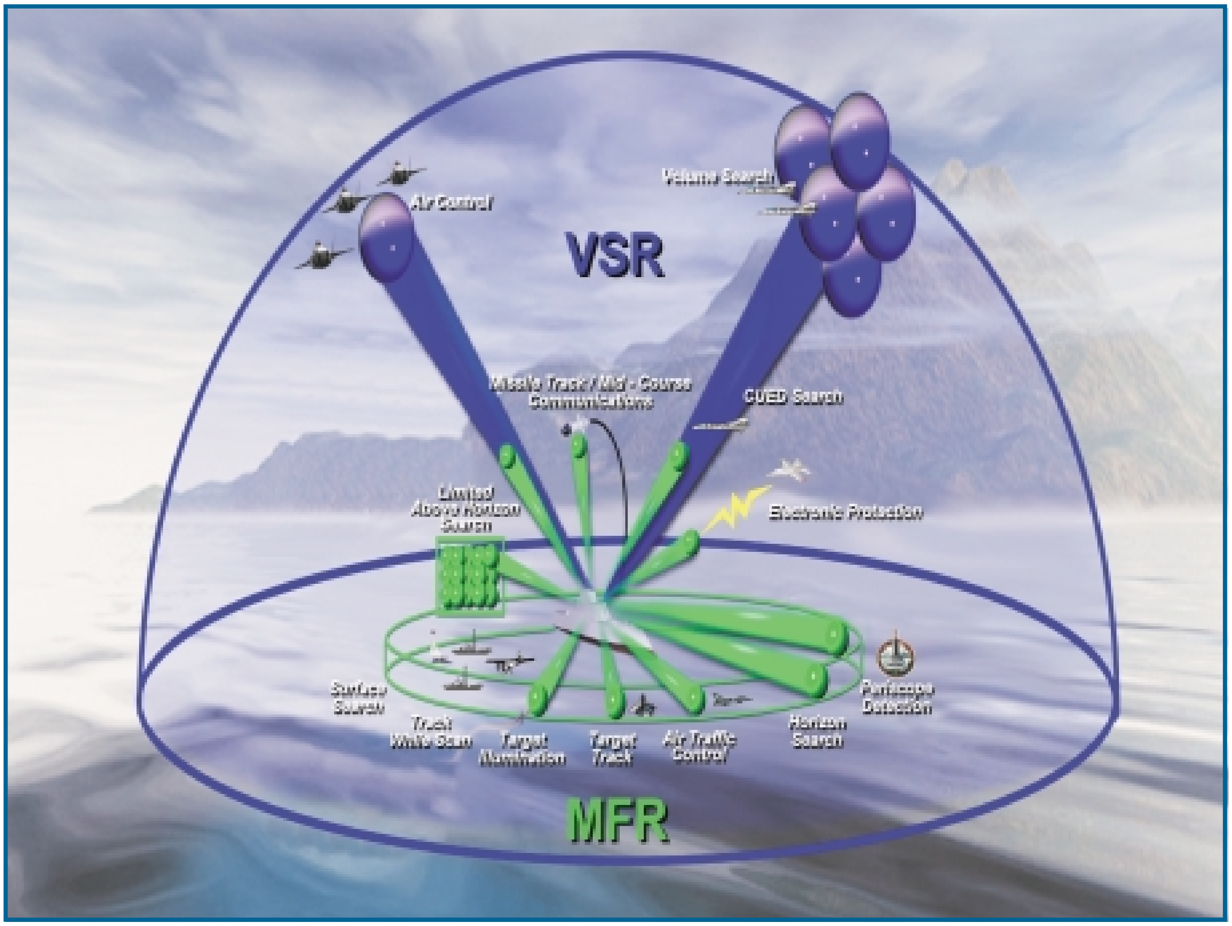


Figure 2. Multi-Function Radar/Volume Search Radar Suite Functionality

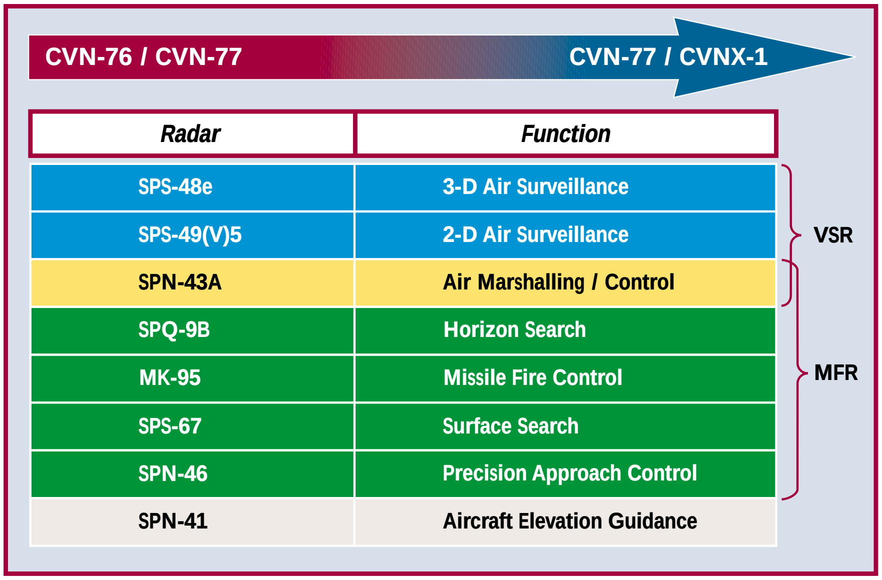
However, due to cost and schedule considerations, the Navy is considering installing legacy radars (SPS-48, SPS-49, SPN-43, SPQ-9, MK-95, SPS-67, and SPN-46) instead of the MFR / VSR.

Other current issues include selecting a radar for the LPD-17 amphibious transport and deciding how to upgrade existing radar systems within the Cruiser Conversion Program. For the longer term, DoD is examining radar and weapon alternatives for a new surface combatant called the Littoral Combat Ship (LCS).

Preliminary Findings

IDA has focused recently on the programmatic risks of the MFR and VSR radars for the CVN-77. Figure 3 lists the principal legacy radars on current aircraft carriers, the functions they perform, and the functions that will be served by the MFR and VSR.

The major MFR / VSR programmatic risks resulted from the Navy's decision to fund the MFR / VSR development out of the former DD-21 destroyer program. In FY 1999, the MFR was awarded to Raytheon as a separate contract, while the VSR continued its development under the DD-21 program. The original plan was to award the DD-21 contract in FY 2001, but the DD-21 program suffered a number of delays and finally was terminated in FY 2002. The DD-21 program was restructured into the DD-X program with additional ship design uncertainties. Delays in the DD-21 program and the subsequent restructuring caused significant delays in the VSR development and inevitably the integration of MFR with VSR. The fate of the MFR / VSR installation on the CVN-77 is now tied to the DD-X program resulting in considerable risk for meeting the CVN-77 schedule. The CVN-77 must meet a 2007 delivery date and that translates into required delivery date of 2005 for its radar suite. Our



Radar	Function
SPS-48e	3-D Air Surveillance
SPS-49(V)5	2-D Air Surveillance
SPN-43A	Air Marshalling / Control
SPQ-9B	Horizon Search
MK-95	Missile Fire Control
SPS-67	Surface Search
SPN-46	Precision Approach Control
SPN-41	Aircraft Elevation Guidance

Figure 3. Consolidation of Aircraft Carrier Radars and Functions

study determined that the VSR is not likely to meet the CVN-77 schedule requirements given its current pace of development. Furthermore, a decision must be made by early 2003 in order to affect CVN-77 island design to accommodate legacy radar alternatives. The decision date is based on considerations of hardware and software developments, detailed design and construction, system procurements, and materiel lead times for the island and legacy radars.

There are a limited number of options if the Navy forgoes the installation of MFR/VSR radar suite on the CVN-77:

1. Install legacy radars.
2. Install MFR and resort to legacy radars for VSR related functions.
3. Install a SPY-1D/F or variant Aegis Radar.
4. Slip CVN-77 schedule to wait on MFR/VSR availability.

Based on our assessment, options one and two are risky due to lengthy delays in acquiring legacy radars that can perform VSR functions; the SPS-48E, SPS-49, and SPN-43 are all out of production. Although radars can be salvaged from decommissioned ships, some have already been ear marked for new amphibious ships. The legacy radar options also carry significant cost risks if future back-fitting of CVN-77 with MFR/VSR or other modern radar suites is contemplated.

According to the Navy, the MFR option will contribute to CVN-77 cost growth since the CVN-77 program will have to pay the costs of accelerating the MFR testing and evaluation. The Navy also claims option three will cause unacceptable cost growth to the CVN-77 program. The Navy considers any schedule delays to the CVN-77 program as unacceptable, thus ruling out option four. For these reasons, the Navy is leaning toward an all legacy radar suite for the CVN-77. To retain the future option of back-fitting the CVN-77 with a modern radar suite, the Navy has proposed a flexible island design that can accommodate both modern and legacy radars.

IDA is continuing to examine the pros and cons of the options, collecting additional data, and carrying out analyses to support OSD's review of the program.

Ship Air Defense Model

Over the past several years, IDA has been developing the Surface Ship Air Defense Model (SSADM), a constructive simulation of Naval theater air and missile defense at the force-on-force level. SSADM models the attrition of cruise missiles (CM), aircraft, tactical ballistic missiles (TBM), surface ships, and land-based targets during waves of CM and / or TBM attacks. SSADM also models the performance of the Navy's cooperative engagement capability. SSADM's fast run-time, flexible level of data input, clear analytical construct, and emphasis on analytical measures-of-merit rather than virtual realism distinguish it from other recently developed force-on-force models.

Using SSADM, the analytical process begins with a scenario, including a specific AAW mission for the task force. From the scenario and mission, alternative task force composition and structure may be postulated. Threat level and characteristics are also developed. Next, the weapon and sensor configuration of each ship are specified along with other relevant ship characteristics, such as signature. A typical measure of effectiveness is the probability that every threat to the task force is defeated. SSADM also provides a number of other measures of effectiveness such as individual weapons effectiveness, weapons expenditure, and statistical distribution of ships killed in an attack. Although the example below illustrates an assessment at the task force level, SSADM may also be used to examine ship formation and systems configuration alternatives.

Currently, IDA is updating the SSADM database. The update will reflect new estimates of threat and defensive system performance characteristics. In addition, the model's algorithms are being enhanced to reflect more accurately the physical processes (e.g., intercept geometry) and enemy tactics (e.g., stream raids) that could occur during a battle. Legacy constructs within SSADM will be replaced with higher fidelity algorithms that can take advantage of the greatly improved desktop computational power that was not available just several years ago.

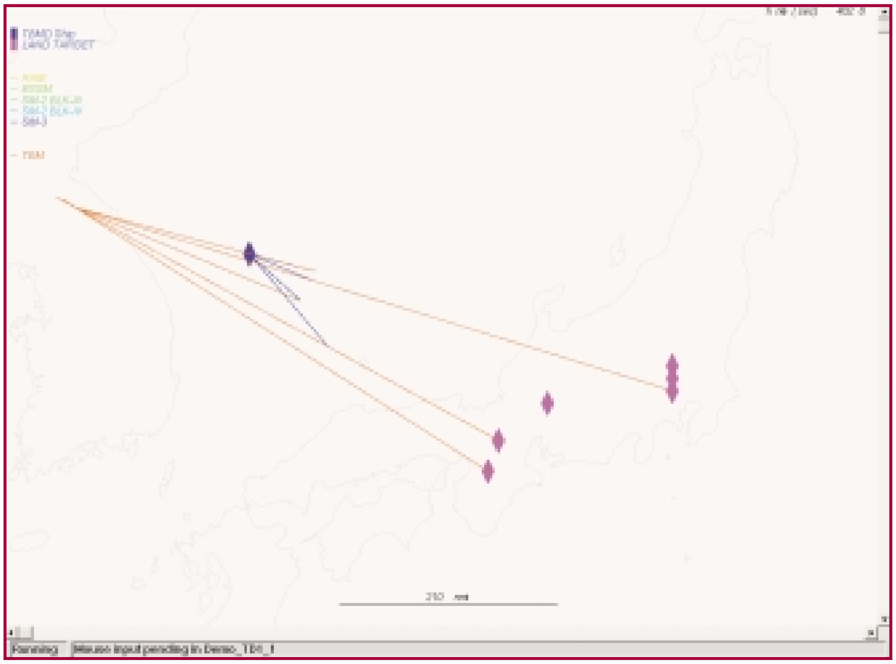


Figure 1. SSADM Performing Tactical Ballistic Missile Defense

COATS: A New Approach to Submarine Testing

The Navy is looking for a new nuclear attack submarine (SSN) class to replace the aging *Los Angeles* or 688-class, which has been in service for a quarter of a century. Originally designated the New Attack Submarine, the *Virginia*-class is expected to serve as the primary U.S. attack submarine for decades to come. The design requirements call for retaining the *Seawolf* stealth levels in a smaller ship with a lighter, but more flexible, payload. In recognition of the Navy's shift in emphasis from open ocean fleet operations to smaller scale regional conflicts, *Virginia* is intended to be optimized for littoral warfare. Among its missions, the ship is designed to support antisubmarine warfare (ASW), anti-surface warfare (ASUW), Tomahawk missile strikes, covert intelligence gathering, and special operations. A series of technology insertion upgrades are planned for later submarines in the class, and the modular construction is expected to reduce the work required for major modifications.

IDA has been involved with the *Virginia* program from its inception, analyzing requirements and test plans, and developing an independent evaluation plan to help the Navy and the Director of Operational Test and Evaluation (DOT&E) to ensure a rigorous assessment of the system. In a related effort, IDA is examining the Acoustic Rapid Commercial-Off-the-Shelf (COTS) Insertion hardware, which will be used as the basis for the *Virginia's* own sonar suite.

USS Virginia: *A Study in Innovative Construction*

Traditionally, the interior structures of submarines have been assembled inside preformed steel hull sections, which were then joined together. Major electronic systems, such as the sonar, were built and tested at the factory, disassembled, shipped, and reassembled at the shipyard inside a hull section. In contrast, the *Virginia*-class is using a novel modular construction technique. Large functional elements of the ship are being assembled as standalone segments, known as modular isolated deck sections (MIDS), which are then inserted as a unit into hull sections. These individual hull sections are later welded together to complete the ship. One of the most critical MIDS is the Command and Control System Module (CCSM). Consisting of the control room, radio room, electronic support measures (ESM) compartment, and electronics spaces, the CCSM houses the overwhelming majority of the processors, wiring, and electrical connections found aboard *Virginia*. The modular assembly approach facilitates testing of the CCSM, with its myriad delicate electronic components, as a unit, prior to installation in the hull.

COATS

To support module testing, the General Dynamics Electric Boat Company built the CCSM Off-hull Assembly and Test Site (COATS) facility in a hangar at its shipyard adjacent to the main submarine assembly building. The CCSM, which is roughly 60 feet long and two stories high, resides inside a large bay, along with its large spherical sonar array. A computer-driven simulation / stimulation (SIM / STIM) system provides signal inputs directly to the sonar array, as well as to the other sonar, combat, and ESM systems. The fact that *Virginia* has a new electro-optical "photonics" mast for visual detection, rather than a conventional optical periscope, simplifies testing. COATS is able to generate highly realistic synthetic images and inject them as inputs to the photonics system. The radio room and ship control consoles are not yet fully functional, but eventually will be integrated into the COATS environment.

The key to the COATS concept is the testing of the entire CCSM as a fully assembled unit. The CCSM in the COATS bay is the actual control room for the lead ship of the *Virginia* class. Every wire, console, light fixture, socket, handle, pipe, rivet, bulkhead, ladder, and deckplate is the real hardware, and, following testing, the entire module will be slid into a hull section. As the program continues, each ship's CCSM will, in turn, undergo COATS testing prior to hull installation. This approach allows analysts to test hardware and software integration and reliability, which are the primary areas of concern with such a complex electronic system. Also, any necessary repairs or replacements can be more easily accomplished off-hull. COATS also provides a valuable training environment for the crew. Rather than using a separate trainer or simulator, they are able to operate the very same systems they will take to sea.

Recent Operational Testing

In April 2002, the first *Virginia* CCSM underwent initial operational testing, designated OT-IIB, at Electric Boat's COATS facility. The Navy's Operational Test and Evaluation Force designed and directed the test, and IDA analysts worked closely with them to create a realistic test plan and develop a suitable assessment approach. IDA team members then spent 5 days aboard COATS observing the test. A variety of warfare scenarios, including ASW, ASUW, strike, and surveillance, were played out, with the test directors inserting appropriate synthetic adversary forces as necessary. OT-IIB is a key milestone in undersea warfare combat system testing.

During the test, most of the data were synthetic representations of acoustic, RF, and visual scenarios of combat situations. A team of naval officers and enlisted operators had been trained in the system operations and were free to operate the ship in a realistic tactical manner to accomplish the assigned missions. While a trained operator could easily recognize the data as synthetic, most of the data handling and transfer capabilities of the system, as well as operational procedures, appeared to be adequately tested. The objective of the test was to evaluate the system hardware, software, and interfaces, rather than measure *Virginia's* specific operational effectiveness. For example, regardless of the simulation's realism, there was no expectation that the ship's ASW search rate or torpedo firing accuracy would be assessed at COATS. However, there was a great deal to be learned about how the combat system processes, transfers, and presents the critical data that the crew will one day need to carry out their operational duties.

At IDA's suggestion, portions of the test used actual TB-29 towed hydrophone array data that had been recorded by submarines at sea. IDA had been instrumental in arranging for the collection of these valuable data tapes during other tests. While the use of prerecorded data deprived the ship operators of some of the control they desired, it was, nonetheless, a good test of the processing system in the analysis of real acoustic data, which is not as well behaved as synthesized data.

In the absence of a ship's control station, maneuvering commands during the test were relayed via radio to the SIM / STIM operator, who executed the appropriate speed, course, and depth changes. This process was relatively seamless and did not appear to affect the test. There was generally good coordination in the simulation of the radar, visual, and ESM signatures associated with the targets of interest. In particular, the images of waves, periscope wakes, fog, sun glare, and surface ships were quite detailed and realistic. The system even featured realistic star fields for night operations.

One significant difference between the physical layout of *Virginia* and its predecessors is that the sonar room has been eliminated in favor of integrating the sonarmen into the attack center team. Sonar and fire control functions are distributed among 10 identical workstations to maximize configuration flexibility. There has been controversy regarding this design, with speculation that sonarmen could be distracted by the noise and activity in the attack center. The COATS environment is unlikely to provide definitive results on this issue, which will best be decided at sea. However, the COATS test did provide some taste of the new control room environment, where internal communications take place via wireless headsets, rather than the traditional overhead speakers. The officers and crew also were able to get a sense of the shift in group dynamics generated by the collocation of the sonar, ship control, and fire control teams.

While COATS testing focused on the effectiveness and reliability of the electronics systems, the presence of a group of experienced submariners in the CCSM provided an opportunity for an informal assessment of some of the ship's other spaces and fittings. The cramped layout was the universal complaint. While the modular construction technique being employed for *Virginia* might simplify assembly, it also results in critical constraints on the design. Since the control room and associated spaces were constructed as a freestanding module instead of built into the hull itself, some internal volume is dedicated to the module framework. Thus, the overall usable volume within the hull appears to be reduced.

Overall, OT-IIB was well conceived and professionally executed, and should provide timely and valuable results. COATS has opened a new era for testing, which promises to facilitate both operational evaluations as well as system development.

SACLANT Non-Acoustic Technical Advisory Group

In November 2000, NATO published the results of its long-term scientific study, "Implications of New Technologies for Anti-Submarine Warfare and Maritime Operations (MO 2015)" – a three-year multinational study on how to improve NATO's capabilities to conduct maritime operations in littoral environments.

Key among the study's approximately 20 findings was the recognition that the traditional acoustic techniques used to conduct anti-submarine warfare (ASW) in the open ocean would have policy limitations when employed in the coastal environments that are most likely to characterize future NATO maritime operations. MO 2015 therefore recommended initiating collaborative research efforts based on "non-acoustic" techniques for ASW. These techniques involve sensing mechanisms based on phenomena not traditionally associated with ASW sensors, such as laser and infrared imaging.

Headquarters Supreme Allied Command Atlantic (HQ SACLANT) has taken a leading role in advancing opportunities for collaborative research in non-acoustics. Because IDA had participated in the MO 2015 study and had chaired a non-acoustic technical advisory group to support MO 2015 analyses, our researchers were invited to participate in initial discussions with HQ SACLANT on how to structure NATO collaboration in non-acoustics. Following these initial discussions, IDA was formally tasked by HQ SACLANT to organize and chair a multinational group to develop a non-acoustic sciences research plan for NATO. The working group was established in September 2001 and includes scientists from Belgium, Canada, the Netherlands, Norway, the United Kingdom, and the United States.

The first 6-12 months were dedicated to establishing a non-acoustic research plan for NATO's SACLANT Undersea Research Centre. Twelve research proposals were consolidated into the following three-projects for the five-year research plan proposal for the Centre:

1. Develop and verify an integrated model of the electro-optical properties of littoral waters,
2. Research next generation non-acoustic netted bottom sensors, and
3. Research the detection and discrimination of floating mines.

Each of these research projects addresses a significant operational shortfall identified in the MO 2015 study.

HQ SACLANT accepted the advisory group's recommendations, which were formally presented in May 2002 to the Scientific Committee of National Representatives, the technical oversight board for NATO's SACLANT Undersea Research Centre. These recommendations are included in ongoing efforts to develop the next scientific program of work for the Centre.

Having completed work for NATO's SACLANT Undersea Research Centre, the advisory group next will focus on identifying other opportunities for NATO collaboration during Fall 2002-Fall 2003. NATO's Naval Armament Groups for ASW and mine warfare (NG-2, NG-3) will be considered, as will NATO's Research Technology Organization.

Naval Expeditionary Warfare Maneuver, Planning, and Execution

Part of the Navy and Marine Corps efforts to transform their forces includes the concept of littoral combat and power projection. This includes efforts to enable the Marine Corps and Navy to conduct operational maneuvers from the sea – the Marine Corps' operational concept for maritime power projection. Key to implementing this concept is the ship-to-objective maneuver (STOM) in which a combined arms force is transported, from ships at sea, inland by air, surface, and subsurface means. Future landing forces operating in accordance with STOM will attack through selected littoral penetration points, move directly to the inland objectives in fighting formations, and eliminate the need for the traditional beachhead.

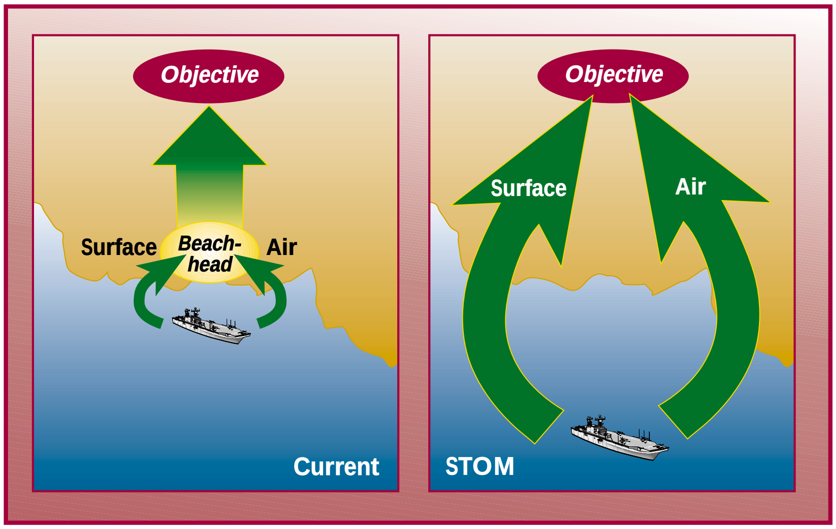


Figure 1. Comparison of Current Amphibious Operations and Ship-to-Objective Maneuver (STOM)

Under the current assault concept, forces are progressively deployed by air and sea from amphibious ships to bases ashore until sufficient strength is assembled to move toward the objectives inland (Figure 1). STOM provides greater security for the amphibious ships by operating over the horizon from the shore. This eliminates the need for vulnerable beachhead support bases and provides opportunities for tactical flexibility and momentum.

STOM will allow future Marine forces to maneuver in tactical array starting the moment they depart the sea base some 25 miles off shore until they reach their key objectives. Whereas current surface movements follow a pre-arranged plan whereby the commander of the amphibious task force controls all sea surface movement until landing force units are ashore, the STOM concept introduces maneuver into the surface assault element from the onset and places the surface assault units under control of the commander of the landing force. Command and control can be further decentralized to the individual surface operating units.

DoD is acquiring improved systems to permit an assault to begin from well over the horizon at sea. In addition to the MV-22 Osprey for air assault, these include an extended life with upgrades for the high-speed Landing Craft, Air Cushioned, and acquisition of the Advanced Amphibious Assault Vehicle (Figure 2) to replace the current slower amphibious assault vehicles. The faster-moving assault vehicles would minimize the time at sea for strike forces while still permitting the location of amphibious ships 25 miles off shore.

The STOM concept also requires a high level of situational awareness and skillful navigation to enable landing force commanders to maneuver their units beginning the moment they cross the line of departure at sea. This may require new capabilities or modifications to existing systems. DoD has asked IDA to examine this issue in detail, identifying potential shortfalls that could limit STOM effectiveness in the areas of command and control, communications, computers, intelligence, surveillance, and reconnaissance.

The IDA study will take account of new amphibious assault operational concepts, as well as approved DoD programs. We then will recommend science and technology initiatives in which the Office of Naval Research should invest to enhance the surface maneuver component of STOM by 2010. This report is scheduled for the spring of 2003.

Figure 2. The Advanced Amphibious Assault Vehicle (left) and the Landing Craft, Air Cushioned (right).

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