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INSTITUTE FOR DEFENSE ANALYSES

Exploration of Potential Future Fleet Architectures

W. L. Greer, Project Leader

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PREFACE

In the legislation for FY 2004, Congress asked the Secretary of Defense for two studies on the future fleet architectures. The Center for Naval Analyses was selected to conduct one study and the Office of Force Transformation (OFT) the other. Both were to be conducted independently and were not to be constrained by current fleet programs. The OFT turned to several organizations, including the Institute for Defense Analyses (IDA) for ideas and analyses. This paper documents the analyses and findings in the IDA examination of possible future fleet architectures.

The IDA study team benefited from extensive communications with Government offices and their contractors. We wish to thank our OFT study sponsors, namely VADM Arthur Cebrowski (USN, retired), CAPT Frank Caruso (USN), and Mr. Terry Pudas, for arranging meetings, establishing contacts, and critiquing our work in a timely and useful manner. We also benefited from discussions with Dr. Stuart Johnson, Dr. Elihu Zimet, Mr. David Gompert, and Dr. Paris Genalis of the National Defense University and with Mr. Robert Button and other analysts from the RAND Corporation.

The study team consisted of Dr. William L. Greer (project leader), Dr. Alfred I. Kaufman, Dr. Daniel B. Levine, Dr. Daniel Y. Nakada, and Dr. Jack F. Nance. The study team gratefully acknowledges expert assistance from Mr. Gene H. Porter and the IDA Review Committee: Dr. George E. Koleszar (Co-Chair), Dr. L. Dean Simmons (Co-Chair), Dr. Joseph T. Buontempo, Mr. Waynard C. Devers, Mr. Michael Leonard, Dr. David L. Randall, RADM Grant A. Sharp (USN, retired), Dr. John R. Shea, and Mr. Peter B. Strickland.

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Part 1

INTRODUCTION AND SUMMARY

INTRODUCTION

A. BACKGROUND

The Congress directed the Secretary of Defense to provide two studies on the future fleet architectures by January 2005. One study was to be conducted by one of the Federally Funded Research and Development Centers (FFRDCs), and the other by the Office of Force Transformation (OFT) within the Office of the Secretary of Defense (OSD). The two studies were to be conducted independently and to be cognizant of projected and programmed naval platforms but not to be constrained by them. The Center for Naval Analyses (CNA) was selected to conduct the FFRDC study. To assist in the OFT study, the sponsor requested several organizations, including the Institute for Defense Analyses (IDA), to provide inputs. After receiving and deliberating on these inputs, the OFT produced a report in January 2005 for the Congress. This IDA document, written as a stand-alone report, served as one input to the OFT report. Some of the OFT report findings are drawn from analyses described in this document. Nonetheless, the results found here represent the views of IDA and not necessarily those of the OFT.

One important motivating factor for re-examining naval architectures is the change in geopolitical circumstances. The world has changed greatly since the years in which current naval combatants were designed against an open-ocean threat of the Soviet Union, a force of comparable might and worldwide military interests at that time. With the recent restructuring of world events following the demise of the Soviet Union and the ascendance of international terrorism and territorial disputes, naval challenges now are shifting to more confined areas near land, such as littorals or straits, not the open ocean. These are often referred to as “non-traditional” challenges. The U.S. Navy itself is acknowledging this shift through its introduction of the Littoral Combat Ship (LCS) within the traditional naval architecture. Nonetheless, despite recent trends, we cannot dismiss the potential for a major naval challenge to parts of the open ocean in the future from countries such as China who are building major military forces. So any new design of U.S. naval forces must also take this into account even as it addresses the more numerous and more likely non-traditional combat conditions. Balance across great areas of uncertainty is required, greater than at any time in the recent past. The U.S. Navy is attempting this balance by adding smaller ships to the large combatant fleets. The Congressionally directed studies indicate that other balancing architectural ideas may prove useful.

A second factor motivating these studies is the continuous erosion of funding for and the rising cost of building ships, a situation that has required the U.S. Navy to plan for fewer aircraft carriers and other capital ships in the near term. According to recent comments by the Chief of Naval Operations (CNO),[1] the cost for new DDX destroyers, the new aircraft carrier CVN-21, and Virginia-class submarines are all rising well above initial estimates, a condition that puts at risk the fleet desired by the Navy. The Navy shipbuilding budget is about $10 billion per year, less than the cost of a single CVN-21 and approximately the cost of four Virginia-class submarines. The new DDX destroyers are now estimated to cost more than $3 billion each.[2] The rising cost of building combat ships and the constrained shipbuilding budgets may necessitate some kind of change in direction.

So the basic question is: Are there alternative architectures that can preserve or improve vital naval capabilities under these combined geopolitical and budgetary constraints? That is the question addressed in this report.

B. OBJECTIVE

The purpose of this report is to identify realistic alternatives to the programmed fleet and to assess their advantages and disadvantages. This will inform decision makers within the Department of Defense and the Congress as they deliberate on the future of the Navy. By Congressional direction, platforms in current and programmed fleets were not considered as constraints to any future architecture.

C. APPROACH

The basic approach to identifying and then evaluating all fleets used in this study is outlined in Figure 1. It consists of six main stages: (1) the identification of an irreducible set of naval capabilities, (2) a reflection on the general nature of the geopolitical situations that a future Navy might encounter in exercising these capabilities,

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1 "Navy of Tomorrow, Mired in Yesterday's Politics," *New York Times*, April 19, 2005.

2 "U.S. Navy Sets 30-Year Plan," *Defense News*, March 28, 2005.

(3) a consideration of new technology, recently proposed ship designs, and shipbuilding costs to propose new platforms, (4) the identification of several alternative architectures using these platforms, chosen as comparable in cost with the programmed fleet, (5) the development of a set of quantitative metrics by which to measure and contrast capabilities among the alternative fleets, and (6) an assessment of alternative fleets relative to the current and programmed one. This approach does not yield a complete set of all-encompassing architectures, but it does provide an organized mechanism to ensure that reasonable architectures are identified and assessed. Additional architectures could be introduced and assessed in the same fashion as the ones analyzed in this report.

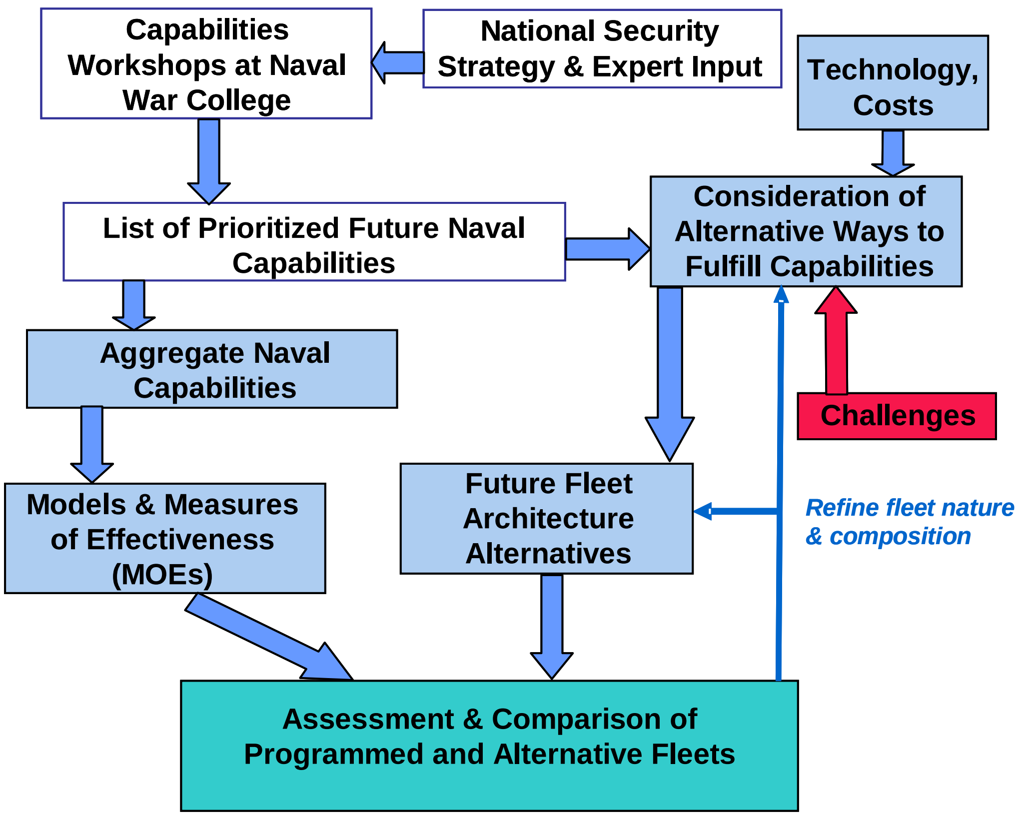

Figure 1. General Approach

The measures of effectiveness, or quantitative metrics, used in this study to assess architecture performance in supporting the identified capabilities are unusual but appropriate for this level of exploratory analyses. Such quantification is routinely provided by campaign analyses that embed the fleet within specified strategic and tactical situations and then calculate the likely outcomes as a function of inputs describing the enemy, the fleet, and their systems. However, campaign analyses require a large number of detailed assumptions, details that can obscure the generalities sought. As an alternative to campaign models, the study team developed generic models to illustrate the critical factors that drive a specific capability. We believe these are more useful in an exploratory overview than results of multi-parameter campaign analysis. The models used to support the arguments made in this study are intentionally simple, transparent, and straightforward. They are also exceptionally general in order to capture the essence, rather than the particulars, of generic situations. They are general enough to capture generic aspects of jointness, in which contributions to intelligence, surveillance, and reconnaissance (ISR) could equally come from national, joint, or other service systems as well as from organic naval systems. These general models are described in greater detail in Part 2, Chapter IV.

D. SCOPE AND LIMITATIONS

The study looks at a time period circa 2030, a time by which the current and programmed fleet could realistically be replaced entirely by a completely new design ship. However, it uses currently available technology and so could also be viewed as a near-term alternative to the fleet if funds were made available. This study examines the finished product of the alternatives, not intermediate stages of evolution from current to one of the alternatives, with mixed fleets over time. In this sense, the study examines limiting cases to establish high contrast, not constrained by current fleet platforms and not constrained by how one migrates from the present fleet to the various alternative future ones. In fact, decision makers could well mix some of the alternatives to provide for a different balance over time as well as in the ultimate composition of ships.

The study is not an advocacy study. It is investigative. Its purpose is to identify reasonable alternative fleets and to illuminate their capabilities vis-à-vis the programmed fleet.

The general quantitative metrics discussed earlier prove to be both an advantage and a limitation. The metrics illustrate broad general tendencies but are inadequate to determine details such as specific ISR systems, optimal weapon load outs, ship dimensions, or construction materials. Moreover, it does not distinguish among different warfighting operational concepts. Significantly more complex models and considerations need to be made if any of the alternatives should prove interesting enough from this general approach for more detailed examination. This study should, therefore, be seen as probing and exploratory, not definitive.

The main force attributes involved in selecting alternative architectures are those espoused by the OFT sponsoring office: flexibility, adaptability, agility, speed, and information dominance through networking. These can be modeled. Another characteristic of military forces often promoted by OFT is *relevancy.* High relevancy refers to the situation in which U.S. forces focus appropriate strength to limit options available to the enemy because of the overwhelmingly larger number of options (called *complexity* by the OFT) or focused joint ISR that the United States can use to seek and prosecute enemy forces. What is needed to make relevancy and complexity happen is not modeled, but their possible consequences can be captured within the models we use.

The study assumes that technical advances can be made to allow modular weapon systems on small ships with small but highly capable sensor, small long-range weapons, and survivability measures. However, excursions in all these areas are also explored.

E. ORGANIZATION OF REPORT

This report is organized as follows. It consists of two parts.

Part 1 of this report contains the Introduction and Summary. The Introduction introduces the main question and outlines the objective, approach, and limitations. The Summary section, next in this paper, contains the main study findings.

Details of the fleets and of the methodology are found in the chapters of Part 2, Analyses. In summary, the chapters in Part 2 provide the detail needed to understand the more summary materials that precede them. The chapters include the following:

Chapter I—Future Navy Warfighting Concepts and Capabilities

Chapter II—Naval Capabilities

Chapter III—Alternatives for Future Fleet Architectures

Chapter IV—Methodology for Assessing Alternatives

Chapter V—Cost Analysis

Chapter VI—Unmanned Vehicles.

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SUMMARY

In summarizing this report, the first topics addressed are challenges and capabilities. The alternative fleets analyzed in this report are then briefly described, and finally major findings are identified.

A. CHALLENGES IN AN UNCERTAIN FUTURE

We start with a consideration of the kind of future likely to confront the U.S. Navy. The future, characterized as potential challenges rather than specific threats associated with specific countries, is summarized in Table 1. This table was used at the Naval War College Workshops, organized in March and May 2004 by the Office of Force Transformation to orient thinking about future conflict. In this table, the concepts of traditional and non-traditional challenges are introduced and differentiated. Traditional challenges are those for which the programmed fleet is often said to be designed: an advanced threat that fights in traditional ways, even if not completely predictable. It includes warfare against established militaries, possibly those that also possess nuclear weapons. These traditional enemies are said to fight in a symmetric fashion. To a large extent, many of the planning scenarios heretofore used in DoD acquisition deliberations have involved these traditional challenges.

The non-traditional or asymmetric challenges consist of irregular, catastrophic, and disruptive sub-challenges. In these situations, the enemy recognizes its inferiority vis-à-vis the United States in symmetric warfare and instead chooses unconventional means to try to gain advantage. The enemy's goals in non-traditional warfare may not be to defeat U.S. forces in the normal sense of the word as much as to prevent U.S. forces from defeating them. The three types of non-traditional warfare are defined in Table 1. They include unconventional or irregular warfare (irregular challenge) such as urban warfare, surprise attacks on critical and significant assets (catastrophic) with the possible use of weapons of mass destruction, and usurpation of U.S. advantages through the introduction of novel technical means (disruptive). These are not mutually exclusive. A non-traditional war could combine elements of two or more of these sub-challenges.

Table 1. Challenges to the U.S. Military

Challenge		Enemy Intent	Description of Threat to which U.S. Military Forces Respond
Traditional		**Challenge** American power	Legacy and advanced military capabilities of conventional and nuclear forces for established nuclear powers
Non-traditional	Irregular	**Erode** American influence & power	Unconventional/irregular means (terrorism, insurgency, civil war, unrestricted warfare)
	Catastrophic	**Paralyze** American leadership & power	Surprise attacks on symbolic, critical, or other high-value assets (9/11, terrorist use of WMD, rogue missile attack)
	Disruptive	**Usurp** American influence & power	Breakthrough capabilities (advances in sensor, information, biotechnology, nanotechnology, cyber operations, directed-energy, and other emerging fields)

Source: Briefing materials provided at Workshop II on Future Fleet Architectures at Naval War College, May 2004.

In this paper we focus initially on the non-traditional asymmetric challenges but use the traditional symmetric challenges as a check on the capabilities, since a properly balanced fleet should be able to acquit itself well against this full range of adversaries.

B. CAPABILITIES NEEDED

Although the nature of future warfare is unpredictable and can consist of a range of conventional and unconventional challenges, the future U.S. naval fleet must possess specific and basic capabilities in order to engage any potential enemy. These are viewed as fixed, even though the specific way in which they are manifested through technology advances and operational considerations may change. What is this irreducible set of capabilities the future Navy needs?

This was answered through the series of sponsor-organized Naval War College workshops in 2004 noted earlier. The Navy proposed a large number of candidate capabilities, and workshop participants were then asked to rank them. At the end of the workshops, a set of six essential capabilities was derived. These capability areas were chosen to be independent of specific architectures, specific ship types, and challenge areas and thus could serve as a kind of requirement against which all alternative future fleets and the programmed fleet can be measured. These six capability areas are listed in Table 2.

Table 2. List of Warfighting Capabilities

Capabilities	Descriptions
1. Develop and communicate knowledge of forces and situation	Develop and communicate knowledge about forces and the military situation. Generate and maintain persistent intelligence information, to develop and maintain a common operating picture of the tactical circumstances prevailing on the battlefield, and to communicate both intelligence and common operating picture to all relevant military entities.
2. Control operational domain	Control the area where operations are conducted. Clear that area of any undersea weapons, keep enemy surface ships and aircraft beyond the danger line, and defend itself against enemy missile attacks launched either from the opposing fleet or from shore-based batteries. Exercise sea and air control in its domain of operations.
3. Promptly bring forces to bear where needed	Deploy its forces to arrive in the right place at the right time. Given potential access and control, this capability requires a fleet to be strategically quick and highly maneuverable.
4. Fight from the sea	Be ready to fight from the sea. Engage and destroy opposing fleet's assets. Alternatively, attack and destroy both fixed and mobile land targets and insert regular and special operation forces where needed.
5. Sustain joint forces	Be able to sustain itself and its expeditionary forces operating ashore.
6. Deny enemy ability to hold homeland at risk	Contribute to denying an enemy the ability to hold the U.S. homeland at risk. This capability might require that the fleet participate significantly in missile defense, in port defense, and in sea control along U.S. shores, to include interdiction.

These six capability areas serve as the backbone of the analyses in this report.

C. PROGRAMMED AND ALTERNATIVE FLEETS

1. Programmed Fleet

The current and programmed Navy surface fleet is designed around several formations: the carrier strike group (CSG), the expeditionary strike group (ESG), and the surface strike group (SSG). Twelve CSGs were programmed when this study was begun. Subsequent decisions in 2005 to reduce the numbers of nuclear-powered aircraft carriers (CVNs) from 12 to 11 or even possibly 10, are not taken into account. Such details are felt not to be important in the comparisons since alternative fleets are designed at equal cost to programmed ones. Reductions in one would cause comparable reductions in the others. This study retains the 12 CSGs. In addition there are 12 ESGs and 9 SSGs in the programmed fleet, with a total of 219 surface and 24 subsurface combatants. While this number is always under challenge with new budgets, this study viewed that these would include the following surface ship numbers and types: 12 CVNs, 87 new-design cruisers (CGXs), 12 new design destroyers (DDXs), 60 littoral combat ships (LCSs), 12 auxiliary ships (T-AOEs), and 36 landing ships: 12 LHDs, 12 LPDs, 12 LSDs. Also included are the aviation units for these ships. It should be noticed that many different hull sizes and designs are involved. All attack submarines are nuclear-powered *Virginia* (SSN 774) class boats.

2. Alternative Fleets

The main attributes of the programmed fleet are (1) extensive use of nuclear powered vice fossil-fuel-powered propulsion, (2) a large number of different hull shapes and sizes, and (3) integrated multi-capable platforms. We introduce contrasting platforms in all three attributes. In this selection, the study team used sponsor-provided guiding principles to identify alternative candidate platforms.

a. Guiding Principles

The Office of Force Transformation posited several guiding principles for military forces, including naval forces, which we used. The OFT advocates flexibility, adaptability, agility, speed, and information dominance through networking.

This suggests a fleet of small fast craft. For a fleet composed of small craft, modularity rather than integration of many systems within a single hull is required, since smaller craft are not capable of housing numerous large weapon and sensor suites simultaneously without significant advances in miniaturization. Thus, part of the speed alluded to is not only the speed of advance but speed in exchanging modules on the spot to ensure immediate relevance and to spawn complexity with which an enemy must contend. Such module swap-out speeds argue for carrying modules on larger nearby ships that support the smaller ones, not just in stocks ashore at main bases. Large ships to carry aviation and massive firepower are also implied, since these contribute to speed of response and defense for the fleet formations.

To operate to best effect, naval forces will require extensive networking among spatially distributed forces. Individually, future fleet ships may not need to be as large as current and programmed forces. As a consequence, networking can bring together the information and defenses of all to be used by one—or by one to be used by all.

b. Alternative Ship Designs

Alternative fleet architectures were developed with the required naval capabilities in mind, using a minimal number of designs to reduce overall costs while supporting the capabilities. The basic functional formations planned for programmed fleets, such as 12 carrier strike groups and 12 expeditionary strike groups, were also assumed for the alternative fleets. This maintained accord with naval concepts of operations while introducing new ships in the traditional roles. It may prove desirable, of course, to adapt future employment concepts to the specific design features of future ships. The basic new designs of the ships that populate these traditional formations center about a large number of small common-hull design craft and a smaller number of large common-hull design sea base ships that provide high volume firepower, aviation, troop spaces, module support at sea, and transport if needed. The main issue was to reduce the number of different hull designs to reduce overall costs and allow more ships in the fleet than currently planned. The nuclear-powered attack submarines (SSNs) in the formations were replaced by a larger number of air-independent propulsion (AIP) submarines. Earlier studies have addressed the advantages and disadvantages of such systems.[3] Other parts of the Navy were considered beyond the scope of this study and were not altered, including the SSNs not assigned to formations (most of the submarine fleet), the nuclear-powered ballistic missile submarines (SSBNs), the nuclear-powered cruise missile submarines (SSGNs), support ships like the combat logistics force (CLF), mine warfare ships, tenders, land-based air, and the entire training and supporting structure of the Navy. Thus, the alternatives in this report focused on the surface ships, aviation assets, and submarines of the strike formations.

Large Ships. The large ship sea bases are new-design, large, mono-hull ships with flat tops that accommodate systems and sensors for combat as well as provide modules for the small combatants, unmanned vehicles, and space for maintenance and housekeeping functions. Existing concept ship designs for the alternative hull forms were used to avoid unrealistic speculation on what the ships can carry and do. Aviation capability was maintained in the same numbers of aircraft, but only short take-off, vertical landing (STOVL) and vertical take-off and landing (VTOL) aircraft were used on the alternative smaller carriers. The aircraft would be equally numerous but considerably less capable than those that launch from traditional CVNs.

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3 *The Cost and Effectiveness of Non-Nuclear Attack Submarines*, IDA Report R-384, October 1992, Classified.

With the exception of one ship in the third alternative (discussed next), all of the large ships are built using a common hull taken from the Maritime Prepositioning Force Future (MPF(F)) Analysis of Alternatives (AoA).[4] The hull is configured as a vertical or short take-off and landing (VSTOL) carrier for VSTOL and VTOL aircraft and unmanned aerial vehicles (UAVs). This ship is 57,000 tons full load displacement and is 830 feet long. Thus, it is larger than an LHD in displacement (40,000 tons) and about the same length. It is significantly smaller than a typical CVN aircraft carrier at 90,000 tons displacement and 1,000 feet length. The propulsion uses conventional fuels with electric drive. Maximum speed for these ships is 24 knots.

Medium-Sized Aircraft Carrier. In one of the alternatives, a corsair-sized aviation ship was introduced upon recommendation from the OTF sponsor. This ship, labeled X-CRS, holds 10 aviation assets [notionally, 8 Joint Strike Fighters (JSFs) and 2 MV-22s], weighs 13,500 tons, and is about 550 feet long, in contrast with the 830-foot-long support ship (X-SPT), combat system ship (X-WPS), and aviation ship (X-AVN) large-ship alternatives. The X-CRS aviation ship has a maximum speed of 60 knots.

Small Ships. The modular small combatants are to provide agility, flexibility, and speed. Two types of small craft are proposed: one with a displacement of 1,000 tons and the second of 100 tons. Both are conceptual, though based on actual Naval Sea Systems Command (NAVSEA) designs; there is no intention in this paper to indicate that these specific designs are the most desirable ones. They are merely illustrative of small combat craft. It should be noted that both are significantly smaller than the programmed LCS, which displaces about 3,000 tons, and are smaller than the ships considered in the recent IDA study on small combatants.[5]

Small ships, being lower in cost than programmed combatants, will be more numerous. Their size presents challenges in high sea states, however.

c. Alternative Ship Architectures

Three alternative architectures—defined as a set of ships and attendant aviation and subsurface combatants—are presented. All three contain smaller ships than programmed, as noted previously. It is imagined that the programmed Navy ships are

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4 *Maritime Prepositioning Force Future (MPF(F)) Analysis of Alternatives (AoA)*, CNA Report D9814, April 2004, Unclassified.

5 *Small Combatants: Implications for the Effectiveness and Cost and Navy Surface Forces*, IDA Paper P-3716, September 2002, Classified.

individually more survivable, once hit, than the small craft in the alternatives, but the alternative small combatants may prove less targetable because of their small size and high speed. The alternative forces are less complex individually but collectively may confer greater complexity on the fleet.

For ease in comparisons with the programmed fleet, the traditional strike formations were retained—12 CSGs, 12 ESGs, and 9 SSGs—in all three alternatives. The numbers of ships in these formations were derived from cost considerations.

Fleet Costs. Alternative fleet architectures were constructed at equal cost to the programmed fleet architecture in two ways: in terms of procurement costs alone and in terms of the combination of procurement costs and 30 years of operating and support (O&S) costs. For ships, design and development costs are captured in lead ship costs. The fleet sizes derived from these were essentially equivalent. To achieve equal cost while generating a substantially larger surface fleet, the number of hull types was minimized, generally one large and one small, to take advantage of the cost learning curve in ship construction. Cost details can be found in Chapter IV of Part 2, Analyses.

Comparison of Architectures. Equal cost architectures are compared and contrasted with the programmed fleet and with each other in Table 3 for the carrier strike groups. In all cases, programmed and alternative, there are 12 CSGs or aviation strike groups. The X-AVN aviation ships in Alternatives A and B are the large hull ships described earlier. Alternative C contains the smaller corsair-like X-CRS aviation ship with fewer aviation assets per ship but the same total number of aviation assets per formation. The single SSN per formation is replaced in all the alternatives with a conventional AIP submarine of one-quarter the cost.

The aviation strike groups also contain other large hull ships: the X-WPS or weapons ship in all alternatives fleets, and the X-SPT or support ships in two other alternatives. The X-SPT ships are required to transport the small 100-ton combat ships to and from foreign theaters. These are parts of Alternatives B and C.

The aircraft in the future are notionally identified as JSF and MV-22 aircraft. Different variants of these would need to be developed for specialized missions, such as airborne early warning (AEW). Thus the aircraft names are proxy categories. Note that the JSF aircraft on the alternative platforms are STOVL and do not have arresting gear. This will limit their range compared to the JSF(CV) variants that will be used in the programmed fleet.

We also postulate relatively large numbers of organic unmanned vessels, including airborne unmanned aerial vehicles (UAVs), unmanned surface vehicles (USVs) and unmanned underwater vehicles (UUVs). In addition to these organic ISR and attack systems, national and joint systems would also contribute.

Table 3. Comparison of Programmed CSG and Alternative Aviation Strike Groups

Programmed Carrier Strike Group (12 Formations)		Alternative Aviation Strike Groups (12 Formations)			
			Alternative A	Alternative B	Alternative C
Platform Type	Number of Vessels in Each Formation	Platform Type	Number of Vessels in Each Formation	Number of Vessels in Each Formation	Number of Vessels in Each Formation
CVN	1	X-AVN	2	2	-
		X-CRS	-	-	8
Aircraft	60 JSF(CV) and 12 MV-22	Aircraft	60 JSF(STOVL) and 12 MV-22		
CGX	3	X-WPS	1		
LCS	2	SSC-1000	16	-	-
		VSC-100	-	24	24
		X-SPT	-	1	1
UVs	6	UVs	6 UAVs, 6 USVs, and 36 UUVs total spread over large ships		
SSN	1	AIP Submarine	4		
T-AOE	1	T-AOE	1		

The alternatives for the expeditionary strike groups are summarized in Table 4. The table compares numbers and types of ships in the programmed fleet and in the three alternatives. The main differences between the programmed and alternative fleets is the replacement of programmed amphibious ships with a large hull ship and replacement of surface combatants with the small 1,000 or 100 ton craft. Alternative A contains 1,000-ton small ships. Alternatives B and C are identical in the ESG, with smaller 100-ton ships and a large support ship (X-SPT) to carry these craft to and from the theaters of operation and to support them with modules in theater. As was also done for the aviation strike groups, the SSN is replaced by four AIP submarines.

Table 4. Comparison of the Programmed and Alternative ESGs

Programmed Expeditionary Strike Group (12 Formations)		Alternative Expeditionary Strike Groups (12 Formations)			
			Alternative A	Alternative B	Alternative C
Platform Type	Number of Vessels in Each Formation	Platform Type	Number of Vessels in Each Formation	Number of Vessels in Each Formation	Number of Vessels in Each Formation
LHD, LPD, and LSD	1 each (3 total)	T-AKX (MPF(F))	2		
Aircraft	6 JSF(STOVL) and 24 MV-22	Aircraft	6 JSF(STOVL), and 18 MV-22, and 3 Gyrocopter Heavy Lift		
CGX	2	X-WPS	1		
DDX	1	SSC-1000	15	-	-
LCS	3	VSC-100	-	23	23
		X-SPT	-	1	1
UVs	9	UVs	6 UAVs, 6 USVs, and 36 UUVs total spread over large ships		
SSN	1	SSN	0		

The surface strike groups are shown in Table 5. A single weapons ship (X-WPS) in all alternatives replaces the three CGX ships in the programmed fleet. Alternatives B and C are identical in this case, since their main difference is in the aviation platforms, not a part of the surface strike groups. The total number of alternative ships for the strike formations is larger than the number of programmed fleet ships, but the downside for the alternatives is that all the weapons capability is centralized in a single X-WPS ship rather than three dispersed CGX ships. This limits decentralized firepower but can result in larger individual weapons for surface strike carried by the X-WPS ship. The number of SSC-1000 and VSC-100 ships are the same because the VCS-100s need to be transported by a larger ship, the X-WPS in this case. This places an upper bound on how many can be deployed. If these groups were used for homeland defense, larger numbers of VSCs could be accommodated within the SSG.

Not explicitly shown are the fleet helicopters. These would be dispersed on the programmed surface combatants but centralized on X-WPS and X-SPT ships in the alternatives. Such centralization could prove constraining.

Table 5. Comparison of the Programmed SSG and the Alternative SSGs

Programmed Surface Strike Group (9 Formations)			Alternative Surface Strike Group (9 Formations)			
				Alternative A	Alternative B	Alternative C
Platform Type	**Number of Vessels in Each Formation**		**Platform Type**	**Number of Vessels in Each Formation**	**Number of Vessels in Each Formation**	**Number of Vessels in Each Formation**
CGX	3		X-WPS	1		
			SSC-1000	5	-	-
			VSC-100	-	5	5
UVs	0		UVs	3 UAVs, 3 USVs, and 18 UUVs on X-WPS		

These three alternatives clearly increase the fleet size (numbers of craft) as they reduce the average size of each platform. This is the tradeoff that must occur if the cost is kept comparable between programmed and alternative fleets. The numbers of ships and submarines in each alternative are compared to the planned fleet architecture by formation in Table 6.

Table 6. Comparison of Programmed and Alternative Fleet Sizes

Formation Type	Number Formations in Fleet	Number Surface and Subsurface Warships			
		Programmed	Alternative Fleets		
			A	B	C
Carrier Strike Group	12	96	288	396	468
Expeditionary Strike Group	12	120	216	324	324
Surface Strike Group	9	27	54	54	54
Total Number Warships		**243**	**558**	**774**	**846**
Total Number UVs		180	1,368	1,368	1,368

As Table 6 clearly shows, the alternatives significantly increase the number of warships in the fleet over the programmed number. *The results show the numbers of* *warships increasing from 243 in the planned architecture to 558 in Alternative A, 774 in Alternative B, and 846 in Alternative C.*

It is possible that a mixed fleet consisting of some ships of the alternatives and some ships of the programmed fleet will be the best choice. This may provide the hedges and affordability needed.

D. U.S. SECURITY POLICY AND ENEMY BEHAVIOR

While a fleet must be prepared to provide all the capabilities noted earlier, they are not all equally important in all situations. Which capability turns out to be most important depends upon the national security policy and upon the nature of the enemy. We introduce two policies—intervention and strategic advantage—and two different modes of enemy behavior—symmetrical and asymmetrical—in order to capture the full spectrum.

One possible future policy would have the United States involved in wars designed to control the actions of nations or groups attempting to interfere with U.S. security interests abroad. This policy we refer to as *intervention* and is likened to the policy that supported recent conflicts in Afghanistan and Iraq. The second U.S. policy would focus more on the United States concern for free access to the grand commons of the world's oceans and the security of its homeland. The second policy is referred to as *strategic advantage* and can be thought of as a policy more appropriate to a possible confrontation with a newly muscular China trying to keep U.S. forces out of its sphere of influence in the western Pacific. It could also include dealing with a possible attack upon the homeland.

In either of these two futures, intervention or strategic advantage, the enemy could behave in one of two different ways: it could operate symmetrically according to the same rules of battle as the United States, much like the enemies encountered during the 20th century, or it can operate asymmetrically according to rules that are deliberately different than those used by U.S. forces and aimed at exploiting technical and tactical vulnerabilities, much like the enemies encountered on the threshold of the 21st century.

This taxonomy of U.S. policy and enemy behavior generates four cases of interest. *Thus, there is an intervention policy involving a symmetric enemy, an intervention policy against an asymmetric enemy, a policy seeking strategic advantage over a symmetric enemy, and a policy of strategic advantage over an asymmetric enemy*.

Table 7 summarizes in a two-by-two matrix form, the driving capabilities for a given combinations of national policy and enemy behavior. The capabilities are from Table 2.

Table 7. National Security Matrix Indicating Driving Capabilities

Enemy Behavior	U. S. Policy	
	Intervention	Strategic Advantage
Traditional or Symmetric	Control the operational domain Promptly bring forces to bear where needed Fight from the sea	Control the operational domain
Non-Traditional or Asymmetric	Develop and communicate knowledge of forces and situation Control the operational domain Promptly bring forces to bear where needed Fight from the sea	Develop and communicate knowledge of forces and situation Control the operational domain Deny ability of enemy to hold homeland at risk

E. CHALLENGES IN ALTERNATIVE FLEET ARCHITECTURES

Due to the time and resources allocated for this study and the inherent uncertainty in the nature of the future threats, this study does not provide a comprehensive assessment of all technical and operational aspects of the alternative fleets. Challenges to the architectures of future fleets need to be examined further. Example challenges are noted next.

1. Ships

Using the MFP(F) hull for aviation ships, weapons ships, and support ships in all formations, including CSG, ESG, and SSG, reduces survivability from the programmed ships. Level I survivability is planned for MPF(F), while amphibious ships and CLF station ships (like the T-AOE) are Level II. Major combatants [aircraft carrier (CV), guided missile cruiser (CG), guided missile destroyer (DDG)] are Level III. In less precise terms, MPF(F) will have two-compartment stability (two compartments can be flooded and not lose the ship), while the combatants have three-compartment stability. Similarly, the small ships at 100 and 1,000 tons displacement are built with signature-reduction techniques but with minimal capability to survive more than hits by small-caliber weapons. Speed and reduced signatures are arguably effective alternatives to hull compartment stability.

In order to increase the number of ships in the fleet, some consolidation of otherwise dispersed capability is included in the alternative fleets. Three CGXs in the programmed fleet are replaced by a single weapons ship (X-WPS) that carries all of the payload of the CGXs but has only one radar (vice three on the CGXs). Thus, the one weapons ship's sensor coverage will not be as great as that of the three CGXs.

The programmed Navy continues to concentrate its maintenance and support for aviation in CVN and LHA/LHD type large ships. This approach has proven to be sound for achieving a high level of readiness in sea-based aircraft. The alternatives divide the aircraft over either 2 or 8 ships that support 30 to 10 aircraft, respectively. Providing the same level of aviation maintenance and support for aviation will be more difficult, especially in the small aviation capable ship (i.e., the corsair-like X-CRS).

2. Aircraft

To simplify the analysis, the programmed aircraft are assumed equivalent to a mix of JSF STOVL variants and tilt-rotor aircraft. The alternative aviation assets have a reduced capability relative to the programmed aircraft. Since smaller aviation ships are employed in the alternatives, STOVL JSF aircraft are used in place of the carrier-capable JSFs included in the programmed force. The JSF (CV) variants provide roughly twice the range and payload as do the STOVL versions. V-22 tilt-rotor (T/R) aircraft were also used in the alternatives. The T/R and STOVL assets are likely to face particular challenges providing comparable AEW, EW, and tanking support that the programmed E-2C, F-18G, and F/A-18 provide.

3. Submarines

In CSG alternatives, nuclear submarines are replaced by AIP diesel submarines in order to have more numerous, though individually less capable, submarines. IDA has examined under what circumstances forward deployed AID submarines are appropriate.[6] AIP submarines are limited in range and speed: they can either transit at a low speed for a long time or sprint at a high speed for a short time. Thus, they cannot keep pace with the rest of the CSG, so they must be moved into position or forward stationed in anticipation of an operation. This could be a substantial impediment to a fast-moving operation. An SSN can maintain pace with the CVN. In the ESG, the SSN is replaced by unmanned

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6 *The Cost and Effectiveness of Non-Nuclear Attack Submarines,* IDA Report R-384, October 1992, Classified.

vehicles. This may not be as great an impediment as it sounds. When Marines are landed in a hostile environment, a CSG will be present to form an Expeditionary Strike Force (ESF), so several submarines will be in the ESF formation.

4. Combat Logistics Force (CLF)

In the CLF, the alternatives include many more ships than the programmed fleet. At issue is the capability of the programmed CLF ships, and current support concepts, to support the larger number of ships in the alternative fleets.

5. Additional Areas to Investigate

This paper indicates where there may be payoffs in alternative fleets. To gain greater confidence in their utility, several areas need to be investigated. Costs to develop these have not been estimated, nor are they accounted for in the study.

a. Technical

Technical advances are clearly needed in the following areas to take full advantage of the alternative architectures and reduce vulnerabilities:

- Advanced high-capability and small sensors
- Small long-range weapons
- Survivable hulls through novel compartmentation designs for small craft
- Small detection, tracking, and engagement radars on ships for ballistic missile defenses.

It is possible that work may already be underway; this study had no access to special access program/special access required (SAP/SAR) information.

b. Operational

Finally, a number of operational issues need further examination. The best way to test many of these general concepts is through war-gaming at the fleet level in various settings to ascertain the following:

- How do the alternatives perform relative to the programmed Navy in detailed assessments, or war games, for traditional (specific planning scenarios) and non-traditional conflicts?
- How do joint operations impact the desirability of alternative fleets?
- Are AIP submarines appropriate for forward-deployed operations in fast-moving scenarios?

- Does the centralization of helicopters and firepower on the X-WPS ships instead of programmed combatants introduce undesirable constraints?

F. FINDINGS

These are the main findings that emerge from a comparison of programmed forces and alternatives in the capability areas and within the context of specific U.S. policy and enemy behavior. This study does not attempt to define the optimum fleet, only to posit several alternative fleets that appear to have useful attributes and to analyze their capabilities in general scenarios. It is an exploratory study.

1. Networking

The programmed Navy with its emphasis on large multi-mission integrated ships finds advantages from networking. Plans are in place to provide as much networking as possible. Networking proves to be useful for all the fleets considered and vital for the alternative fleets. *Without networking, all alternative fleets do not perform as well as the programmed one.*

2. Traditional Enemy, Strategic Advantage

Controlling the operational domain is a major metric for assessing how well all the fleets perform in accord with the strategic advantage policy. Networking is assumed by all four fleets. What is crucial here is whether the alternative fleets are more relevant and complex in their operations than the programmed one. *With a survivability advantage given to the multi-hull ships of the programmed fleet, the programmed fleet exhibits better capability than all alternatives except extremely large fleets such as that depicted by Alternative C in controlling the operational domain against symmetric enemies. If the alternative fleets can reduce their vulnerability, all are superior to the programmed fleet*. For this case, the more ships, the more capable the alternatives. Clearly much depends on how well the alternative fleets can turn their size and speed into an advantage in avoiding enemy weapons.

Examples are shown in Figures 2 and 3. The programmed fleet, represented by a CSG with traditional ships, is depicted on the far left-hand bar. Its performance in clearing enemy forces from a large ocean domain in 2 weeks is set at unity for relative comparisons with the alternative fleet. The three alternatives are shown to the right in order of ascending numbers of ships. These are CSG equivalents, with their own compositions of aviation ships and small combatants. For illustration purposes, in Figure

2, the programmed ships are assumed to be three times more survivable on average than the alternative ships. Survivability is a combination of targetability and vulnerability, once hit. In Figure 3, the alternative ships are assumed to have a survivability comparable to that of the programmed fleet. This would be attained through hit avoidance via rapid maneuverability and low cross-section, since the alternative ship hulls are unquestionably more vulnerable to damage if hit.

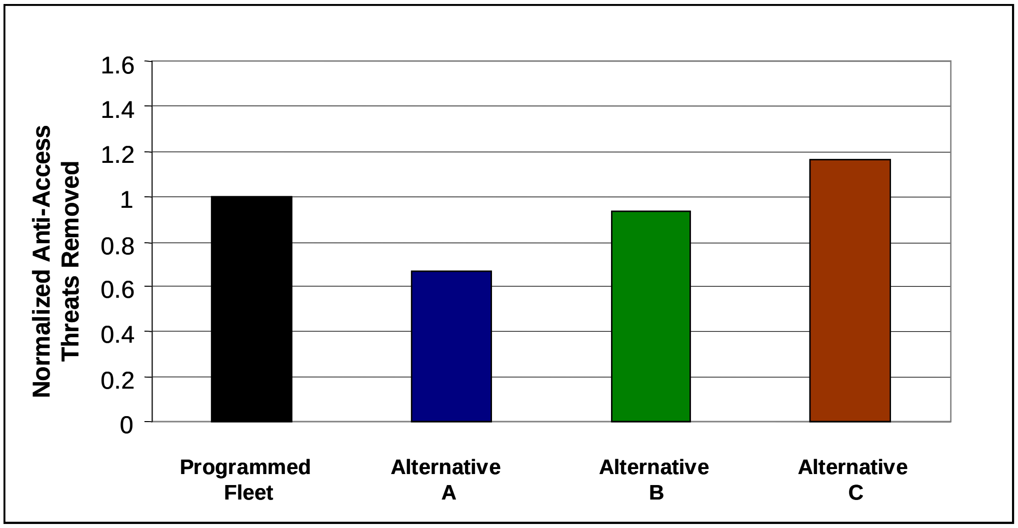

Figure 2. Programmed and Alternative Fleet Capabilities to Control Operational Domain, Strategic Advantage, Symmetric Enemy, with Networking

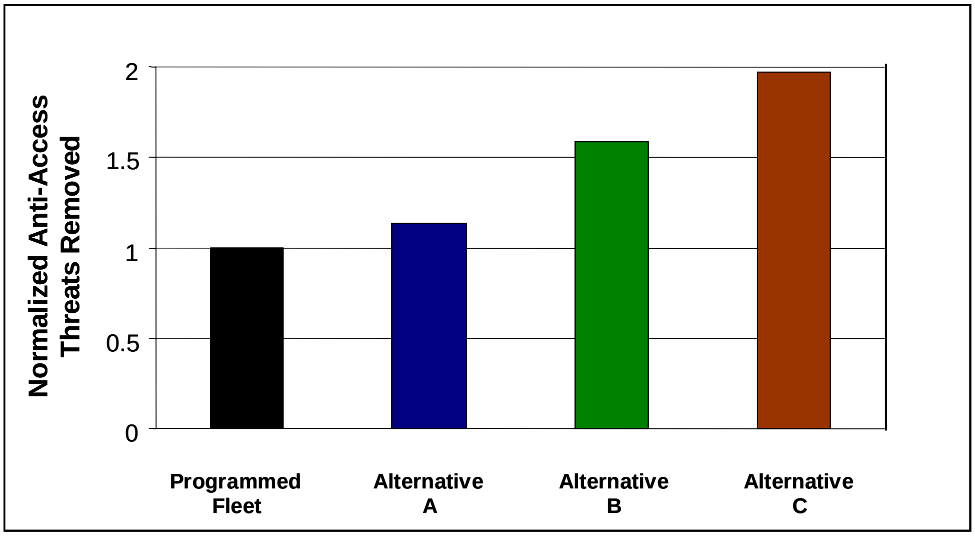

Figure 3. Programmed and Alternative Fleet Capabilities to Control Operational Domain, Strategic Advantage, Symmetric Enemy, with Networking and Comparable Survivability

3. Non-Traditional Enemy, Strategic Advantage

At issue here is Homeland Defense. The picture is mixed. *In Homeland Defense, alternative fleets are better at sea interdiction, while the programmed fleet is best at missile defense*. The reasons are clear: speed and large numbers of alternative fleet ships give them an overmatching advantage in interdiction, while the larger numbers and dispersed locations of Aegis-class ship radars in the programmed force allow better lateral defensive coverage against ballistic missiles.

4. Traditional Enemy, Intervention Policy

In the intervention case, attention is focused on finding and defeating the enemy rather than prevailing against assaults. Against a traditional enemy, networking to reduce uncertainty in target locations adds marginal capability. Enemy force positions are assumed to be generally well known in this type of battle, so additional networking of this information makes it more widely available but does not increase its accuracy.[7] Even if we assume one-third lower target detection capabilities by all alternative ships because of their reduced size, the programmed and alternative fleets exhibit comparable overall capabilities. Examples are shown in Figures 4 and 5.

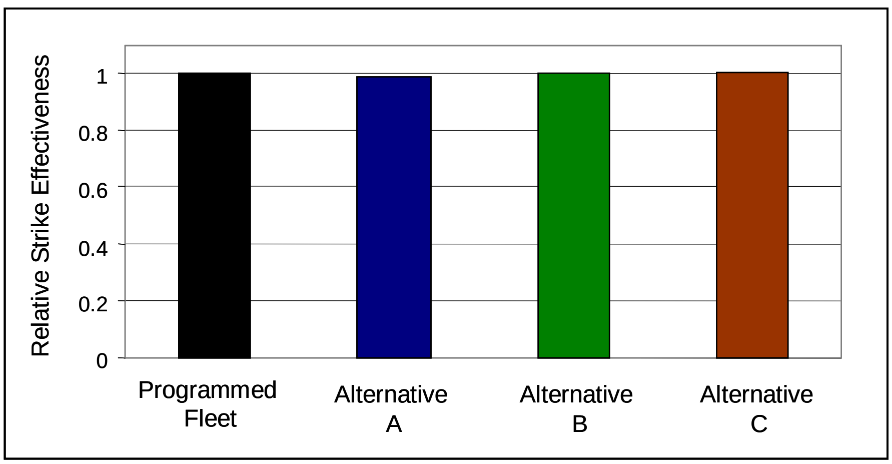

Figure 4. Programmed and Alternative Fleet Capabilities to Fight from the Sea, Intervention, Symmetric Enemy, with Networking

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7 Networking would almost certainly aid in self-defense against a symmetric enemy, but the emphasis here is on finding and prosecuting targets.

In Figure 5, we posit that the small more numerous craft in the alternatives might limit enemy evasion measures. Even with this advantage to the alternatives, all fleets still provide comparable levels for capability. In summary, *against a traditional enemy in a intervention policy, there are no substantive differences between the programmed fleet and any of the alternatives.*

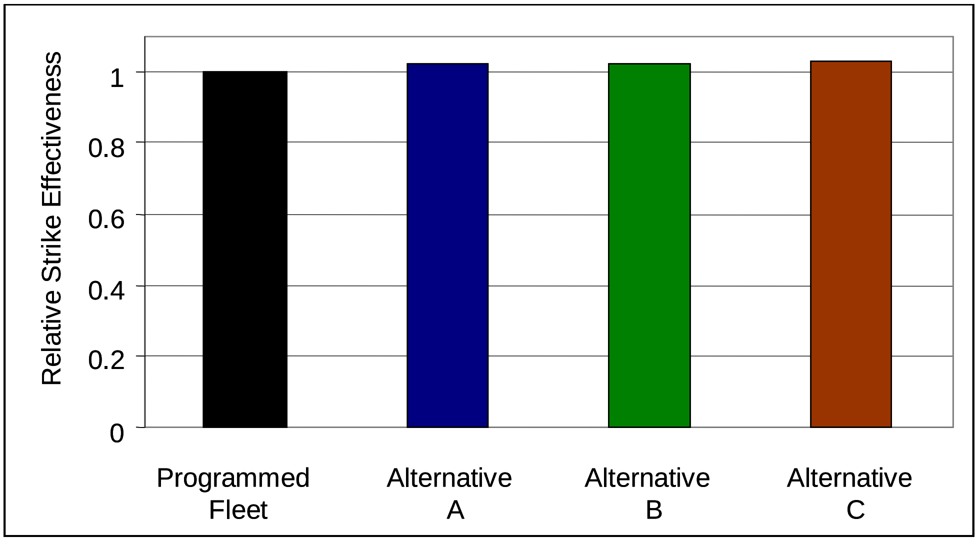


Figure 5. Programmed and Alternative Fleet Capabilities to Ability to Fight from the Sea, Intervention, Symmetric Enemy, with Networking and Counter-Evasion

5. Non-Traditional Enemy, Intervention Policy

In the intervention future against a non-traditional threat, networking can provide a boost to fleet capabilities. Without networking, the alternative fleets almost always provide less capability than the programmed fleet. With networking, programmed forces are as capable as the alternatives with the advantage going to Alternatives B and C with the most ships. Examples are shown in Figure 6.

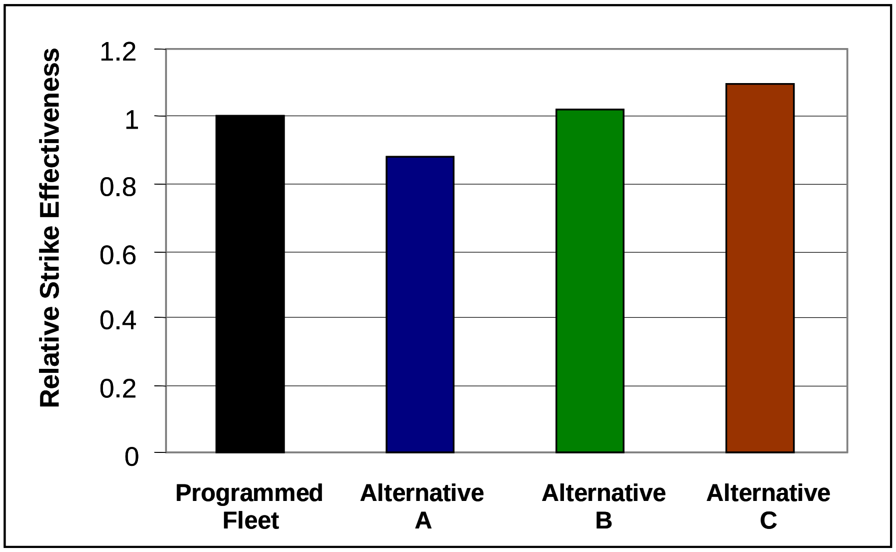


Figure 6. Programmed and Alternative Fleet Capability to Fight from the Sea, Intervention, Asymmetric Enemy, with Networking

The greatest advantages of alternative fleets over programmed ones come about if the alternative fleets through sheer size and speed can reduce the likelihood that an enemy can successfully evade targeting, once detected. In these cases, the larger the fleet size, the more capable the fleet. Examples are shown in Figure 7.

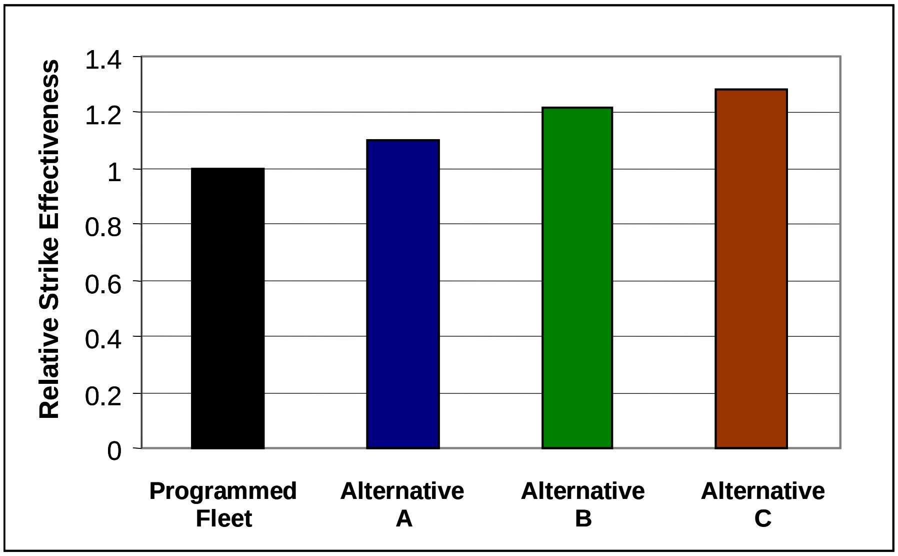


Figure 7. Programmed and Alternative Fleet Capability to Fight from the Sea, Intervention, Asymmetric Enemy, with Networking and Counter-Evasion

For the intervention policy against non-traditional enemies, the programmed fleet is superior to the alternatives examined if those fleets cannot confound enemy decisions and capabilities through complexity and relevance. Networking and larger numbers of ships alone is inadequate to provide the needed differences in capabilities. *If the ability to evade targeting is generated by the alternative fleets, they are better than the programmed one in all significant capability areas. In this case, the more ships in the alternative, the better the capability.* Thus central to determining fleet capability is a determination of how well they can reduce the numbers of deceptive options available to enemy forces.

6. Concluding Observation

The concluding observation is a mixed one, with the advantage sometimes going to the programmed fleet and sometimes to the alternatives. *Nonetheless, there appear to be alternative fleets that can provide the flexibility, agility, and presence needed in the unpredictable future, especially against non-traditional enemies. Networking is essential, and the attainment of high levels of survivability and restricting enemy evasion options through overmatching presence and joint and organic ISR could make alternatives superior to the programmed fleet in many circumstances.*

Part 2

ANALYSES

I. FUTURE NAVY WARFIGHTING CONCEPTS AND CAPABILITIES

A description of the way the Navy will operate in the future in terms of warfighting concepts and capabilities is taken in large part from IDA Paper P-3716, *Small Combatants; Implications for the Effectiveness and Cost of Navy Surface Forces,* September 2002.

Wile previous naval strategies focused on regional conflicts, the challenge of the future is to think more broadly. The new strategic focus emphasizes both regional challenges and transnational threats. In future conflicts, the Navy has plans to expand strike power, realize information dominance, and transform methods to fulfill traditional missions of sea control, power projection, strategic deterrence, strategic sealift, and forward presence.

Outline

- **Sea Power 21**
  - **Sea Strike**
  - **Sea Shield**
  - **Sea Basing**
  - **ForceNet**
  - **Global Concept of Operations**
- **Future Naval Capabilities (FNCs)**
- **Future Naval Systems**
  - **Pervasive Littoral Sensing**
  - **Littoral Combat Ship (LCS)**
  - **DD(X)**
  - **CG(X)**
  - **MCS(X)**
  - **Joint Strike Fighter (JSF)**
  - **SSGN**

Sea Power 21 is the concept for employment of naval forces in the future, by integrating sea, land, air, space, and cyberspace. It includes the Sea Strike, Sea Shield, Sea Basing, and FORCEnet concepts along with the Global Concept of Operations that describes the naval force structure and formation elements. Sea Power 21 will fully integrate naval forces into global joint operations.

The Future Naval Capabilities (FNCs) are developed at the Office of Naval Research (ONR) and include a wide spectrum of future naval capability categories. Future naval systems include Pervasive Littoral Sensing (PLS), Littoral Combat Ship (LCS), DD(X), CG(X), MCS(X), Joint Strike Fighter (JSF), and SSGN.

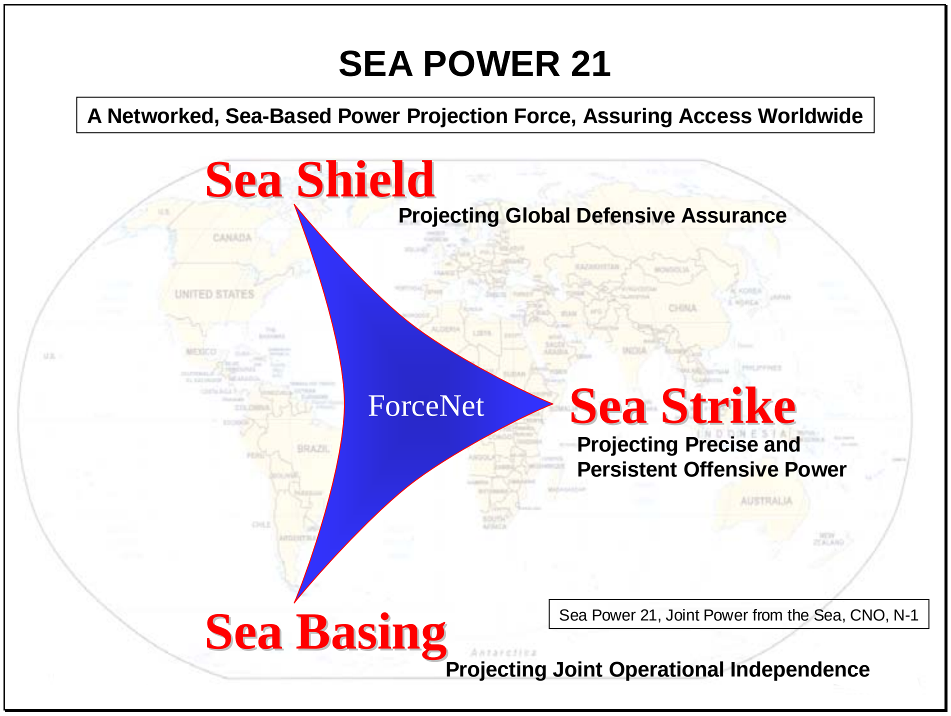
Background

- **"Sea Power 21" is the Navy's *vision* to organize, integrate, and *transform* in order to meet the challenges ahead**
- **In near to mid-term, the Navy expects large increases in precision, reach, and connectivity**
- **Future Navy forces will use information superiority and dispersed, networked forces to provide**
  - **Offensive power**
  - **Defensive assurance**
  - **Operational independence**
- **Continuing evolution of the Navy's strategy:**
  - **From**
    - **"Maritime Strategy" (1986) war-at-sea focus**
    - **"Forward … from the Sea" (1994) littoral focus**
  - **To a broadened strategy, Sea Power 21, where the Navy is fully integrated into global joint operations**

Sea Power 21 Series, *Naval Proceedings*, October 2002

"Sea Power 21" is the Navy's vision as to how to organize, integrate, and transform in order to meet the challenges ahead. In the near to mid-term, the Navy expects large increases in precision, reach, and connectivity, which will enable increased effectiveness. Future Navy forces will use information superiority and dispersed, networked forces to provide offensive power, defensive assurance, and operational independence.

"Sea Power 21" is part of a continuing evolution in the Navy's strategy from the "Maritime Strategy" in 1986 with its focus on war-at-sea open-ocean issues, tactics, and systems and "Forward…from the Sea" in 1994 with its emphasis on the littoral environment. The current state of the evolutionary process is the broadened strategy, "Sea Power 21," where the Navy is fully integrated into global joint operations.



"Sea Power 21" is a networked, sea-based power projection force assuring access worldwide. Three basic concepts integrated by a powerful network lie at the heart of "Sea Power 21." These are Sea Strike, Sea Shield, and Sea Basing. Sea Strike is the capability to project precise and persistent offensive power from the sea. Sea Shield extends defensive assurance throughout the world. Sea Basing enhances operational independence and support for the joint force. These three will be enabled by ForceNet, an overarching effort to integrate warriors, sensors, networks, command and control, platforms, and weapons into a fully netted, combat force.

The Navy of the future under the "Sea Power 21" strategy includes the following new capabilities:

- Extensive use of unmanned vehicles—air, surface, and underwater
- More effective and efficient versions of ships, submarines, and aircraft
- A global concept of operations (CONOPS) with new formations
- Emphasis on state-of-the-art technology in all of the Future Naval Capabilities
- A network that permits fully coordinated and integrated joint operations.

New ships include new carriers CVN(X), cruisers CG(X), destroyers DD(X), Littoral Combat Ships (LCSs), Maritime Prepositioning Force-Future [MPF (F)] ships, and Mine Countermeasures Support Ships (MCS).

New aircraft include the Joint Strike Fighter (JSF) and the F/A-18 E/F. The SSGN is a new guided-missile nuclear submarine. There are also new command and control initiatives like Littoral Pervasive Sensing (LPS), a Global Command and Control System-Maritime (GCCS-M). Future naval capabilities are being developed in areas including power projection, time critical strike, littoral antisubmarine warfare (ASW), missile defense, organic mine countermeasures (MCM), and autonomous operations.

New formations included in the Global Concept of Operations include the Carrier Strike Group (CSG) and the Expeditionary Strike Group (ESG).

Foundations of Sea Strike

- **Projection of dominant and decisive offensive power**
  - **Responsive, precise, and persistent**
- **Focus Elements**
  - **Precision strike**
  - **Marines**
  - **Special Forces**
- **Focus Capabilities**
  - **Persistent ISR**
  - **Time Sensitive Strike**
  - **Information Operations**
  - **STOM**
- **Action (not reaction)**
  - **Disrupt enemy timelines**
  - **Preempt enemy options**
  - **Ensure operational success**

Sea Power 21 Series, CNO, Proceedings, Oct 02
Naval Transformational Roadmap, CNO, CMC, Jun 02
Sea Power 21, Joint Power from the Sea, CNO, N-1

Sea Strike is a combination of transformational capabilities and a new concept of operations, the Expeditionary Strike Force

Projection of dominant and decisive offensive power from the sea in a responsive, precise, and persistent manner is the basis of Sea Strike. Through Sea Strike operations, the Navy will exert direct, decisive, and sustained influence in joint campaigns. The focus elements are precision strike including strike aircraft and cruise missiles, Marines, and Special Operating Forces. Sea Strike can also include the joint strike capabilities of the Army and Air Force as well as the offensive abilities of allies and coalition partners.

Focus capabilities of Sea Strike include persistent intelligence, surveillance, and reconnaissance (ISR), time-sensitive strike, information operations, and ship-to-objective maneuver (STOM). Sea Strike promotes action, as opposed to reaction, including disruption of enemy timelines and preemption of enemy options to ensure operational success.

Sea Strike is a combination of transformational capabilities, such as the JSF and the SSGN, and a new CONOPS that includes the Expeditionary Strike Force (ESF) composed of CSGs and ESGs.

Sea Strike Vision

- **Networked Navy sensors integrated with national and joint systems to penetrate all types of *__weather__* and cover producing vast amounts of timely data**
- **Rapid planning processes to tailor joint strike packages**
- **Full array of Sea Strike options: missiles with in-flight targeting, aircraft with stand-off precision weapons, ER naval gunfire, info ops, submarines, unmanned vehicles, Marines and SEALs**
- **Information superiority and flexible strike options will provide time-sensitive targeting faster and more accurately**
- **For expeditionary warfare, networking and info superiority will allow agile ground forces to produce warfighting impact similar to heavier forces of today**
- **Info superiority will enable the Navy to dominate timelines, limit enemy options, and deny enemy sanctuary**
- **Sea Strike operations add the unique independence, responsiveness, and on-scene endurance of naval forces to joint strike operations**

Sea Power 21 Series, CNO, Proceedings, Oct 02
Naval Transformational Roadmap, CNO, CMC, Jun 02
Sea Power 21, Joint Power from the Sea, CNO, N-1

With Sea Strike, networked, long dwell Navy sensors integrated with national and joint sensors are used to penetrate all types of weather and cover producing vast amounts of timely data. These data are used by rapid planning processes to tailor joint strike packages. A full array of strike options are available to be used including missiles with in-flight targeting, aircraft with stand-off precision weapons, extended range (ER) naval gunfire, information operations, submarines with strike missiles, unmanned vehicles, Marines and Navy Special Operations capabilities.

Information superiority and flexible strike options will provide time-sensitive targeting at far greater speed and accuracy than available today. For expeditionary warfare, networking and information superiority will allow agile ground forces to produce warfighting impact similar to heavier forces today. Information superiority will allow the Navy to dominate timelines, limit enemy options, and deny the enemy sanctuary.

Sea Strike operations will add the unique independence, responsiveness, and on-scene endurance of naval forces to joint strike operations. Sea Strike will provide amplified, effects-based striking power and increased precision attack. Increased information operations will give enhanced warfighting ability to Marines and Special Forces. Additional advantages include round-the-clock offensive operations and seamless integration with joint strike packages.

Sea Strike Programs

Representative Programs

	Time Sensitive Strike	Expeditionary Maneuver Warfare	Persistent ISR	EW/IO
Transformational	• JSF • CVN(X) • DD(X) • SSGN • Tactical Tomahawk	• Expeditionary Strike Group • MV-22	• Global Hawk • UUVs • E-2 Radar Modernization Program	• Airborne Electric Attack (AEA) Aircraft
Core	• F/A-18E/F • JDAM	• LPD-17 • LHD-8	• Multi-Mission Aircraft (MMA) • SSN-774	• Improved Capability EA-6B (ICAP III)

Stretch Goal:
- Sensor to Shooter from Minutes to Seconds
- Deep Inland Maneuver
- Continuous ISR

Near-Term Goal:
- Sensor to Shooter from Hours to Minutes
- Coastal Maneuver
- Responsive ISR

Sea Power 21 Series, CNO, Proceedings, Oct 02
Naval Transformational Roadmap, CNO, CMC, Jun 02
Sea Power 21, Joint Power from the Sea, CNO, N-1

The near-term goals for Sea Strike programs are sensor-to-shooter time reduction from hours to minutes, coastal maneuver, and responsive ISR, while the stretch goals are sensor-to-shooter time reduction from minutes to seconds, deep inland maneuver, and continuous ISR.

Representative programs are divided into four categories: time-sensitive strike, expeditionary maneuver warfare, persistent ISR, and electronic warfare (EW)/ information operations (IO). In each category, both core and transformational programs are identified.

Representative time-sensitive strike core programs are the F/A-18 E/F fighter/attack aircraft and the Joint Direct Attack Munition (JDAM). Representative transformational programs are Tactical Tomahawk, SSGN, DD(X), CVN(X), and JSF.

Representative expeditionary maneuver warfare core programs are the LHD-8 and LPD-17 amphibious ships. Representative transformational programs are the MV-22 tilt-rotor aircraft and the ESG formation. The ESG consists of an Amphibious Ready Group (ARG) of one LDA/LHD, one LPD-17, one LSD-41, one CG, one DDG, and one DD(X).

Representative persistent ISR core programs are the SSN-774 and the Multi-Mission Aircraft (MMA), while representative transformational programs are Global Hawk, unmanned undersea vehicles (UUVs), and the E-2 Radar Modernization Program.

The representative EW/IO core program is the Improved Capability EA-6B (ICAP III), while the representative transformational program is the Airborne Electric Attack (AEA) Aircraft.

Foundations of Sea Shield

- **Exploits sea control, global naval presence, and networked intelligence to:**
  - **Protect homeland**
  - **Assure allies**
  - **Dissuade and deter enemies**
  - **Ensure access**
- **Focus Elements**
  - **Defense in depth, speed**
  - **MPA, ships, sea-based aircraft**
  - **SSNs, SSBNs (strategic deterrence)**
  - **Prepositioned assets, unmanned vehicles**
  - **Long-range radars and missiles, CEC**
- **Focus Capabilities**
  - **Theater Air and Missile Defense**
  - **Sea and Littoral Superiority**
  - **Homeland Defense**
  - **Force Entry Enabling**

Sea Power 21 Series, CNO, Proceedings, Oct 02
Naval Transformational Roadmap, CNO, CMC, Jun 02
Sea Power 21, Joint Power from the Sea, CNO, N-1

Sea Shield uses transformational capabilities in order to project Global Defensive Assurance

In the past naval defense has provided protection for the unit, fleet, and sea lines of communications. Sea Shield broadens this protection to include sea-based theater and strategic defense. Sea Shield exploits sea control, global naval presence, and networked intelligence to protect the homeland, assure allies, dissuade and deter enemies, and ensure access. The focus elements of Sea Shield are defense in depth, speed, Maritime Patrol Aircraft (MPA), ships, sea-based aircraft, SSNs, SSBNs for strategic deterrence, prepositioned assets, unmanned vehicles, long-range radars and missiles, and Cooperative Engagement Capability (CEC). These elements will work together to contribute to the main benefit of the Sea Shield concept: achieving battle-space superiority in forward theaters.

The focus capabilities of Sea Shield are Theater Air and Missile Defense, sea and littoral superiority, homeland defense, and force entry enabling. The focus elements and capabilities enable the Navy to protect high-valued elements in transit or in operations off the coast of a hostile country. In addition, these focus elements and capabilities enable the Navy to dominate the littorals and provide access for joint and coalition forces into these areas. These same elements will be used to identify, track, and intercept threats before they endanger the homeland.

Sea Shield uses transformational capabilities to project Global Defensive Assurance.

Sea Shield Vision

- Project defensive power globally
- Extend homeland security via forward presence
- Ensure access via dominance in littorals
- Protect joint forces and allies ashore
  - Extend defensive umbrella inland
  - Provide operational security for ground forces
  - Enhance strategic stability for friends and allies

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Sea Power 21, Joint Power from the Sea, CNO, N-1

The Sea Shield vision is to protect U.S. interests with layered global defensive power based on control of the seas, forward presence, and networked intelligence. These strengths will extend homeland security via forward presence, ensure access via dominance in the littorals, and protect joint forces and allies ashore. Protection of forces ashore includes extending the defensive umbrella deep inland, providing operational security for ground forces, and enhancing strategic stability for friends and allies. Again, these operations will be based on information superiority, total force networking, and an agile and flexible sea-based force.

Sea Shield Programs

Representative Programs

	Homeland Defense	Sea/Littoral Control	Theater Air and Missile Defense	Force Entry Enabling
Transformational	• USCG Deepwater Project • Ballistic Missile Defense	• LCS • DD(X) • Global Hawk	• SM-5 • CG(X) • Cooperative Engagement Capability	• Organic MCM • Modular Mission Payloads • AUVs • CUP
Core	• NBC Response Capability • National Maritime Intelligence (NMIC) • Patrol Craft	• SSN 774 • SSN 688 • P-3 • DDG-51	• SM 2 BLK IIIB • AIM-9X • CG Conversion	• MH-60 • MCM • MHC

Stretch Goals:
- Theater Defense
- JOA Clearance: Days to Hours

Near-Term Goals:
- Area Defense
- JOA Clearance: Weeks to Days

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Sea Power 21, Joint Power from the Sea, CNO, N-1

The goals for Sea Shield are established for the near term and far term, called stretch goals. In the near term, the goals are solid, deep, and broad area defense and clearance of the Joint Operating Area (JOA) in days as opposed to weeks.

Representative Sea Shield programs are given for both core and transformational programs in each of four categories: homeland defense, sea and littoral control, Theater Air and Missile Defense, and force entry enabling. Homeland defense core programs that are representative include nuclear, biological, and chemical (NBC) response capability, National Maritime Intelligence Capability (NMIC), and patrol craft for coastal surveillance and defense. Representative homeland defense programs that are transformational include the U.S. Coast Guard Deepwater Project to develop and build highly capable cutters and ballistic missile defense.

For sea and littoral control, representative core programs include SSN 688 and 774 attack submarines, the P-3 surveillance and ASW aircraft, and the DDG-51 guided missile destroyer. Representative programs that are transformational include the LCS, the DD(X), and Global Hawk.

Theater Air and Missile Defense core programs include the SM-2 Block IIIB standard missile, AIM-9X air intercept missile, and cruiser (CG) conversion program. Representative programs that are transformational include the SM-5 missile, CG(X), and CEC.

Force Entry Enabling representative core programs include the MH-60 helicopter, and MCM and MHC ships for mine warfare and mine countermeasures (MCM). Representative programs that are transformational include organic MCM modular mission payloads to deploy and employ MCM capabilities on Navy warships, Autonomous Underwater Vehicles (AUVs), and the Common Underwater Picture (CUP) part of ForceNet.

Foundations of Sea Basing

- **Employs a secure, mobile, networked base of ships to:**
  - **Exploit maneuver space of the sea**
  - **Reduce vulnerability of U.S. forces**
  - **Enhance operational employability and redeployability**
  - **Provide base for global C2 and extended logistics support**
  - **Only land forces required to fight ground battle**
  - **Reduce dependency on foreign bases**
- **Focus Elements**
  - **Warships, submarines**
  - **CLF ships**
  - **Maritime Prepositioned Ships and Squadrons**
  - **Strategic sealift and support ships**
- **Focus Capabilities**
  - **Command and control**
  - **Fire support (offensive and defensive)**
  - **Integrated joint logistics**

Sea Basing provides the platforms from which offensive and defensive fires are projected, making Sea Strike and Sea Shield realities

Sea Power 21 Series, CNO, Proceedings, Oct 02
Naval Transformational Roadmap, CNO, CMC, Jun 02
Sea Power 21, Joint Power from the Sea, CNO, N-1

Sea Basing is the foundation from which offensive and defensive fires are projected. The foundation of Sea Basing is a secure, mobile, networked base of capable platforms to exploit the maneuver space of the sea, to reduce vulnerability of U.S. forces, to enhance operational employment and the capability for redeployment, to provide a base for global command and control (C2) and extended logistics support, to only land the forces required to fight the ground battle, and to reduce dependency on foreign bases. Sea Basing capabilities also extend integrated logistical support to other Services, strengthens force protection, and allows air/sea lift to support on-shore missions.

Focus elements include warships, submarines, combat logistics force (CLF) ships, Maritime Prepositioning Ships (MPS) and Squadrons (MPSRons), and strategic sealift and support ships. Focus capabilities include command and control, offensive and defensive fire support, and integrated joint logistics.

Sea Basing provides the platforms from which offensive and defensive fires are projected, making Sea Strike and Sea Shield realities.

Sea Basing Vision

- **Provide a secure, mobile, networked base from which U.S. forces can operate or from which forces can be deployed, employed, and redeployed**
- **Increase operational independence**
- **Generate greater efficiencies in joint logistics support afloat**
  - **Joint supplies**
  - **Common ammunition**
  - **Critical maintenance**
  - **Selective offload**
- **Provide a base for global C2 and offensive and defensive power projection**
- **Accelerate timelines for deployment, employment, and redeployment**

Sea Power 21 Series, CNO, Proceedings, Oct 02
Naval Transformational Roadmap, CNO, CMC, Jun 02
Sea Power 21, Joint Power from the Sea, CNO, N-1

The vision of Sea Basing is to provide a secure, mobile, networked base from which U.S. forces can operate or from which forces can be deployed, employed, and redeployed. Such a sea base increases operational independence and generates greater efficiencies in joint logistics support afloat with joint supplies, common ammunition, critical maintenance, and selective offload. A sea base also provides a base for global command and control and offensive and defensive power projection. The sea base accelerates timelines for deployment, employment, and redeployment providing more options for commanders.

The prepositioning of vital equipment and supplies in-theater accelerates expeditionary deployment timelines. Strategic sea-lift is central to this effort. Providing joint supplies, common ammunition, and repairs from afloat platforms to in-theater commanders will greatly increase operational effectiveness—both to U.S. troops and coalition allies. Benefits gained from Sea Basing include pre-positioned warfighting capabilities for immediate employment, enhanced joint support from a fully netted, dispersed naval force, strengthened international coalition building, increased joint force security and operational agility, and minimized operational reliance on shore infrastructure.

Sea Basing Programs

	Representative Programs		
Transformational	• MPF(F)	• ForceNet Concept • Cooperative Engagement Capability (CEC)	• JSF • DD(X) • AGS • Naval Fires Network (NFN) • Tactical Tomahawk
Core	• MH-60S • T-AOE(X) • T-AK	• NMCI/IT-21 • GCCS-M • Mobile User Objective System (MUOS)	• F/A-18E/F • JDAM • Tomahawk • ERGM
	Logistics	Command and Control	Fire Support

Stretch Goals:
- Years on station
- Deep fire support
- Heavy sea transfer
- Seamless C3

Near-Term Goals:
- Months on station
- Coastal fire support
- Light sea transfer
- Enhanced C3

Sea Power 21 Series, CNO, Proceedings, Oct 02
Naval Transformational Roadmap, CNO, CMC, Jun 02
Sea Power 21, Joint Power from the Sea, CNO, N-1

Near-term goals for Sea Basing programs are to remain on-station for months and to provide coastal fire support, light transfer at sea, and enhanced command, control, and communications (C3). The stretch goals are to remain on-station for years and to provide deep fire support, heavy transfer at sea, and seamless C3.

Representative Sea Basing programs are given for core and transformational programs in three categories: logistics, command and control, and fire support.

Core programs that are representative of the logistics category include the MH-60S helicopter, the T-AOE(X) CLF resupply ships, and the T-AK current MPF ships. The representative transformational program for logistics is MPF(F).

In the command and control category, representative core programs for Sea Basing are National Maritime Command Information (NMCI)/Information Technology-21 (IT-21), Global Command and Control System-Maritime (GCCS-M), and the Mobile User Objective System (MUOS). Representative transformational programs include the ForceNet concept and CEC.

Representative core programs for Sea Basing in the fire support category include the F/A-18 E/F fighter and attack aircraft, JDAM, Tomahawk land attack missile, and Extended Range Gun Munition (ERGM). Transformational core programs include the JSF, DD(X), Advanced Gun System (AGS) 155-mm gun for the DD(X), Naval Fires Network (NFN), and Tactical Tomahawk.

Transformational Impact

Sea Strike

- Double strike aim points within 10 years
- Continuous battlespace coverage via long-dwell sensors
- Agile targeting via unmanned loitering vehicles
- Enhanced strike presence via Expeditionary Strike Groups

Sea Shield

- Extended homeland defense via forward deployed forces
- Assured access via networked ships, submarines & aircraft
- Projected defense over joint and allied forces
- Ballistic missile defense over homeland and strategic partners

Sea Basing

- Global connectivity afloat for joint commanders
- Forward bases & logistics via prepositioned ships
- Extended fire support via Advanced Gun System and Enhanced Range Guided Munition
- Focused logistics in support of joint forces

Fully integrated naval, land, and air forces across a unified battlefield

Sea Power 21, Joint Power from the Sea, CNO, N-1

The transformational impact of Sea Strike, Sea Shield, and Sea Basing is fully integrated naval, land, and air forces across a unified battlefield.

For Sea Strike, the transformational impact is twice the aim points within 10 years, a continuous battlespace coverage with long-dwell sensors, agile targeting with unmanned loitering vehicles, and enhanced strike presence with ESGs. Sea Strike will accomplish this through use of autonomous, organic, long-dwell sensors, integrated national, theater, and force sensors, knowledge-enhancement systems, unmanned combat vehicles, hypersonic missiles, electro-magnetic rail guns, and hyper-spectral imaging.

The transformational impact of Sea Shield is extended homeland defense with forward deployed forces, assured access with networked ships, submarines, and aircraft, projected defense over joint and allied forces, and ballistic missile defense over homeland and strategic partners. Transformation will be attained through use of interagency intelligence and communications reach-back systems, organic mine countermeasures, multi-sensor cargo inspection equipment, advanced hull forms and modular mission payloads, directed-energy weapons, autonomous unmanned vehicles, common undersea picture, single integrated air picture, distributed weapons coordination, and theater missile defense.

For Sea Basing, the transformational impact is global connectivity afloat for joint commanders, forward bases and logistics with prepositioned ships, extended fire support with AGS and ERGM, and focused logistics in support of joint forces. Future transformational impact will be achieved through enhanced sea-based joint command and control, heavy equipment transfer capabilities, intra-theater high-speed sealift, improved vertical delivery methods, integrated joint logistics, rotational crewing infrastructure, and international data-sharing networks.

ForceNet

- The operational construct and architectural framework for naval warfare using an integrated, networked, distributed force
- Combat capabilities are increased with aligned and integrated systems, functions, and missions
- Impact
  - Connected warriors, sensors, networks, command and control, platforms, and weapons
  - Accelerated speed and accuracy of decision
  - Integrated knowledge to dominate the battlespace
- Capabilities
  - Expeditionary, multi-tiered, sensor and weapon grids
  - Distributed, collaborative command and control
  - Dynamic, multi-path and survivable networks
  - Human-centric integration

Sea Power 21, Joint Power from the Sea, CNO, N-1

ForceNet is the operational construct and architectural framework for naval warfare using an integrated, networked, distributed force. It enables and integrates Sea Strike, Sea Shield, and Sea Basing. It integrates warriors, sensors, command and control, platforms, and weapons into a networked, distributed combat force.

With ForceNet, combat capabilities are increased with aligned and integrated systems, functions, and missions. The impact of ForceNet includes connected warriors, sensors, networks, command and control, platforms, and weapons; accelerated speed and accuracy of decision; and integrated knowledge to dominate the battlespace.

ForceNet capabilities include expeditionary, multi-tiered, sensor and weapon grids; distributed, collaborative command and control; dynamic multi-path and survivable networks; adaptive/automated decision aids; and human-centric integration.

Global Concept of Operations

- **Disperse combat striking power around the world by:**
  - **Creating additional operational groups**
  - **Using technological advancements to increase platform capability**
  - **Networking all assets together**
- **Impact of Global CONOPS**
  - **Distributed, networked striking power**
  - **Increased presence, flexibility, and responsiveness**
  - **Task-organized forces to deter forward, respond to crises, and win decisively**
- **Naval capability packages assembled from forward-deployed forces**
  - **Tailored to the mission need**
  - **Sized to magnitude of task**
  - **Made to complement other available joint assets**
- **Result: Simultaneous naval response to a continuum of conflict around the world with increased striking power, flexibility, and responsiveness**

Sea Power 21, Joint Power from the Sea, CNO, N-1

The Navy has developed a Global CONOPS. This concept disperses combat striking power around the world by creating additional operational groups, using technological advancements to increase platform capability to act as power projection forces, and networking all assets together for expanded warfighting effect.

The impact of Global CONOPS includes distributed, networked striking power to support joint operations, increased presence, flexibility, and responsiveness, and task-organized forces to deter forward, respond to crises, and win decisively.

Capability packages of naval forces can be assembled from forward-deployed forces. The packages are tailored to the mission need, sized to the magnitude of the task, and made to complement other available joint assets.

The result of the CONOPS is simultaneous naval response to a continuum of conflict around the world with increased striking power, flexibility, and responsiveness.

Global CONOPS will implement a force structure that includes CSGs, ESGs, MDSAGs, specifically modified Trident submarines and enhanced capability CLF.

Force Structure for Global CONOPS
OPNAV Instruction 3501.316A (Draft)

- **Draft instruction dated Sep 03 provides definitions for force structure supporting Naval Operating Concept (NOC) for Joint Operations through 2020**
- **Elements of naval forces:**
  - **Expeditionary Strike Forces (ESFs)**
  - **Carrier Strike Groups (CSGs)**
  - **Expeditionary Strike Groups (ESGs)**
  - **Surface Strike Groups (SSGs)**
  - **Missile Defense Surface Action Groups (MDSAGs)**
  - **Individual units**
  - **Reinforced by Maritime Prepositioning Groups (MPGs)**
- **The Instruction**
  - **Does not specify total numbers of these elements**
  - **Defines the elements in general terms (CG or DDG)**
  - **Includes older ships (FFG and DD)**
- **More specific definition, based on projected force levels, developed in 2002 by N81**

OPNAV instruction 3501.316A dated September 2003 (as yet unsigned) provides definitions for the elements of the force structure supporting the Naval Operating Concept (NOC) for joint operations through 2020. The elements are defined on this chart. The instruction does not specify total numbers for these elements based on the projected force levels for the ship types. It defines the elements in general terms, like "CG or DDG," and includes the older ships, FFGs and DDs, that will be replaced by CGXs and DDXs.

More specific information was developed in 2002 by N81. This information is based on projected force levels and may be more useful to studying the future Navy. This information is summarized in the next two charts.

N81 Force Structure for Global CONOPS

- Requires a fleet of surface combatants, submarines, CLF ships and other support ships
- Developed in 2002
- Based on projected force levels:
  - 27 CGs, 61 DDGs, 16 DDXs; 104 total surface combatants
  - 4 guided-missile submarines (SSGNs)
- Increased striking power from 12 Carrier Battle Groups (CVBGs) to:
  - 12 CSGs
  - 12 ESGs
  - 9 SSGs or MDSAGs
  - 4 SSGNs
  - These groups can operate independently or combine to form ESFs when engaged in regional conflict and can be reinforced by MPGs

The force structure for the Global CONOPS, as defined by N81 in 2002, requires a fleet of surface combatants, submarines, CLF ships, and other support ships. Striking power is increased from 12 Carrier Battle Groups (CVBGs) to 12 CSGs, 12 ESGs, 9 SSGs or MDSAGs, and 4 SSGNs. These groups can operate independently or combine to form ESFs when engaged in regional conflicts. Any of the groups can be reinforced by one or more MPGs.

Number of Combatant Formations
-In the Navy's Global CONOPs-

- 12 Carrier Strike Groups (CSG)
  - 1 CVN, 1-TAOE, 1 SSN
  - 1 CG, 2 DDGs, 2-3 LCSs
- 12 Expeditionary Strike Groups (ESG)
  - 1 LHD, 1 LPD, 1 LSD
  - 1 CG, 1 DDG, 1 DDX, 2-3 LCSs, 1 SSN
- 9 Surface Strike Groups (SSG) or Missile Defense Surface Action Groups (MDSAG)
  - Either 1 CG and 2 DDGs or 3 DDGs
- 4 SSGNs
- 4 DDXs for surge
- One additional DDG in Japan
- Total Number of Surface Combatants
  - 27 CGs, 61 DDGs, 16 DDXs, 60 LCSs; 164 Total

The Navy's (N81) Global CONOPs force structure, developed in 2002, defines surface combatant formations for CSG, ESG, and SAG assuming 16 DDXs

This chart summarizes the assignment of surface combatants to the 33 formations in N81's Global CONOPs. Based on the assumption that there would be 60 LCSs, we added the LCSs to the formations in this CONOPs. Each of the 12 CSGs have one CG, two DDGs, two or three LCSs and one AOE-type CLF ship. Each of the 12 ESGs have one CG, one DDG, one DDX and two or three LCSs in addition to the three amphibious ships in the ARG. Three of the SAGs have one CG and two DDGs, while six have three DDGs. Four DDXs are held for surge. One additional DDG is stationed in Japan. The total numbers of surface combatants is 27 CGs, 61 DDGs, 16 DDXs, and 60 LCSs for a total of 164 ships. There are 12 carriers and 12 ARGs made up of a large deck amphibious ship, LHA or LHD, one LPD, and one LSD. Recent reports have indicated that the entire purchase of 12 LPD-17 class ships may not be completed.

Carrier Air Wing and ARG Aviation Combat Element (ACE) Aircraft

- **Carrier Air Wing**
  - **44-46 strike/attack aircraft**
    - **Now: F-14 A/D, F/A-18 A/C/E/F**
    - **Future: Joint Strike Fighters (JSFs)**
  - **4 E-2C AEW**
  - **6 F-18G, replacing the EA-6B for SEAD, EW**
  - **6 S-3B ASUW, tanker**
  - **12 MH-60 R/S ASW, CSAR, logistics**
- **ARG**
  - **6 fighter/attack**
    - **Now: AV-8B VSTOL**
    - **Future: JSF**
  - **12 medium/heavy-lift helicopters**
    - **Now: CH-46 medium-lift and CH-53E heavy-lift**
    - **Future: MV-22 and CH-53E**
  - **4 AH-1 gunship helicopters**
  - **2 UH-1 command helicopters**
  - **1 multi-mission detachment: MH-60 R/S (likely 4 to 8)**

OPNAV instruction 3501.316A indicates that the carrier air wing will be composed of the following aircraft:

- 44-46 strike/fighter aircraft: F-14 A/D, F/A-18 A/C/E/F now and JSFs in the future
- 4 E-2C AEW aircraft
- 6 F-18Gs, replacing the EA-6B for suppression of enemy air defense (SEAD)/EW aircraft
- 6 S-3B aircraft for surface warfare and tanking
- 12 MH-60 R/S helicopters for ASW, combat search and rescue (CSAR), and logistics.

The instruction also indicates that the three amphibious ships in the ARG will carry the following aircraft:

- 6 AV-8 VSTOL fighter/attack aircraft
- 12 CH-46/53 helicopters now and MV-22s in the future with the CH-53Es
- 4 AH-1 gunship helicopters
- 2 UH-1 command helicopters
- 1 multi-mission helicopter detachment of MH-60 R/S helicopters, likely 4 to 8 helicopters

To simplify the analysis, the programmer aircraft are assumed equivalent to a mix of JSF and tilt-rotor aircraft. This results in 60 EX-JSF and 12 tilt-rotor aircraft in the Carrier Air Wing and 6 VSTOL JSF and 24 tilt-rotor aircraft in the ARG.

Outline

- Sea Power 21
  - Sea Strike
  - Sea Shield
  - Sea Basing
  - ForceNet
  - Global Concept of Operations
- Future Naval Capabilities (FNCs)
- Future Naval Systems
  - Pervasive Littoral Sensing
  - Littoral Combat Ship (LCS)
  - DD(X)
  - CG(X)
  - MCS(X)
  - Joint Strike Fighter (JSF)
  - SSGN

Future Naval Capabilities (FNCs) are described in this section.

Future Naval Capabilities (FNCs)

- **Developed by ONR**
  - **Investment Strategy: Capabilities by Priority**
  - **Transition Opportunities**
  - **Sustaining Science and Technology**
- **List of 12**
  - **Littoral ASW**
  - **Missile Defense**
  - **Power Projection**
  - **Organic MCM**
  - **Time-Critical Strike**
  - **Autonomous Operations**
  - **Electric Warships and Combat Vehicles**
  - **Platform Protection**
  - **Warfighter Protection**
  - **Capable Manpower**
  - **Total Ownership Cost Reduction**
  - **Knowledge Superiority and Assurance**

Source: ONR

FNCs are programs at the Office of Naval Research (ONR) to guide research and development in specific capability areas. Each of the 12 FNCs is described by ONR in terms of an investment strategy with capabilities prioritized, opportunities for transitioning from current to future capabilities, and the science and technologies important to sustaining the development of the future capability.

Littoral ASW

- **Investment Strategy Capabilities**
  - **Detect, classify, localize, and track targets**
  - **Characterize the littoral battlespace**
  - **Deploy and sustain surveillance systems rapidly and covertly**
  - **Engage or neutralize bottomed, surfaced, or low-Doppler undersea targets**
- **Science and Technology Focus Areas**
  - **Advanced materials**
  - **Autonomous control theory to optimize sensor capabilities**
  - **Ocean acoustics**
  - **Signal processing**
  - **Environmental measurement technology for accurate *in-situ* measurement of environmental parameters**

Source: ONR

ONR's investment strategy for the littoral ASW FNC includes capabilities to detect, classify, localize, and track targets for engagement before they reach their weapon release range. The littoral battlespace will be portrayed to provide input to the common tactical and environmental picture. In addition, surveillance systems will be deployed and sustained rapidly and covertly for wide area search, detection, and cueing. Naval forces will engage and neutralize bottomed, surfaced, or low-Doppler undersea targets beyond enemy weapon release range.

The science and technology focus areas of the littoral ASW FNC include advanced materials, autonomous control theory to optimize sensor capabilities by facilitating automated environmental adaptation, ocean acoustics, signal processing, and environmental measurement technology for accurate in-situ measurement of environmental parameters to allow sensor automation and adaptation.

The investment strategy for missile defense is focused on the gaps in the current Navy and Marine Corps Theater Air and Missile Defense and development of technology to enable baseline overland missile defense. The capabilities and characteristics of this technology include the following:

- Capability to engage all air threats in the littorals where clutter is often severe and terrain may hinder surface-based sensors
- Integration of organic Navy airborne surveillance and tracking systems with battle management and surface missile-firing units
- Basis for overland missile defense for units engaged in Operational Maneuver from the Sea (OMFTS) and STOM.

Missile Defense
-Continued-

- Science and Technology Focus Areas
  - Advanced math techniques
  - Multicolor focal plane arrays
  - Solid state radar components
  - Photonics for improvements in data transmission
  - Automated decision-making to improve battle management
  - Advanced warhead materials

Source: ONR

The Missile Defense FNC includes several science and technology focus areas. Advanced mathematics techniques will be implemented to improve data correlation, sensor fusion, combat identification (CID), and threat evaluation. Multicolor focal plane arrays will be used for infrared (IR) long range, precision detection and tracking of theater ballistic missiles (TBMs). Solid-state radar components will enable affordable, lightweight, and powerful new radars. Photonics for improvements in data transmission will enable improved sensor performance and better processors. Automated decision-making will improve battle management involving multiple sensors and firing units against numerous simultaneous missiles. Advanced warhead materials using lightweight fragments will react to inflict catastrophic damage to missile airframes, seekers, propulsion, and payloads.

Littoral Combat and Power Projection

- Expeditionary operations require full spectrum of combat capability and flexible, efficient logistics support
- Initial focus on logistics
- Investment Strategy Capabilities
  - Capability to deploy from and reconstitute to sea base, and to supply or resupply both sea base and maneuver units—delivery is first priority
    - Current limitations at SS3, seek to improve up to SS5
  - Provide tactical and logistical C2 within a common C4ISR architecture shared with maneuver forces
- Science and Technology Focus Areas
  - Mathematical modeling to improve logistics wargame simulations
  - Ship structures and hydrodynamics to enhance surface distribution of equipment and sustainment
  - Information technology for improved C2
  - Motion and load control studies critical to enable higher sea state operations

Source: ONR

The Littoral Combat and Power Projection FNC enhances expeditionary operations, which require the full spectrum of combat capability and flexible, efficient logistics support. Initially, this FNC will focus on logistics. Investment strategy for the Littoral Combat and Power Projection FNC includes the capability to deploy from and reconstitute to the sea base and to supply or resupply both the sea base and the maneuver units. Delivery is the first priority. Currently loading of surface delivery craft at the sea base is limited to Sea State 3 (SS3). This FNC seeks to improve this capability to Sea State 5 (SS5).

The FNC will also provide tactical and logistical C2 within a common command, control, communications, computers, intelligence, surveillance, and reconnaissance (C4ISR) architecture shared with the maneuver elements.

Science and technology focus areas for this FNC include mathematical modeling to improve logistics wargame simulations, ship structures and hydrodynamics to enhance surface distribution of equipment and sustainment, information technology for improved C2, and motion and load control studies critical to enable higher sea state operations.

Organic MCM

- **Investment Strategy Capabilities**
  - **Provide organic MCM to enable OMFTS and STOM**
  - **Provide rapid, stand-off organic MCM to support movement of combatants throughout Littoral Penetration Area (LPA)**
- **Science and Technology Focus Areas**
  - **Nanoelectronics to permit development of small low-power electronics for small, highly capable AUVs, UUVs, and smart weapons**
  - **Autonomous control theory to enable control of multiple AUVs and UUVs**
  - **Coupled ocean and atmospheric modeling for enhanced representation of boundaries in Wx and ocean forecasting**
  - **Photonics for improvements in lasers, comms, and data processing. Laser line scan is important to sensors used to detect and classify mines**
  - **Biosensors and biodetectors to enable breakthroughs in mine detection and classification**
  - **Automated decision-making with robotics to permit replacement of humans in dangerous situations**

Source: ONR

The investment strategy for the Organic Mine Countermeasures (MCM) FNC includes capabilities to provide organic MCM to enable OMFTS and STOM, and rapid, stand-off organic MCM to support the movement of combatants throughout the Littoral Penetration Area (LPA).

Science and technology focus areas for this FNC include nanoelectronics to help in development of small low-power electronics for small, highly capable AUVs, UUVs, and smart weapons. Autonomous control theory will enable control of multiple AUVs and UUVs. The FNC also provides coupled ocean and atmospheric modeling for enhanced representation of boundaries in weather and ocean forecasting and photonics for improvements in lasers, communications, and data processing (laser line scan is important to sensors used to detect and classify mines). Biosensors and biodetectors will enable breakthroughs in mine detection and classification, and automated decision-making with robotics will permit replacement of humans in dangerous situations.

Time-Critical Strike

- **Investment Strategy Capabilities**
  - **Capability to defeat the following target types at long range**
    - **Expeditionary warfare targets with naval fires**
    - **Relocatable targets**
    - **Short dwell-time targets**
    - **Moving targets**
    - **Hard and deeply buried targets**
- **Science and Technology Focus Areas**
  - **Advanced electronics to improve sensors and seekers**
  - **Advanced materials to improve strike systems in the areas of structure and energy**
  - **Research on propulsion and aerodynamics to enable small, high-speed missiles for strike missions**
  - **RF systems and architectures as well as information systems, technologies, and operations to improve C4ISR for operational agility**

Source: ONR

The Time-Critical Strike FNC investment strategy includes the capability to defeat the following target types at long range: expeditionary warfare targets with naval fires, relocatable targets, short dwell-time targets, moving targets, and hard and deeply buried targets.

Science and technology focus areas for this FNC include advanced electronics to improve sensors and seekers, advanced materials to improve strike systems in the areas of structure and energy. Research on propulsion and aerodynamics will enable small, high-speed missiles for strike missions. Radio frequency (RF) systems and architectures as well as information systems, technologies, and operations will improve C4ISR for operational agility.

Autonomous Operations

- **Investment Strategy Capabilities**
  - **Provide access in all conditions to areas of responsibility thru organic uninhabited systems that can be dynamically retasked**
  - **Enable automated surveillance and reconnaissance in all environmental conditions thru miniaturized, low energy sensors and payloads**
  - **Enable automated surveillance and reconnaissance data processing**
  - **Enable secure jam-resistant network-centric warfare at extended ranges thru data relay and sensor-to-shooter to weapon connectivity**
  - **Minimize human intervention by automating operating functions, and by enabling the operations and interoperability of manned and unmanned platforms**

Source: ONR

The investment strategy for the Autonomous Operations FNC includes the capabilities to provide access in all conditions to areas of responsibility through organic uninhabited systems that can be dynamically retasked. Automated surveillance and reconnaissance in all environmental conditions will be enabled through miniaturized, low energy sensors and payloads.

The FNC will also enable automated surveillance and reconnaissance data processing and secure jam-resistant network-centric warfare at extended ranges through data relay and sensor to shooter to weapon connectivity. In addition, human intervention will be minimized by automating operating functions and by enabling the operations and interoperability of manned and unmanned platforms.

Autonomous Operations
-Continued-

- **Science and Technology Focus Areas**
  - **Autonomous control theory to improve system performance and the capability to control multiple vehicles**
  - **Automation of human decision-making to enhance design and operation of autonomous vehicles**
  - **Advanced materials and nanoelectronics crucial to development of autonomous vehicles, including structures, propulsion plants, and electronics**

Source: ONR

The science and technology focus areas for the Autonomous Operations FNC include autonomous control theory to improve system performance and the capability to control multiple vehicles, automation of human decision-making to enhance the design and operation of autonomous vehicles, and advanced materials and nanoelectronics critical to the development of autonomous vehicles, including structures, propulsion plants, and electronics.

Electric Warships and Combat Vehicles

- **INVESTMENT STRATEGY CAPABILITY OBJECTIVES**
  - **To improve tactical endurance**
  - **To support high-energy weapons and systems**
  - **To enhance survivability**

Source: ONR

The investment strategy for the Electric Warships and Combat Vehicles FNC includes the improvement of tactical endurance by increasing the power available to mission-critical systems, enabling tactical efficiency and increased payload fraction.

The FNC also supports high-energy weapons and systems in order to provide power on demand for such systems as pulsed power weapons and aircraft launch systems. It will also enhance survivability by reducing susceptibility to damage and increasing the capability to continue operations after sustaining damage to electrical systems.

Electric Warships and Combat Vehicles
-Continued-

- **SCIENCE AND TECHNOLOGY FOCUS AREAS**
  - **Materials science, including wide bandgap semiconductors and devices**
  - **High-temperature superconductivity and magnetic materials**
  - **Energy-dense capacitors and advanced energy storage devices**
  - **Integrated hydrodynamic and propulsion system design**

Source: ONR

The science and technology focus areas for the Electric Warships and Combat Vehicles FNC include materials science, especially wide bandgap semiconductors and devices to increase solid state power and efficiency. High-temperature superconductivity and magnetic materials will enable development of advanced electric motors and power distribution grids. Energy-dense capacitors and advanced energy storage devices will permit miniaturization pulsed power systems. Finally integrated hydrodynamic and propulsion system design will enable significant performance improvements in the littorals.

Platform Protection

- INVESTMENT STRATEGY CAPABILITIES
  - Avoid or defeat torpedoes and mines
  - Avoid or defeat threat weapons and platforms in littorals
  - Resist and control damage while preserving operational capability
- SCIENCE AND TECHNOLOGY FOCUS AREAS
  - Nanoelectronics (N/E)
  - Micro Electro-Mechanical System (MEMS) and N/E
  - Material science, including wide bandgap semiconductors and devices

Source: ONR

The investment strategy for the Platform Protection FNC includes capability objectives to avoid or defeat torpedoes and mines, to avoid or defeat threat weapons and platforms in the littorals, and to resist and control damage while preserving operational capability.

The science and technology focus areas for the Platform Protection FNC include Nanoelectronics (N/E) to permit faster electronic devices and revolutionary circuit architectures. In addition, Micro Electro-Mechanical System (MEMS) and N/E will provide advances in sensors for large area external acoustic and electro-magnetic arrays. Materials science, including wide bandgap semiconductors and devices, will increase solid state power and efficiency and enhance platform survivability.

Platform Protection
-Continued-

- **SCIENCE AND TECHNOLOGY FOCUS AREAS-CONTINUED**
  - **Structural acoustic models**
  - **RF architectures and technologies**
  - **Integrated hydrodynamic and propulsion system design**

Source: ONR

The science and technology focus areas for the Platform Protection FNC also include structural acoustic models that include the ocean free surface and radiation from surface ships to continue improving platform protection and understanding of the operational environment. RF architectures and technologies, like radar cross section (RCS) prediction models using hybrid finite element analysis, physical theory of diffraction, and E/M scattering models will enable high fidelity predictions. To enhance stealth and improve mobility in the littorals, an integrated hydrodynamic and propulsion system design will be implemented.

Knowledge Superiority and Assurance

- **INVESTMENT STRATEGY CAPABILITIES TO PROVIDE**
  - Consistent knowledge for a common tactical and operational picture
  - Dynamically managed, flexible, and interoperable bandwidth, with high capacity connectivity and enhanced network management
  - Tools for rapid threat assessment and response to time-critical threats
  - Tools for distributed, collaborative planning, rehearsal, and execution for all levels of command
- **SCIENCE AND TECHNOLOGY FOCUS AREAS**
  - Cognitive science
  - RF architectures and technologies and the physics of radiation
  - Information science and collaborative technologies
  - Environmental sciences

Source: ONR

The investment strategy for the Knowledge Superiority and Assurance FNC includes capability objectives to provide consistent knowledge for a common tactical and operational picture, and dynamically managed, flexible, and interoperable bandwidth with high capacity connectivity and enhanced network management. New tools will be employed for rapid threat assessment and response to time-critical threats, and for distributed, collaborative planning, rehearsal, and execution for all levels of command.

The science and technology focus areas for the Knowledge Superiority and Assurance FNC include cognitive science to provide the basis for human-computer interfaces and decision aids. RF architectures and technologies and the physics of radiation will enable new radio technologies. Information science and collaborative technologies will provide effective wireless networks and accurately and consistently depict the battlespace. Environmental sciences will characterize the operational environment.

Other FNCs

- **Three FNCs are not described due to lack of direct relevance to environmental battlespace characterization with an enhanced T-AGS 60 ship**
  - **Warfighter Protection**
  - **Capable Manpower**
  - **Total Ownership Cost Reduction**

Three FNCs are not described because they will likely have no direct relevance to environmental battlespace characterization with an enhanced T-AGS-60 ship. The three are Warfighter Protection, Capable Manpower, and Total Ownership Cost Reduction.

Outline

- Sea Power 21
  - Sea Strike
  - Sea Shield
  - Sea Basing
  - ForceNet
  - Global Concept of Operations
- Future Naval Capabilities (FNCs)
- Future Naval Systems
  - Pervasive Littoral Sensing
  - Littoral Combat Ship (LCS)
  - DD(X)
  - CG(X)
  - MCS(X)
  - Joint Strike Fighter (JSF)
  - SSGN

Future naval systems are described in this section, including Pervasive Littoral Sensing (PLS), LCS, DD(X), CG(X), MCS(X), JSF, and the SSGN.

Pervasive Littoral Awareness (PLA)

PLA is a concept for providing tactical and operational warfighters transformational awareness thru access to decision quality information

- **In FY01, CNO directed NWDC to develop and mature a concept and capabilities for enhanced situational awareness**
- **PLA initiatives**
  - **May provide parts of the ForceNet vision**
  - **Include experimentation efforts with ONR and DARPA**
- **New sensors, processing, and information networks will provide the situational awareness to maintain battlespace dominance**
- **PLA provides or supports sensing, data archiving, processing, fusion, COA assessment, and information presentation**
- **Combinations of existing databases with in situ collected target and environmental data**
- **PLA will provide interoperability between different data systems and capability to reconfigure information grid as systems enter and leave**

Pervasive Littoral Awareness (PLA) is a concept for providing tactical and operational warfighters with transformational awareness through access to decision-quality information. New sensors, processing, and information networks will provide the situational awareness to maintain battlespace dominance.

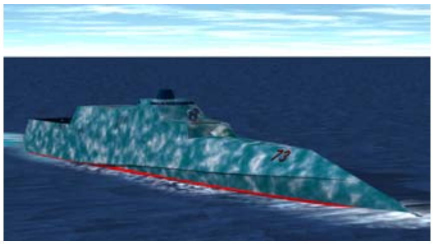
In FY01, the CNO directed the Navy Warfare Development Command (NWDC) to develop and mature a concept and capabilities for enhanced situational awareness. PLA initiatives may be or become inputs into the ForceNet vision and include experimentation efforts with ONR and Defense Advanced Research Projects Agency (DARPA).

PLA provides or supports sensing, data archiving, processing, fusion, assessment, and information presentation. Combinations of existing databases with in situ collected target and environmental data will be used in PLA. PLA will also provide interoperability between different data systems and the capability to reconfigure the information grid as systems and sensors enter and leave the battlespace.

Littoral Combat Ship (LCS)

- **Part of the DD(X) family of ships including the next generation destroyer DD(X) and cruiser CG(X)**
- **Mission-assure access to the littorals dealing with threat submarines, mines, and surface vessels**
- **Operate where it's less desirable to employ larger, multi-mission ships**
- **Deploy with CSGs, ESGs, SAGs, or independently**
- **Newest generation hull form—small, fast, agile, stealthy, relatively inexpensive**
- **Procurement in large numbers with reconfigurable mission modules**

General Dynamics LCS Concept



The LCS is part of a new family of ships, including the next generation destroyer DD(X) and cruiser CG(X), being developed by the Navy. The LCS is in the concept development phase of acquisition, and six initial concept designs have been reduced to two options.

LCS will support mission-assured access to the littorals by dealing with threat submarines, mines, and surface vessels. Since the LCS will be stealthy, fast, and smaller than the DDGs and CGs, it will operate where it is less desirable to employ larger, multi-mission ships.

The newest generation hull form will yield an LCS that is small, fast, agile, stealthy, and relatively inexpensive. Plans indicate that the LCS will be procured in large numbers, supporting lower average ship cost, with reconfigurable mission modules. Modules for mine warfare, ASW, and surface warfare make the LCS an operationally flexible and agile platform. LCS will be capable of landing Special Operations Forces.

DD(X) Future Surface Combatant

- **Part of the DD(X) family of ships including the next generation cruiser CG(X) and the LCS**
- **Mission focus on land attack with the Advanced Gun System (AGS) for Long Range Land Attack Projectiles (LRLAP) and VLS for TLAM**
- **Common hull form for both DD(X) and CG(X) with stealth, 30 knots sustained speed, and mission payload growth potential**
- **Electric drive and integrated power systems**
- **Multi-function and volume search radar systems**
- **Peripheral Vertical Launch System (PVLS)**

DD(X) is part of the new family of surface combatants that includes the LCS and the next generation cruiser CG(X). DD(X) is designed for the littorals to be a multi-warfare capable ship with a land attack focus. Advance technology features include tumble home hall form, all-electric drive, and Peripheral Vertical Launch System (PVLS).

The primary mission for the DD(X) is fire support and land attack. The fire support capability is designed to support Marine requirements. The Advanced Gun System (AGS) is being developed for this mission. AGS is a 155-mm gun that fires the Long-Range Land Attack Projectile (LRLAP) that is part of the AGS design. This gun system provides a substantially greater range than the Navy's current 5-inch guns on CGs and DDGs. LRLAP will use GPS for in-flight guidance. For the land attack mission, the DD(X) will have a PLVS to launch the Tomahawk land attack missile (TLAM) as well as other missile types, like air defense and ASW. PVLS has the missile cells around the periphery of the ship instead of the traditional VLS on the center line of the ship. This arrangement affords the DD(X) better survivability. The DD(X) will have capability in other warfare areas: air and missile defense, ASW, surface warfare, and mine warfare. DD(X) will have multi-function and volume search radars to support all mission areas.

A common hull form is planned for DD(X) and CG(X) providing stealth, 30-knot sustained speed, and mission payload potential. Electric drive and integrated power systems are planned. DD(X) is designed to be operated and maintained by a significantly reduced size crew.

CG(X) Future Surface Combatant

- Part of the DD(X) family of ships including the next-generation cruiser DD(X) and the LCS
- Follow-on ship to the CG-47 with mission focus on air defense and battlespace dominance
- Required capabilities and system configurations have not been specified
- Based on plans for the DD(X) family of ships, the following are likely for CG(X)
  - Common hull form for both DD(X) and CG(X) with stealth, 30-knots sustained speed, and mission payload growth potential
  - Electric drive and integrated power systems

Notional Future Surface Combatants: CG(X), DD(X), LCS

As part of a new family of surface combatants that includes the DD(X) and the LCS, the CG(X) will be the follow-on ship to the CG-47 class cruiser. Its mission focus will be on air defense and battlespace dominance; however, required capabilities and system configurations have not been specified. Based on plans for the DD(X), CG(X) will share a common hull form with DD(X). This will provide stealth, 30 knots sustained speed, and mission payload growth potential. Electric drive and integrated power systems will be used in CG(X).

MCS(X) Future Mine Warfare Support Ship

- **Required capabilities are being developed by the Navy for a new mine countermeasures support ship**
- **Replaces the only MCS, Inchon MCS-12, a converted LPH**
- **MCS-12 was removed from service in 2001 after a fire caused extensive damage in the engine room**
- **MCS(X) will support the MCM-1 *Avenger* class mine countermeasures ships and the MHC-51 *Osprey* class coastal mine-hunting ships**
- **MCS(X) will provide space for the MCM commander and staff, MCM helos, EOD MCM dets, integrated C2, and logistics support**

USS Inchon MCS-12

The MSC(X) is the Navy's future Mine Warfare Support Ship. The Navy is currently developing requirements for this MCM support ship. The MCS(X) will replace the only MCS, U.S.S. *Inchon* MCS-12, a converted LPH. MCS-12 was removed from service in 2001 after a fire caused extensive damage in the engine room.

MCS(X) will support the relatively small MCM-1 *Avenger* class mine countermeasures ships and the MHC-51 *Osprey* class coastal mine-hunting ships. It will provide space for the MCM commander and his staff, integrated command and control for all MCM forces, MCM helicopters (MH-53 or MH-60 type helicopters), explosive ordnance disposal (EOD) MCM detachments, and logistics support and intermediate maintenance support for embarked MCM helicopter squadrons, EOD MCM detachments, and assigned MCM surface ships.

Joint Strike Fighter (JSF) F-35

- **In Oct 2001, DoD selected Lockheed-Martin's F-35 as the winner in the competition with Boeing to manufacture JSF**
- **Variants: Air Force, Navy, Marine Corps, UK Royal Navy and Air Force**
- **Navy variant**
  - **Larger wing and tail control surfaces for low-speed approaches to CVN also enable increased payloads**
  - **Internal structure and landing gear strengthened for CVN landings and catapults**
  - **Increased range and optimized for survivability**
- **Marine Corps variant**
  - **Replaces F/A-18 and AV-8B**
  - **STOVL**

In October 2001, the DoD selected Lockheed-Martin's F-35 as the winner in the competition with Boeing to manufacture the Joint Strike Fighter. Lockheed's design is a lift-fan STOVL aircraft with sufficient excess power to accommodate the weight gain that fighter aircraft historically experience. Lockheed-Martin developed four versions of the JSF to meet the needs of the Navy, Air Force, Marine Corps, and the United Kingdom Royal Air Force and Navy.

The Navy variant is carrier capable. It has larger wing and tail control surfaces for low-speed approaches to the CVN. This also enables the Navy version to accommodate larger payloads. Its internal structure and landing gear are strengthened for CVN catapults and arresting gear recoveries. The Navy version has increased range, relative to the F/A-18, and its design is optimized for survivability. The Navy plans to purchase 480 JSF aircraft.

The Marine version is distinguished by its STOVL capability. It will replace the F/A-18 *Hornet* and the AV-8B *Harrier*. The Marine Corps plans to purchase 480 STOVL versions of the F-35. The STOVL version will carry half the payload and have about half the range of the CV version.

SSGN Guided Missile Submarine

- Four *Trident* class SSBNs are being converted to SSGNs
  - First in 2007
- 22 years of hull life remaining
- Configurations
  - Maximum strike: 154 cruise missiles in 6 minutes
  - Strike/SOF-1: 66 SOF personnel, 2 ASDS, 140 missiles
    - Advanced SEAL Delivery System: mini-subs
  - Strike/SOF-2: 66 SOF personnel, 2 DDSs, 126 missiles
    - Dry Deck Shelters: house SDVs
- Operational availability: 70 percent with two crews

The DoD decided in 1994 that 14 *Trident* SSBN submarines carrying the Trident II (D-5) missile were sufficient to meet national security requirements under the Strategic Arms Reduction Treaty II (START II). This action made four *Trident* SSBN submarines available for conversion to SSGN.

The conversion process is underway with the first SSGN available in 2007. These submarines have 22 years of hull life remaining. Operational availability of 70 percent can be achieved with two crews.

The SSGN submarines can be configured in several ways. For maximum strike, 22 of 24 launch tubes would be fitted with 7-pack cruise missile canisters. This provides 154 TLAMs that can be launched in as little as 6 minutes. For strike and SOF capability, the SSGN can be configured in two ways. Two of the new ASDS (mini-submarines), 66 SOF personnel, and 140 land attack missiles can be accommodated. The other SOF configuration accommodates two dry deck shelters housing the older SDVs (one SDV in each DDS), 66 SOF personnel, and 126 missiles.

Interior modifications provide a SOF command and control area along with work and berthing space for SOF personnel.

II. NAVAL CAPABILITIES

The Naval capabilities form the basis for developing alternative force structures for the future Navy.

Outline

- BACKGROUND
  - What the Navy provides
  - Virtues and constraints
- NAVAL CAPABILITIES
  - Programmed Navy
  - Alternative future Navy
- RECURRING CAPABILITY THEMES

General background is provided describing what the Navy provides, its virtues, and the constraints on it. The naval capabilities are described in terms of how the programmed Navy will provide the capability and in terms of how an alternative future Navy may provide the capability. Finally, after reflection on the capabilities as a whole, we look for recurring capability themes.

What the Navy Provides

- **SEA BASING**
  - **CVN, surface combatants, submarines, MPF(F)**
- **SEA SHIELD**
  - **Sea control**
  - **Force protection**
- **SEA STRIKE**
  - **Sea control**
  - **Forcible entry**
  - **Strike assets**
    - **CVN, cruise missiles, USMC**

As described in Chapter I, Sea Power 21 is the Navy vision for the future. The pillars of the future are Sea Basing, Sea Shield, and Sea Strike. Sea Basing provides the capability to support naval forces on the sea and from the sea and is accomplished with ships and submarines, including carriers, surface combatants, submarines, and Maritime Prepositioning Force Future ships. The future will include small surface ships, like the LCS. Sea Shield provides the capability for the Navy to protect itself and keep the sea lanes open for commercial traffic. Sea Strike is the capability to apply naval power against objectives on land or other naval forces and to gain entry into hostile nations or territories.

Outline

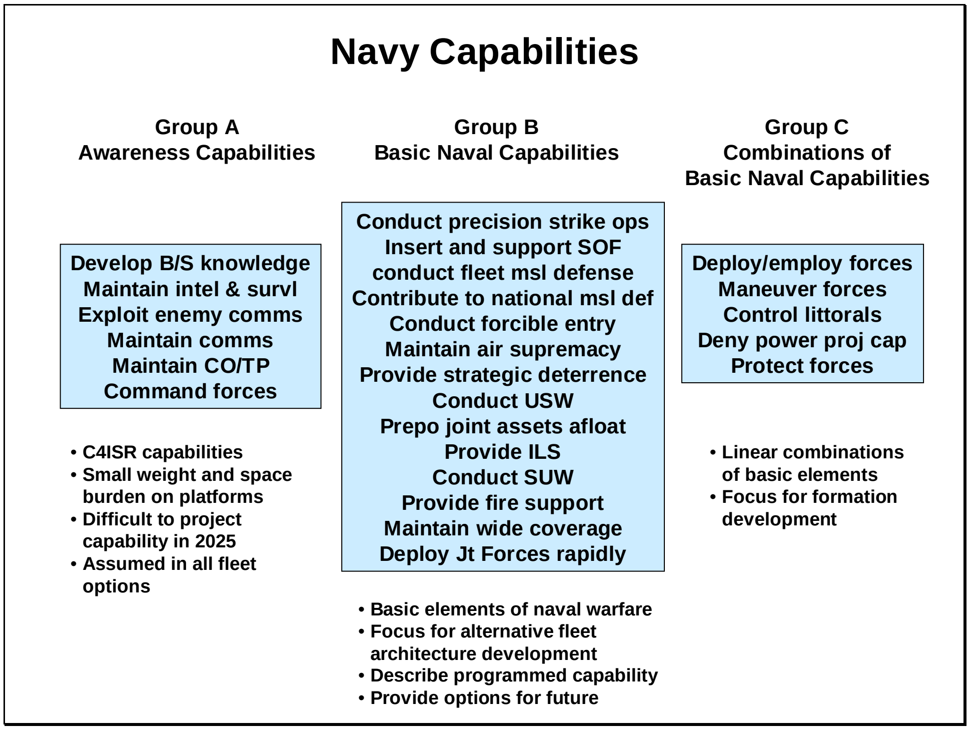
- BACKGROUND
  - What the Navy provides
  - Virtues and constraints
- NAVAL CAPABILITIES
  - Programmed Navy
  - Alternative future Navy
- RECURRING CAPABILITY THEMES

The naval capabilities are described in terms of how the programmed Navy provides the capability and how the alternative future navies may provide the capability.

Approach

- Start with given list of naval capabilities
- Divide into three categories
- Indicate now the capability will be provided by the programmed navy
- Offer options for providing or achieving the capability in future naval alternatives

The approach is to start with the list of capabilities provided to the study team by the study sponsors. We divide these into three categories: awareness capabilities, basic naval capabilities, and combinations of the basic capabilities. Finally, we indicate how the capability is provided.



The identified Navy capabilities are divided into the three categories indicated in the chart. The awareness capabilities include developing battlespace knowledge, maintaining intelligence and surveillance, exploiting enemy communications, maintaining communications and a common operating and tactical picture, and commanding forces. These C4ISR capabilities inflict a small weight and space burden on the platforms, and it is difficult to project their effectiveness and costs in 2025. As a result, we acknowledge these limitations but do not focus on them in this study other than to assume these capabilities in our alternative fleet options.

The second group consists of basic naval capabilities listed on the chart. We provide our interpretation of these capabilities in this chapter and then use them as the focus of our alternative fleet architecture development in subsequent chapters.

The third group consists of combinations of basic capabilities, so these are important to our development of surface combatant formations.

Conduct Precision Strike Operations

- Strike operations: Attacking targets on land
- Current Navy strike assets: CVN, cruise missiles
- CSG: CVN, CGX, SSN, T-AOE, LCS
  - Programmed Strike Capability
    - CVN with weapons carried on manned aircraft
    - CGX and SSN with on-board TLAM
  - Future
    - Naval platform with better weapons and munitions (evolutionary)
    - VSTOL platform with weapons carried on manned tilt-rotor or STOL aircraft
    - UAV platform with weapons carried on UCAV or UCAS
    - LAMs launched from weapon launchers on land
      - Final control, if needed, by on-scene assets (naval platforms, SOF, UAV)
    - LAMs launched from another ship (X-WPS) in the CSG
- ESG: CGX, DDX, SSN, LCS and SAG: CGX
  - As above without CVN

Conducting precision strike operations involves of striking targets on land with precision. This generally implies using a terminally guided weapon launched from an aircraft or a cruise missile to achieve the required precision. Current Navy strike assets are the CVN with manned aircraft carrying cruise missiles and cruise missiles launched from submarines or from Vertical Launch System (VLS) cells on surface combatants.

The programmed CSG will provide precision strike capability with cruise missiles from the CGX and SSN and missiles from manned aircraft off the CVN. Future alternatives may include naval platforms with better weapons and munitions, VSTOL platforms with precision weapons carried on manned tilt-rotor or STOL aircraft, and UAV platforms with precision weapons carried on unmanned combat air vehicles (UCAVs) or unmanned combat air systems (UCASs). In addition, land attack missiles (LAMs) may be launched from weapon launchers on land or on another ship (such as a large weapons ship) with final control provided by on-scene assets (such as other naval platforms, special operations forces (SOF), or UAVs).

The programmed ESG will have manned aircraft launched from the large deck amphibious ships (LHD and LHA) and missiles launched from the CGX, DDX, and SSN. Potential future alternative strike capabilities are similar to those described for the CSG. The programmed SAG has only the CGX combatants to launch cruise missiles. Potential alternatives for the future include missiles and UAVs.

Conduct Undersea Warfare

- Undersea Warfare: Neutralizing hostile submarines and mines
- CSG: CVN, CGX, SSN, T-AOE, LCS
  - Programmed USW capability
    - Helicopters, or tilt-rotor aircraft, with weapons and sensors from CVN or CGX
    - CGX with hull-mounted sonar, towed array, and torpedoes
    - SSN with organic weapons and sensors
    - LCS provides mine detection and clearance and ASW support with modules
  - Future
    - Pervasive battlespace (air, surface, subsurface) awareness, achieved with distributed sensors, processing, and information networks, provides decision-quality information and CUP
    - Small, fast surface combatants and UVs distribute and monitor the sensors like Advanced Deployable System (ADS) arrays, sensors, and comms buoys
    - Modular MIW and ASW systems in small combatants and UVs, MMA, and helicopters all support the neutralization of mines and prosecution of submarine contacts
    - Organic Airborne Mine CM (OAMCM) kits for TR aircraft
    - Towed systems for USVs and laser mine detection systems for UAVs
    - SSNs, or AIP diesel submarines, with better sensors and weapons to neutralize surface and subsurface targets
- ESG: CGX, DDX, SSN, LCS
  - As above without CVN
- SAG: CGX—Organic sensors, helicopters, and UVs will provide ASW and MIW capability as indicated above

Undersea warfare is summarized as neutralizing hostile submarines and mines.

The programmed CSG will conduct undersea warfare with helicopters from the CVN and CGX carrying weapons and sensors, hull-mounted sonar, towed array, and ASW weapons such as torpedoes on the CGX, the SSN with its organic sensors and weapons, and the LCS with modules for mine warfare and ASW. Part of the mine warfare package will include the Remote Minehunting System (RMS), which is a UUV for mine reconnaissance capability.

Future alternative CSGs will include pervasive battlespace awareness, achieved with distributed sensors, processing, and information networks, provides decision-quality information and a common undersea picture (CUP). They may also include small fast ships and UVs to distribute and monitor sensors such as the Advanced Deployable System (ADS) arrays, sensors, and communications buoys. Air-independent propulsion (AIP) diesel submarines could be used.

The future ESG will have capability types as in the CSG but without the helicopters from the CVN. The CGX in the SAG will use its organic sensors and helicopters and UVs to provide ASW and mine warfare (MIW) as indicated in the CSG.

Conduct Air Supremacy Operations

- **Air supremacy operations: Eliminate/reduce enemy aviation threat in AOR while protecting naval forces**
- **CSG: CVN, CGX, SSN, T-AOE, LCS**
  - **Programmed**
    - **CVN with weapons carried on manned aircraft**
    - **CGX with on-board SAM (provides area AAW defense as well as self-defense, while destroying enemy aircraft and missiles)**
  - **Future**
    - **Naval platform with better weapons and munitions (evolutionary)**
    - **VSTOL carrier for VSTOL, tilt-rotor aircraft, and UAVs**
    - **X-WPS ship with many weapons and launchers**
    - **With electric propulsion systems, power available to support high-energy weapons, like EM or laser for AAW, SUW, fire support, and self-defense**
- **ESG: CGX, DDX, SSN, LCS and SAG: CGX**
  - **As above**

Air supremacy operations are conducted to eliminate or reduce the enemy aviation threat in an Area of Responsibility (AOR) while protecting naval forces.

The programmed CSG conducts air supremacy operations with aircraft operated from a CVN and missiles from the CGXs. The ESG and SAG rely on missiles. In the future, this capability will be enhanced with evolutionary improvements in platforms, weapons, and munitions; VSTOL carriers for manned VSTOL or tilt-rotor aircraft; UAV platforms for UCAV or UCAS operations; a ship primarily for weapons, X-WPS, with many launchers and weapons. With the introduction of electric propulsion systems in ships, power will be available for high-energy electromagnetic (EM) or laser weapons for anti-air warfare (AAW), surface warfare (SUW), fire support, and self-defense.

Conduct Fleet Missile Defense and Contribute to National Missile Defense

- **Fleet missile defense: Defeating incoming cruise missiles targeting fleet formations**
- **CSG, ESG, SAG**
  - **Programmed:**
    - **CGX with on-board SAM and close-in weapon system (CIWS-1B)**
- **National missile defense: Defeating incoming ballistic or cruise missiles when properly stationed along the homeland coast**
- **MDSAG: CGX**
  - **Programmed:**
    - **CGX with on-board SAM (SM-3)**
- **Future for both fleet and national missile defense:**
    - **Naval platform with better weapon and munitions (evolutionary)**
    - **X-WPS ship with many weapons and launchers**
    - **With electric propulsion systems, power available to support high-energy weapons, like EM or laser for self-defense or missile defense**

Fleet missile defense is the capability to defeat incoming cruise missiles that are targeting naval fleet formations. The programmed formations rely on fighter aircraft on CVN (CSG), CGX with surface-to-air missiles (SAMs), and close-in weapon systems (CIWS-1B) on surface combatants for missile defense.

National missile defense is the capability to defeat incoming ballistic or cruise missiles when properly stationed along the homeland coast. The programmed capability resides in the CGX, with its SM-3 missiles, in the missile defense SAG formation.

The future for either of these capabilities may include evolutionary weapons, munitions, and platforms, such as the X-WPS ship. Also, electric propulsion may support high-energy weapons like EM weapons or lasers for missile defense.

Conduct Forcible Entry Operations

- **Deploy and employ forces: Transport Marine forces to theater, support the landing, provide the sea-based support for the Marine command, aviation, and service support elements.**
- **ESG (ARG, CGX, DDX, SSN, LCS) and CSG (CVN, CGX, LCS, SSN)**
  - **Programmed**
    - **ARG ships provide transport and limited seabasing**
    - **CVN aircraft provide air supremacy**
    - **CGX with SAMs provide area AAW defense, self-defense, and while destroying crossing enemy aircraft and missiles**
    - **DDX provides fire support**
    - **SSN provides ASW/USW support**
    - **LCS provides mine detection and clearance, and ASW and SUW support**
    - **Landing craft and rotary-wing and TR assets support the landing and deliver sustainment to the landing force**

Forcible entry operations include transporting Marine (or joint) forces to the theater, supporting the landing, and providing sea-based support to the landing force. These operations are generally conducted by the combination of an ESG and a CSG, referred to as a Expeditionary Strike Force.

The programmed forces provide the capabilities to deploy and employ Marine forces. Amphibious ships furnish transport and limited seabasing. CVN aircraft provide air supremacy. CGX provides AAW defense. DDX provides fire support with its trainable rocket launchers (TRLs). The SSNs bestow ASW and USW support. LCS ships grant mine detection and clearance and ASW and SUW support. Landing craft and rotary-wing and tilt-rotor assets support the landing and deliver sustainment to the landed force.

Conduct Forcible Entry Operations -Continued-

- **ESG and CSG**
  - **Future**
    - **Large, flat-top ships provide transport and a sea base to support the deployment and employment of Marine forces**
      - **Similar to MPF(F) potentially with civilian crews like T-AOE**
      - **Same hull could be used for X-WPS ship**
    - **UAV platform with weapons carried on UCAVs or UCASs**
    - **Naval platform with quick-response SAM-like capability**
    - **Fire support platform with UCAVs and quick-reaction weapon with advanced warhead to support the ground forces**
    - **Netted sensor fields provide data for target location and tracking in COP**
    - **SSN 774, MMA, tilt-rotor aircraft, and UUVs prosecute targets in a fully network centric environment**
    - **Modular advanced mine warfare systems on small surface combatants and UUVs provide capability to identify and neutralize or avoid mines**
    - **Advanced surface landing craft and advanced aircraft are used to land the ground force and sustain it, while the ships remain at a safe distance from the beach**

Future capability for forcible entry may include large flat-top ships that provide transport and a sea base to support the deployment and employment of Marine, or other, forces. This capability is similar to the proposed MFF(F) ships potentially with civilian crews to operate the basic ship functions in a manner similar to the T-AOE ships. The same hull as the X-WPS could be used for this platform. Other future capabilities supporting forcible entry operations include a UAV platform carrying UCAVs or UCASs with weapons and sensors and another platform with sufficient missiles to support the AAW, precision strike, and fire support requirements.

Netted sensor fields will provide data for target location and tracking in a COP. Submarines, aircraft, and UUVs may all be called upon to detect, classify, and prosecute targets. Modular advanced mine warfare systems on small surface combatants and UUVs will provide capability to identify and neutralize or avoid mines. Advanced surface landing craft and advanced aircraft, such as the tilt-rotor or heavy-lift STOL aircraft or heliplane, may be used to land the ground force and sustain it, while the ships remain at a safe distance from the shore.

Conduct Surface Warfare

- SURFACE WARFARE OPERATIONS: ELIMINATE/REDUCE ENEMY SURFACE SHIPS AND CRAFT
- CSG: CVN, CGX, SSN, T-AOE, LCS
  - Programmed
    - CGX and LCS with
      - SSM (Harpoon, NetFires) either organic or USV
      - Guns (CIWS-1B or cannon)
      - Helicopters with missiles and cannon
      - UCAV with missiles, cannon, BAT dispenser
    - CVN with weapons carried on manned aircraft or UCAVs
    - SSN with torpedoes
  - Future
    - Naval platforms with better weapons and munitions (evolutionary)
    - Small surface combatants with organic weapons or USVs
    - VSTOL carrier for VSTOL or tilt-rotor aircraft and UAVs
    - X-WPS ship with many weapons and launchers
    - With electric propulsion systems, power available to support high-energy weapons, like EM or laser, for self-defense or AAW
- ESG: CGX, DDX, SSN, LCS and SAG: CGX
  - As above without CVN

Surface warfare operations are conducted to eliminate or reduce enemy surface ships and craft. Programmed CGX and LCS ships will conduct surface warfare with surface-to-surface missiles (SSMs), like Harpoon, with a targeting picture developed by a system like NetFires. SSMs are organic to these ships but could also be fired from unmanned surface vehicles (USVs). CGX and LCS will have a close-in weapon system for use against small boats, helicopters with missiles and cannons, and UCAVs or UCASs with missiles, cannons, and dispensers for submunition weapons. The CVN will have weapons carried on manned aircraft or UCAVs, and the SSN has torpedoes for surface targets.

Future surface warfare capabilities may include small surface combatants with organic weapons or USVs, VSTOL carriers for VSTOL or tilt-rotor aircraft or UAVs, weapons heavy ships like X-WPS with many launchers and weapons, as well as high energy weapons, like EM or laser, powered by the electric propulsion system on ships of the future.

Provide Fire Support

- **FIRE SUPPORT OPERATIONS: PROVIDE ON-CALL GUN FIRE OR ROCKETS IN SUPPORT OF MARINE OPERATIONS ASHORE**
- **CSG: CVN, CGX, SSN, T-AOE, LCS**
  - **Programmed**
    - **CGX with 5”/54 or 5”/62 guns with ERGM**
- **ESG: CGX, DDX, SSN, LCS and SAG: CGX**
  - **Programmed**
    - **CGX with 5”/54 or 5”/62 guns with ERGM**
    - **DDX with 2 Trainable Rocket Launchers (TRL) (formerly AGS) with Long-Range Land Attack Projectiles (LRLAP)**
- **FUTURE**
  - **Naval platforms with better weapons and munitions (evolutionary)**
  - **UAV platform with loitering UCAVs that provide on-call fire support**
  - **X-WPS ship with many weapons and launchers**
  - **With electric propulsion systems, power available to support high-energy weapons, like an EM gun**

Fire support operations provide on-call gun fire or rockets in support of Marine operations ashore. Programmed forces provide fire support with guns, 5-inch 54-caliber or 6-inch 62-caliber, or rockets, like the TRL planned for the DDX. Future fire support capabilities will include evolutionary development of better weapons and munitions and may include VSTOL platforms for manned tilt-rotor or STOL aircraft, UAV platforms for UCAV operations, weapons heavy ships like X-WPS with many launchers and weapons, as well as high-energy weapons, like EM or laser, powered by the electric propulsion system on ships of the future.

Provide Strategic Deterrence

- **STRATEGIC DETERRENCE: PROVIDE CAPABILITY TO LAUNCH STRATEGIC BALLISTIC MISSILES OR TO DEFEAT THEM**
- **MDSAG: DDG, CG**
  - **Programmed**
    - **CGX with ABMD capability**
      - **Currently provided by DDG-51 FLT I/II (ABMD) with SM-3 regional TBMD**
  - **Future**
    - **CGX with ABMD capability**
- **SSBN**
  - **Programmed**
    - **SSBN with SLBMs**
  - **Future**
    - **SSBN with improved BMs**
    - **Large ships for weapons with capability to launch BMs**

Strategic deterrence is provided by the capability to launch strategic ballistic missiles or to defeat them. Programmed naval assets in the MDSAG consist of CGX with Anti-Ballistic Missile Defense (ABMD) capability. This capability is currently provided by the DDG-51 Flight I and II (ABMD) ships with the SM-3 missile for theater ballistic missile defense (TBMD). The future capability will be improved ABMD in the CGX. SSBNs provide strategic deterrence with submarine-launcher ballistic missiles (SLBMs). Future capabilities may include SSBNs with improved SLBMs or large ships for weapons with capability to launch ballistic missiles.

Preposition Joint Assets

- Preposition joint assets: Forward-position joint equipment and supplies in large ships to reduce closure time for joint forces
- Programmed
  - 2 Maritime Prepositioning Groups (MPGs)
    - Seabasing support for deployment and employment of Marine brigades
    - Ground forces are moved directly to the objective
    - Command, FSSG, and aviation elements can remain on the seabase
    - Embarked lift assets for surface, RW and TR lift
- Future
  - Expanded seabasing/prepo support for joint forces
  - Self-sustaining seabase
    - Receive containers or pallets directly from container ships or general sealift ships
    - Receive POL from T-AOE or tanker
  - Delivery of sustainment for ground forces expanded by a heavy-lift aircraft
  - Potential to use common hull (large ship with flat top) for this capability and to replace current amphibious ships as well
  - Potential to use same hull for other applications: CLF replacement, hospital ship replacement, and command ships
  - Potential for life-cycle cost savings with civilian crew for basic ship functions

To preposition joint assets is to forward position joint equipment and supplies in large ships to reduce closure time for joint forces. Strategic airlift transports people to the theater of operations where they either offload the ships or operate from the ships that constitute a sea base.

Programmed naval assets include two Maritime Prepositioning Groups (MPGs) that provide seabasing support for deployment and employment of Marine brigades. The concept indicates that the ground forces move via air or surface lift from the sea base directly to the objective, while the command, force service support group, and aviation elements remain on the sea base. Ship-to-shore lift assets based on the sea base include surface-lift assets, such as the LCAC, and rotary-wing and tilt-rotor aviation assets.

Future prepositioning capabilities may include expanded seabasing and prepositioning support for joint forces and self-sustaining sea bases that can receive containers or pallets directly from container ships or general sealift ships and receive petroleum, oil, and lubricant (POL) products from a T-AOE or tanker. The potential exists to use a common hull for prepositioning, amphibious, CLF, hospital, and command ships. Potential life-cycle cost savings are derived from use of a common hull and the use of civilian crews for basic ship functions. Delivery of sustainment for the ground forces is expanded to include operation of a heavy-lift aircraft of some type. This aircraft could operate from the sea base and be based either on the sea base or at an air station in the theater.

Integrated Logistics Support

- **ILS: Provide sustainment (food, fuel, ammo, other) in a timely manner to formations, ships, aircraft, and ground forces operating ashore**
- **Programmed**
  - **CLF ships**
    - **T-AOE, T-AO, T-AE**
  - **2 Maritime Prepositioning Groups (MPGs): MPF (F)**
    - **Seabasing support for deployment and employment of Marine brigades**
- **Future**
  - **Replace programmed CFL ships with future ILS(F) ships**
    - **Potentially common hull with MPF(F)**
    - **Self-sustaining for containers, pallets, POL**
  - **Expanded seabasing/prepo support for joint forces with MPF(F)**
  - **Food, water, fuel, and ammo delivered via RW/TR assets to ground forces as needed from the sea base: MPF(F) or ILS(F)**
  - **Ship to shore delivery of sustainment is expanded from rotary wing and tilt rotor to include a heavy-lift aircraft**

Integrated Logistics Support (ILS) is the capability to provide sustainment (food, fuel, water, ammunition, and other products) in a timely manner to naval forces and ground forces. The programmed ILS assets include the CLF ships (T-AOE, T-AO, and T-AE) and two MPGs composed of MPF(F) ships. Future ILS capabilities may include replacing the CLF ships with ships built with a common hull with MPF(F). These future ILS ships will likely be self-sustaining for containers, pallets, and POL products. Other future capabilites may include expanded seabasing or prepositioning support for joint forces with MPF(F) ships and ILS products delivered to ground forces from these ships by rotary-wing, tilt-rotor, or a heavy-lift aircraft.

Insert and Support SOF

- **Insert and support SOF: Transport and support (provide shelter, food, water, other) SOF personnel, equipment, and insertion vessels from FDS or FOB to the offload point, and remain on-station to retrieve as needed**
- **Programmed**
  - **Advanced SEAL Delivery System (ASDS) carried on modified SSNs**
  - **SEAL Delivery Vessel (SDV) carried in Dry Deck Shelters (DDS) on SSNs or SSGNs**
  - **SSNs have lock-out hatches for SEALs and Combat Rubber Raiding Craft (CRRCs)**
  - **Surface combatants and support ships can accommodate SEALs and their insertion craft: CRRC, MK-V SOC, SOF RHIB, and riverine craft**
  - **Surface combatants and support ships can provide at-sea refueling to SOF craft like the MK-VI**
- **Future**
  - **X-WPS, X-AVN, and X-CBO type ships will have sufficient space to embark and support SOF and their equipment, including vessels and craft**
  - **Smaller ships, like SSC-1000 and VSC-100, can also provide SOF support when equipped with SOF modules**
    - **Several VSC-100s may be required to provide the lift and support required**

The naval capability of inserting and supporting SOF includes providing transportation and support (shelter, food, water, and other essentials) for SOF personnel, equipment, and insertion vessels from a forward deployed site (FDS) or forward operating base (FOB) to the offload point and remaining on-station in the area to retrieve the SOF under all circumstances.

Programmed naval capabilities for inserting and supporting SOF include the Advanced SEAL Delivery System (ASDS) carried on modified SSNs, the SEAL Delivery Vessel (SDV) carried in Dry Deck Shelters (DDS) on SSNs or SSGNs. SSNs have lock-out hatches for SEALs and Combat Rubber Raiding Craft (CRRCs). Surface combatants and support ships carry SEALs and their insertion craft: CRRC, MK-V Special Operations Craft (SOC), SOF Rigid Hull Inflatable Boat (RHIB), and riverine craft. Surface combatants and support ships also support SOF with at-sea refueling of SOF craft like the MK-V SOC.

Future naval capabilities for inserting and supporting SOF may include new large ships like the weapons ship (X-WPS), the aviation ship (X-AVN), and the ship that is a combination of weapons and aviation (X-CBO). These ships will have sufficient space to embark and support SOF and their equipment, including vessels and craft. Future capabilities may also include small ships, like the small, 1,000 ton, surface combatant SSC-1000 and the very small, 100 ton, craft VSC-100. These ships and craft can support SOF operations when equipped with SOF modules. Several VSC-100 craft may be required to provide the module space needed to support SOF operations.

Maintain Wide Area Coverage

- **WIDE AREA COVERAGE: DEPLOY NAVAL COMBATANTS TO PROVIDE U.S. PRESENCE IN AREAS OF THE WORLD WHERE RAPID INTERVENTION MAY BE REQUIRED**
- **PROGRAMMED**
  - **CVN, SSN, SSGN, CGX, DDX, LCS, LHA/D, LPD, LSD**
- **FUTURE**
  - **Other surface combatants: X-WPS, X-AVN, and X-CBO type ships**
  - **Additional smaller combatants: SSC-1000 and VSC-100**
  - **With more combatants in the future, the Navy can maintain wider area coverage than today with fewer, more expensive, combatants**
  - **Continued use of SSN and SSGN assets**
  - **Potential use of AIP diesel submarines**

Wide area coverage is the naval capability to deploy naval combatants to provide U.S. presence in areas of the world where rapid intervention may be required. The programmed force to provide this capability is composed of the naval combatants listed in this chart. Of course, numbers matter when providing area coverage, and the future may include an increased number of smaller ships and craft. Future combatants may include a mix of large ships like the X-WPS, X-AVN, and X-CBO type ships, small ships and craft like the SSC-1000 and the VSC-100, and continued use of submarines. With more ships in the future, the Navy may be capable of maintaining wider area coverage than today with fewer, more expensive, combatants.

Deploy Joint Forces Rapidly via Strategic Sealift

- Strategic mobility provided by the Navy consists of large civilian-manned ships operated by the Military Sealift Command (MSC)
- Programmed
  - LMSR ships (Large Medium-Speed Roll-on Roll-off (RO-RO)) mainly for vehicles
  - Fast sealift ships (30 knots) for vehicles
  - General cargo and container ships to carry containers in cell guides
  - Crane ships (T-ACS) to offload the container ships
  - Lighterage for in-stream offload to:
    - Form Roll-on Roll-off Discharge Facilities (RRDF) for vehicle offload
    - Carry vehicles and containers to the shore
  - Prepositioning ships: Commercial ships with equipment and supplies forward stationed for marry-up with personnel arriving via strategic airlift for faster force closure
- Future
  - Faster and larger strategic sealift ships for equipment, supplies, and personnel for a limited time period
  - Prepositioning that supports seabasing, like MPF(F)
  - Faster, more efficient offload capability, like high-speed lighters, fast cranes, and heavy-lift aircraft

Deploy joint forces rapidly via strategic sealift is a naval capability provided by large civilian-manned ships operated by the Navy's Military Sealift Command (MSC). The programmed capability includes Large Medium-Speed Roll-on Roll-off (RO-RO) (LMSR) ships mainly for vehicles, fast sealift ships for vehicles, general cargo and container ships, crane ships, lighterage for in-stream offload of vehicles and containers, and prepositioning ships to forward station equipment and supplies for faster force closure.

The future for this capability may include faster and larger strategic sealift ships for equipment, supplies, and personnel for a limited time period; prepositioning that supports seabasing, like MPF(F); and faster, more efficient, offload capability provided by high-speed lighters, cranes that are faster and capable of operating in higher sea states, and heavy-lift aircraft.

Outline

- **BACKGROUND**
  - **What the Navy provides**
  - **Virtues and constraints**
- **NAVAL CAPABILITIES**
  - **Programmed Navy**
  - **Alternative future Navy**
- **RECURRING CAPABILITY THEMES**

Several themes recurred during the capability descriptions.

Derived Characteristics of Future Naval Forces

- **Support deployment and monitoring of distributed sensors of all types, including acoustic, EM, and IR**
- **Support launch and recovery of unmanned vehicles (UAV, USV, and UUV)**
- **Provide final guidance and targeting for weapons launched from outside the formation (land, naval forces in other formations and theaters)**
- **Quick reaction weapons for NMD, TMD, and self-defense**
- **Use a mix of ship capabilities and crewing options while reducing the number of hull types employed for cost savings**
  - **Continue programmed ships: SSN, SSGN, SSBN, support ships**
  - **Build new surface combatants using two hulls—a large and a small hull**
  - **Small, fast, modular ships or craft and UVs for access into the littorals and wide area coverage**
    - **50-60 knots**
    - **Modular: MIW, ASW, SOF, other**
    - **Weapons for SUW and self-defense**
  - **Large ships for "heavy-lifting"**
    - **Weapons (like DDX or arsenal ship)**
    - **VSTOL, rotary-wing, tilt-rotor aircraft, or heavy-lift aircraft**
    - **Modules for small, fast ships or UVs with at-sea module transfer**
    - **"Mother-ship" for UVs and small manned surface craft**
    - **Potential to operate, like the T-AOE, with civilian crew**
    - **Potential common hull with MPF(F): large monohull**
- **Continued use of SSNs and potential for use of AIP diesel submarines**

After reviewing the naval capabilities identified for this study, we determined several recurring themes that should be considered in developing alternative, future naval fleets. These themes include support for deploying and monitoring distributed sensors of all types and support for launch and recovery of all types of unmanned vehicles that support the collection of data, distribution and monitoring of sensors, and identification and destruction of targets. Other themes identified are the potential to provide final guidance and targeting for weapons launched from outside the formation, including land and naval forces in other formations and theaters. Quick-reaction weapons for national and theater missile defense and self-defense are identified as important for the future.

Other themes identified include the use of a mix of ship capabilities and crewing options while reducing the number of hull types utilized. Reducing the hull types used will save money in construction and reduce the types of ships for which training, maintenance, and support are needed. Using civilian crews for the routine functions in a ship while Navy personnel operate the warfare systems may save ship operating costs. This is being tested now in Navy ships. A mix of capabilities may include continuing some of the programmed vessels, like submarines and support ships, while focusing the surface combatant fleet in two types of ships or craft: a large one and a small one.

Small, fast, modular ships or craft may enhance the Navy's capability to access the difficult littoral environment and to provide increased forward presence and wide area coverage. These vessels may have speeds in excess of 50 knots and be modular to use the same platform to perform multiple warfare functions. Modules for MIW, ASW, SOF support, AAW, SUW, and strike may be included. These small ships or craft will be capable of defending themselves with systems for SUW and self-defense. Extensive use of UAVs, USVs, and UUVs may enhance warfighting capability.

Large ships (smaller than a CVN, but similar to LHD or LHA ships) will be needed to carry the launchers and weapons load, aircraft (VSTOL, rotary wing, tilt-rotor, or heavy-lift aircraft), modules for the small ships or craft (with the capability to support at-sea modules transfer), and potentially small manned or unmanned surface craft. The large ships would potentially be built on a common hull similar to the MPF(F) ships and be crewed for the basic ship functions by a civilian crew.

Submarines will continue contributing in the future. AIP diesel submarines may be of value, however, they are limited in speed and range for substantial time periods.

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III. ALTERNATIVES FOR THE FUTURE FLEET ARCHITECTURES

The study team developed alternatives to the programmed Navy architecture based on the capability-based themes identified for how the Navy will operate in the future. The alternatives will be assessed in the analysis section for this study with respect to the appropriate types of threats.

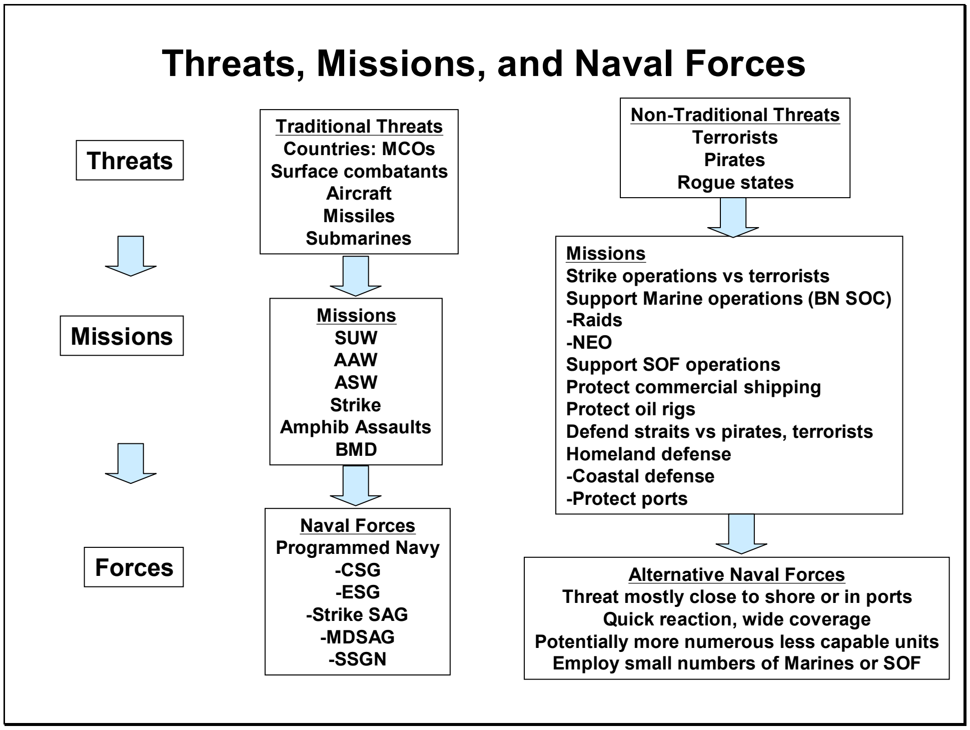
To develop an alternative fleet architecture, we adopted a philosophy different from the one that guided the development of the programmed fleet architecture. Our approach is to build a Navy to address the non-traditional threat and then assess it against both the traditional and non-traditional threats. This approach is reasonable in view of the rise in non-traditional threats and the decline in blue water threats to the Navy. To accomplish this, we wanted to expand the number of ships and take advantage of networking to achieve an operational advantage in addressing a non-traditional threat. In order to expand the numbers of ships in the fleet and stay within the cost constraints, we used a small number of hull types, basically one large and one small hull, and reduced the capability of the alternative ships in a side-by-side, one-to-one comparison to programmed assets. However, a much larger number of ships that are networked offer the potential to provide an operational advantage relative to the programmed fleet architecture. The validity of this proposal is determined in the assessment of the alternatives relative to the programmed fleet architecture.

Outline

- Background
- Approach to Alternative Fleet Development
- Large Surface Combatant Platforms
- Small Surface Combatant Platforms
- Alternative Fleet Development
  - Formations
  - Large Platform Configuration
- Alternative A
- Alternative B
- Alternative C
- Summary

This chapter is organized as shown on this chart. It starts with background information on threats, missions, and naval forces. The approach to alternative fleet development includes the themes and context used for this. Descriptions of the large and small surface combatants utilized lead to alternative fleet development in terms of the formations used and the specific configurations of the large platforms to be used in the alternatives. Fleet Alternatives A, B, and C are described and summarized.

This chapter begins with background information.



Threats lead to missions to address the threats, and missions lead to naval forces with the capabilities needed to counter the threats. Traditional threats are described by the major combat operations. These lead to traditional missions and forces, and, with sufficient numbers, the programmed Navy was planned to address this threat. In this study, we develop alternative fleet architectures to deal primarily with the non-traditional threat, i.e., terrorists, pirates, and rogue states, but then evaluate these alternatives against both the traditional and non-traditional threats. Missions include those shown on this chart along with the characteristics of naval forces to deal with these threats.

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The approach to alternative fleet development is now described in terms of themes used, types of platforms considered, and context.

Themes for Alternative Fleet Architectures
- can be combined in Alternatives -

- **Surface & Air**
  - Increased reliance on small surface combatants, fewer cruisers and destroyers, replace CVNs with smaller flat-deck combat ships like MPF(F)
  - Increased reliance on sea bases and air assault/resupply; less on surface assault and resupply, fewer amphibs, more MPF(F)
- **ISR**
  - Increased reliance on joint ISR, less on dedicated Navy ISR, fewer SSNs, more surveillance, and more joint comms
- **Subsurface**
  - Fewer manned ships near hostile shores; more unmanned vessels; fewer SSNs, more UUVs; maintain SSGNs for stand-off strike and SOF support; and potential use of a new low-cost AIP diesel submarine
- **Stationing**
  - Increased forward stationing, Blue/Gold crews
- **Homeland Defense**
  - Increased focus on homeland defense: more small ships like the ones identified in this study or the national security CG cutters, more missile defense ships, fewer CVNs

Themes guiding our development of alternatives to address the non-traditional threats are listed in this chart. They can be combined in alternatives as appropriate. For the surface and air components of future alternatives, our theme is increased reliance on small surface combatants, fewer cruisers and destroyers, and replacement of CVNs with smaller flat-deck combat ships similar to MPF(F) future ships.

In ISR, we use increased reliance on joint ISR with less on dedicated Navy ISR, fewer SSNs, and more joint communications. Our theme for the subsurface component is fewer manned vessels (SSNs) and more unmanned vessels (UUVs) near hostile shores, maintain the SSGNs for stand-off strike and SOF support, and potential use for a new low-cost AIP diesel submarine for ISR data collection, sensor distribution and monitoring, and homeland defense.

Increased forward stationing by increasing the number of surface combatants and potentially using Blue and Gold crews for ships is another theme. The last theme is increased focus on homeland defense with more small ships like the national security Coast Guard cutters, more missile defense ships, and fewer CVNs.

Alternative Surface Combatants

Programmed Surface Combatants 8 different hull designs

- **Nuclear Aircraft Carrier (CVN)**
- **Amphibious Ships (LHA, LHD, LPD, LSD)**
- **Cruiser (CGX)**
- **Destroyer (DDX)**
- **Littoral Combat Ship (LCS)**

Alternative Surface Combatants

only 2 different hull designs

- **Large**
- **Small**

Another feature of our alternative development is reducing the number of different hull types from eight in the programmed Navy addressing the traditional threat to two in the alternatives developed in this study for the non-traditional threat. The two hull forms are one large ship based on an MPF(F) design and one small ship or craft. In a third alternative, three hull types are used. The alternative fleet architectures offer more modularity and fewer hull types.

Context for Alternative Development

- **Surface combatants**
  - Two hull types used in each alternative
  - 1 large ship and 1 small ship or craft
- **Subsurface**
  - Replace 1 SSN in CSG and 1 SSN in ESG with 4 AIP SS in CSG
  - Retain SSNs for other missions and retain the programmed SSGNs and SSBNs
  - Unmanned UUVs, carried and launched by larger surface ships
- **Support ships**
  - Retain programmed ships
  - Potential to use the large hull for follow-on ships
- **Aircraft**
  - Designed for non-catapult launch
  - JSF-like for strike, air combat, SAR missions
  - Rotary-wing, tilt-rotor, heavy-lift aircraft with large cargo capacity for supply and sustainment
  - Vertical or short takeoff UCAVs or UCASs

The context for alternative fleet architecture development is summarized as follows: two hull types for surface combatants, replace SSNs in CSG and ESG with AIP diesels in CSG, retain SSNs for other missions, retain SSBNs and SSGNs, make extensive use of UUVs, retain support ships, like the T-AOE but follow-ons may potentially use the large common hull, non-catapult aircraft including JSF, rotary-wing, tilt-rotor, heavy-lift aircraft, and UCAVs.

We will first describe a potential future for naval air and then the surface combatants.

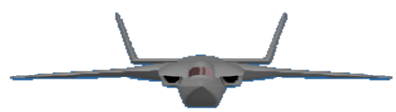
Programmed Aircraft and Aircraft Used in Alternatives for CSG and ESG Formations

Programmed Aircraft

- Joint Strike Fighter (short take-off, vertical landing)
- MV-22 (vertical take-off and land) Helos
- Unmanned Combat Aerial System (UCAS)
- Unmanned Aerial Vehicle (UAV)

Aircraft Used in Alternatives

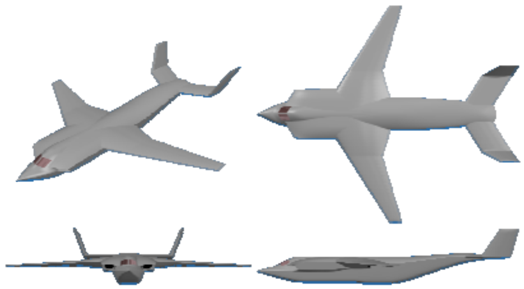
- Programmed aircraft
- Add heavy-lift vertical/short take-off/land cargo and passenger vehicle instead of MH-60 helos



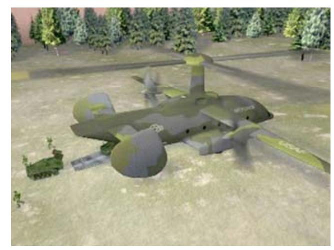
Programmed aircraft are also used in the alternative naval force development along with a new heavy-lift aircraft. The programmed aircraft include the JSF, the MV-22 tilt-rotor vertical take-off aircraft, and UCAS and UAV aerial systems. The JSF has several versions including the F-35C carrier version and the F-35B STOVL version. For alternate naval forces, we use the STOVL version since the extra range and payload will likely not be needed. A new heavy-lift aircraft could be the conceptual MC-X, MV-44 quad tilt-rotor, or the heliplane transport (VTOL aircraft), which we use in lieu of the MH-60 helicopters in the ESG.

New Heavy-Lift Transport Aircraft

	MV-22	MC-X transport VTOL/STOL	Heliplane Transport
Speed (kts)	250	450	400
Cargo (tons)	10	20	25

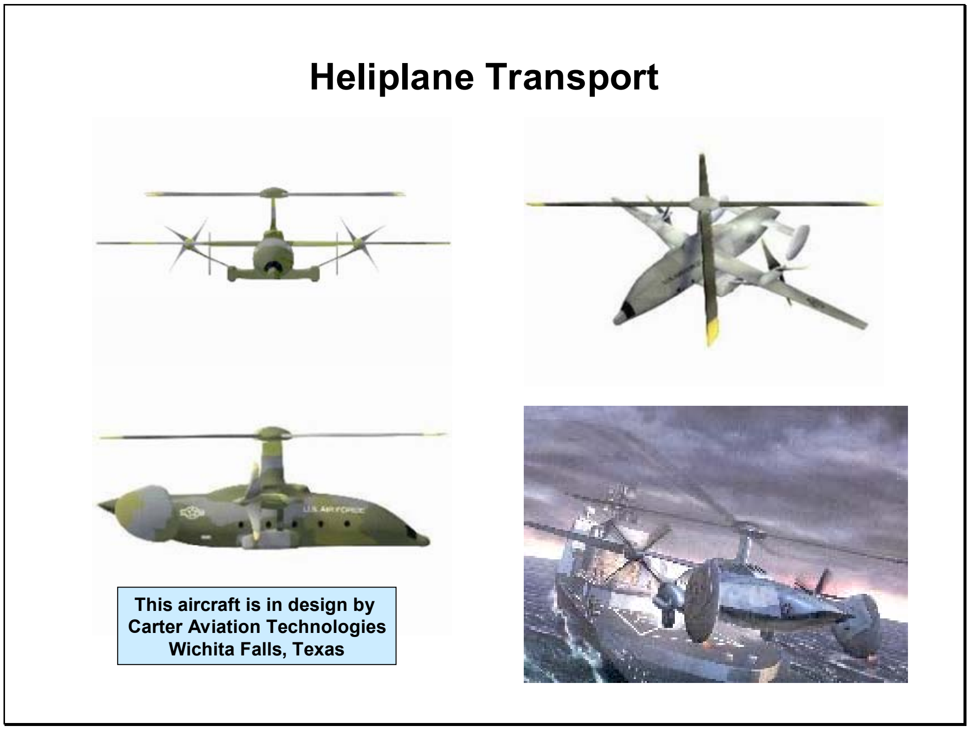


Conceptual MC-X



Heliplane Transport

The MC-X and a heliplane transport made by Carter Aviation (cartercopters.com), are contrasted with the MV-22 here with respect to speed (450 or 350 knots vice 250 knots) and cargo capacity (20 or 25 tons vice 10 tons) for comparable ranges. The vertical take-off and landing version of the MC-X may be more suitable to the X-AVN large hull ship that we define later in this chapter. The gyrocopter takes off and lands vertically or with a short take-off run, then transitions into plane-like flight. This aircraft is more like the V-44 (four-engine tilt-rotor) than the V-22 in capability.



The heavy-lift aircraft used in this study is the heliplane transport by Carter Aviation. This selection is representative of the type of capability that could be used in the heavy-lift role to support amphibious operations and does not imply an endorsement of this particular aircraft.

Carter Aviation uses slowed rotor/compound (SR/C) technology in this aircraft concept. SR/C technology involves dramatically slowing the rotor of a hybrid rotorcraft and transferring lift to wings optimized for high-speed flight. The aircraft is projected to have an empty weight of about 45 tons, cargo volume of 10,000 cubic feet, and a range of about 1,300 nautical miles with payload and VTOL. The company is in the process of building two 3/10th scale versions of the heavy lift transport heliplane to serve as demonstrators.

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The large surface combatant platforms are described next.

New Large Ship Platform Types

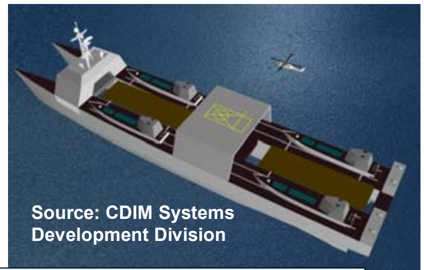
- **Large Ships (50,000 tons)**
  - **X-WPS**
    - **Large ship to carry weapons (land attack, fire support, air defense, and self-defense), modules for the small combatants, and set of UVs (UAV, USV, and UUV)**
  - **X-AVN**
    - **Large ship to carry UVs, rotary wing, tilt rotor, STOVL JSF, and heliplane transport heavy-lift aircraft**
  - **X-SPT**
    - **Mother ship for small surface craft**
  - **X-CBO**
    - **Large ship that could support a combination of subsets of capabilities in X-WPS, X-AVN, and X-SPT**
  - **Cost savings:**
    - **Potential to build these four, MPF(F) (T-AK(X)) and T-AOE(X), using a common hull**
    - **Potential use of civilian crews for general purpose functions**
    - **Navy crew for warfighting functions**

This is not a design study, and the study has not developed concept studies for any of the ships described. Instead, the study has used existing ship concepts in reasonable and realistic ways to support our alternatives. The hull for the large ships is a flat-top monohull developed to support the requirements for MPF(F). Details of the designs are not included in this study. Potential sea-state limitations with transferring modules from these large ships to small ships could be overcome by ongoing development of sea-state compensating cranes.

The large ship concepts are all built using the same hull for different purposes but with enough space to easily accommodate the need. The applications include a large ship to carry weapons, called X-WPS, with VLS cells with missiles for land attack, surface warfare, air defense, and self-defense, advanced gun systems or trainable rocket launchers for fire support. X-WPS will also have space for the modules for the small ships or craft or a limited number of the small craft, space to support limited aviation operations, command space, and accommodations as needed for the particular application. X-AVN uses the large hull for aviation operations for STOVL JSF aircraft, rotary wing, tilt-rotor, UAVs, and a heavy-lift aircraft. Space is available to provide maintenance support and accommodations for personnel. X-SPT carries very small surface combatants along with the support and accommodations needed. X-CBO could provide a combination of subsets of capabilities of the other large ships with the same large common hull.

Cost savings may accrue in the following ways: potential use of a common hull for these four large ships, MPF(F) and the follow-on to the T-AOE, and potential use of civilian crews for general purpose ship functions while Navy crew conduct the warfighting functions.

Potential Large Ships Based on Common Hull Designs



- **X-WPS**
  - **Large ship to carry weapons (land attack, fire support, air defense, and self-defense), a variety of modules for the small ships, and set of UVs**
- **X-AVN**
  - **Self-defense weapons**
  - **Large ship to carry unmanned vehicles/vessels and short-or-vertical takeoff JSF, V-22, and new transport aircraft**
- **X-SPT**
  - **Self-defense weapons**
  - **Mother ship for small surface combatants**

This chart shows MPF(F) ship concept designs developed by the Center for Naval Analyses for the MPF(F) Analysis of Alternatives, along with a concept for carrying smaller vessels. We used the MPF(F) ship as a potential hull for our large ship concepts, namely X-WPS, X-AVN, and X-SPT.

MPF(F) Ship Concepts
Potential X-WPS, X-AVN, X-SPT, and X-CBO

Characteristics
Length 830 ft
Lightship 45K mtons
Full load disp 57K mtons
No. MSC crew 50
No. USMC acc. 2,100
Helo spots 104
LCAC stow 2
Cost $1.4B

Other versions for logistics, or personnel support

MPF(F) AoA: CNA

The MPF(F) ship concept can be configured into several versions. The hull for the aviation ship is about the same length as an LHD but its displacement is about 1.5 times greater.

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  - Large Platform Configuration
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The small surface combatant platforms are described next. The sizes used here are symbolic and represent two small ship options: one with ocean transit capability and the other requires transport to the theater of operations. Again, this is not a design study, and we used existing concept designs to represent potential capabilities. Details of design are not addressed. The performance of the small ships may be limited by weather conditions and sea state.

The approach for determining module configurations was first used in the IDA study of small surface combatants.[1]

1 *Small Combatants: Implications for the Effectiveness and Cost of Navy Surface Forces*, IDA Paper P-3716, September 2002.

New Small Combatant Platform Types

Hull Forms Are Illustrative

SSC-1000

Self-deploys to Theater

Length :	70 m
Full load :	1000 tons
Payload:	15 percent

VSC-100

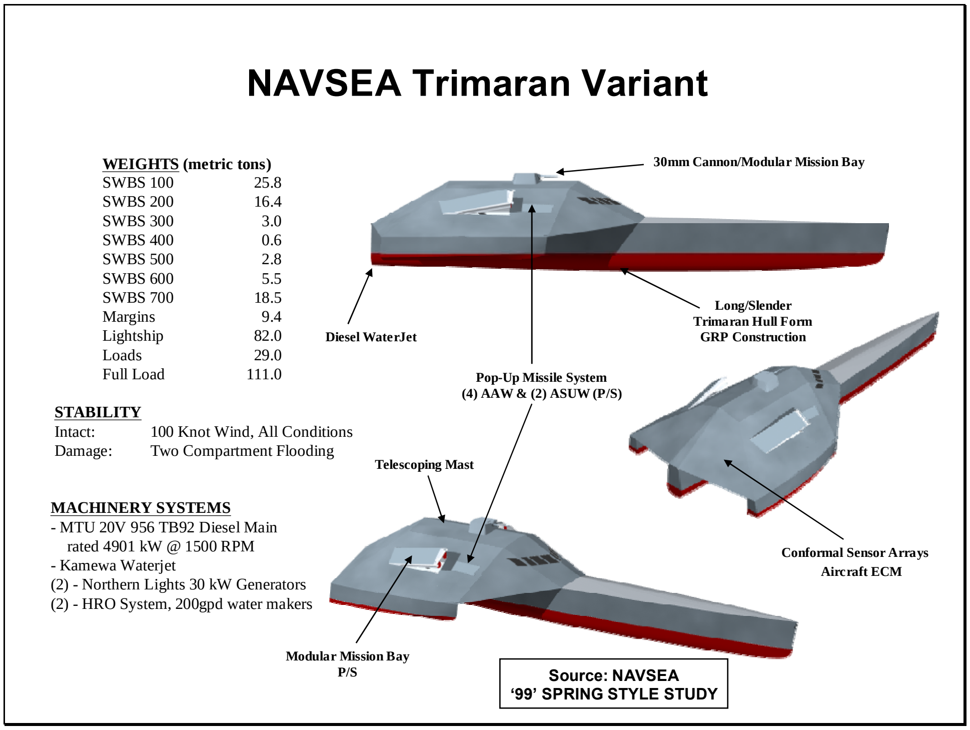
Carried to Theater by X-SPT

Length :	40 m
Full load :	100 tons
Payload:	30 percent

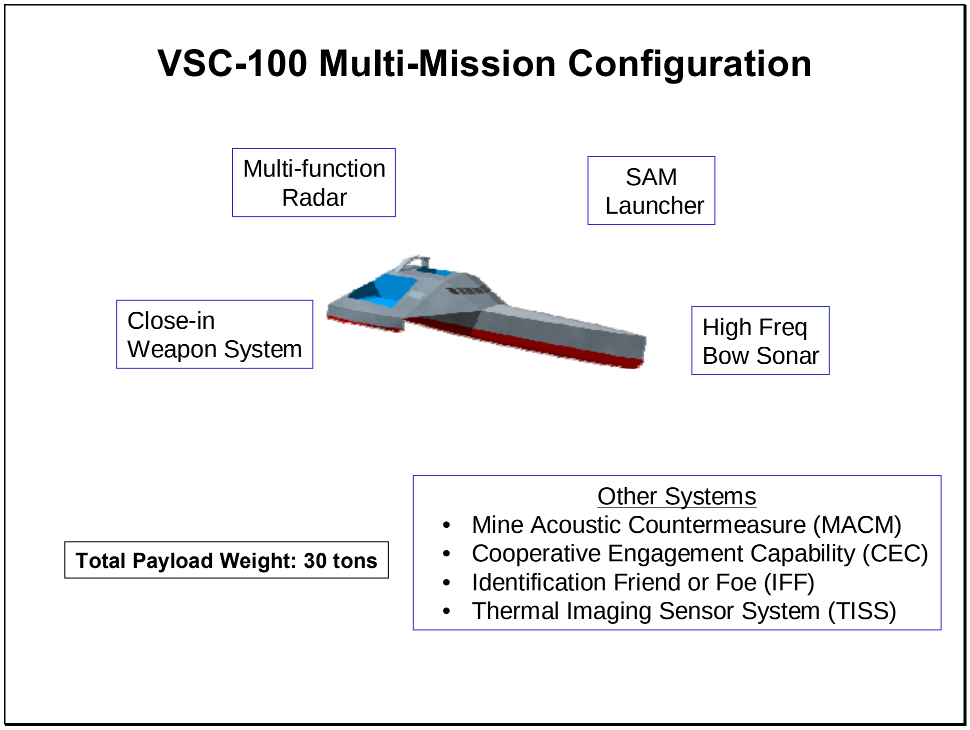
Concept design source: NAVSEA

- Each small ship can carry a weapons or sensor module for specific missions. Modular, very flexible, able to swap out modules at sea at X-WPS, X-AVN, or X-SPT
- All vessels are networked, coordinated

Two new small ship types considered here are the small surface combatant SSC-1000, which is 1,000 tons in full load displacement, and the very small craft VSC-100, which is 100 tons displacement. Based on NAVSEA concept studies, these vessels are assumed to be networked and coordinated with the other ships, large and small, in the alternative forces. They are modular with a variety of weapon and sensor modules that are carried on the large ships in the formations (X-WPS, X-AVN, or X-SPT) and are able to swap out modules at sea. The SSC-1000 carries sufficient fuel to self-deploy to the theater. Its payload is assumed to be 15 percent of its displacement. The VSC-100 is carried to theater on a large ship, like X-SPT, and its payload is assumed to be 30 percent of the displacement since it does not need to carry fuel to self-deploy.

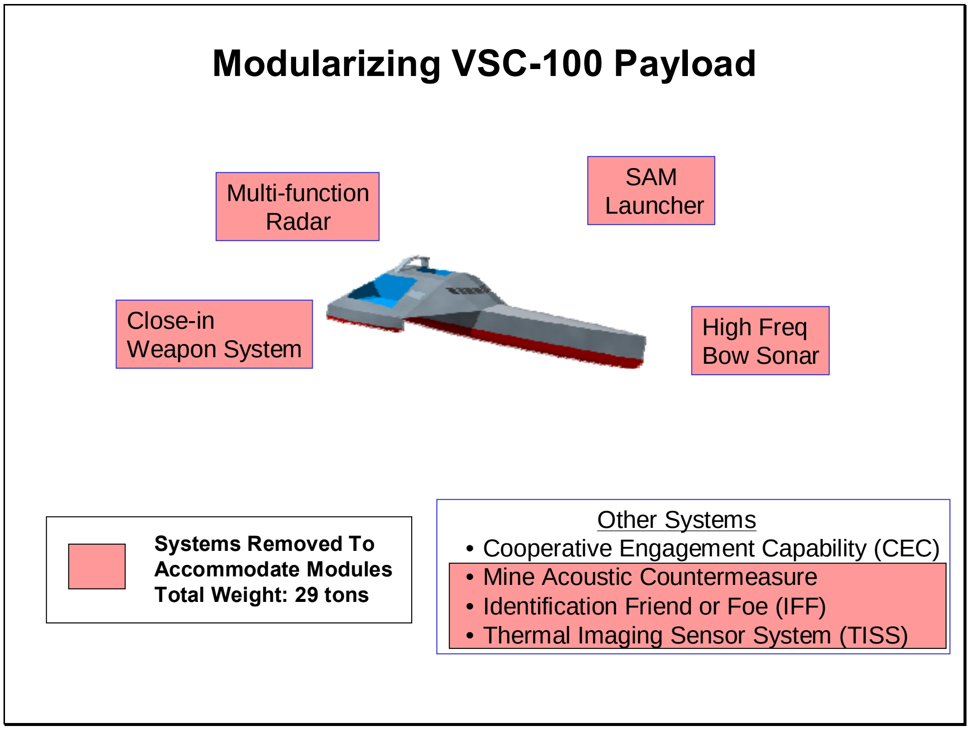


The source concept for the VSC-100 is this small trimaran variant from the 1999 NAVSEA Spring Style Guide. This is not a design study, and we are not endorsing any design. This is representative of a potential VSC-100, but this craft could also be a monohull as well. The Ship Work Breakout Schedule (SWBS) weights are shown along with information of stability and machinery systems. The variant's potential modular mission bays are shown. Also, this craft has the potential to be unmanned with the unmanned versions working with manned versions as hunter-killer teams or sensor deployment and monitoring teams.

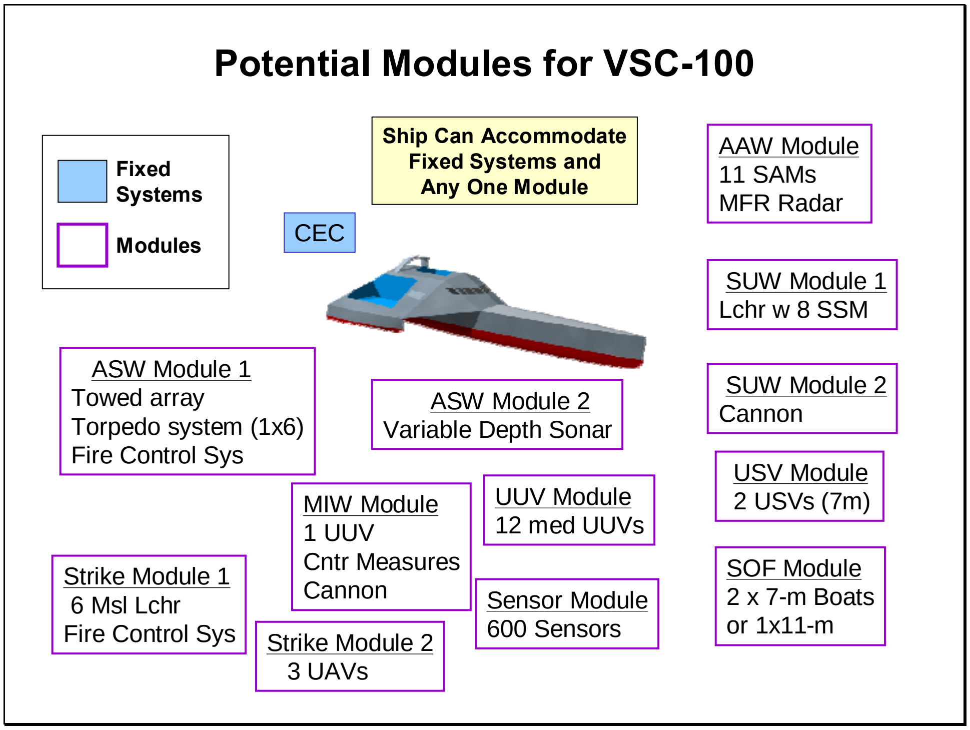


Multi-mission capability implies fixed systems in a vessel configured to provide the vessel with as much capability in several warfare areas as possible within the weight constraint. This chart summarizes the multi-mission configuration for the VSC-100. The ship has limited capability in air defense, mine avoidance, surface warfare, as well as CEC, IFF, and a thermal imaging system.

Air defense capability is provided by a multi-function radar (MFR) and an eight-cell SAM launcher with missiles. The MFR is a surface search radar limited to the horizon. It also serves as a fire control radar for missile and gun systems. This radar is not a full-capability three-dimension AAW radar, like the SPY-1 radar on *Aegis* ships. Limited mine warfare capability is provided by a bow-mounted high-frequency mine avoidance sonar and a Mine Acoustic Countermeasure (MACM) system. Surface Warfare capability is provided by a Close-in Weapon System (CIWS-1B).



To modularize the VSC-100, all systems except the CEC are removed. The total weight of the removed systems is 29 tons. This allows modules weighting up to 29 tons to be accommodated in the modularized version of the VSC-100.

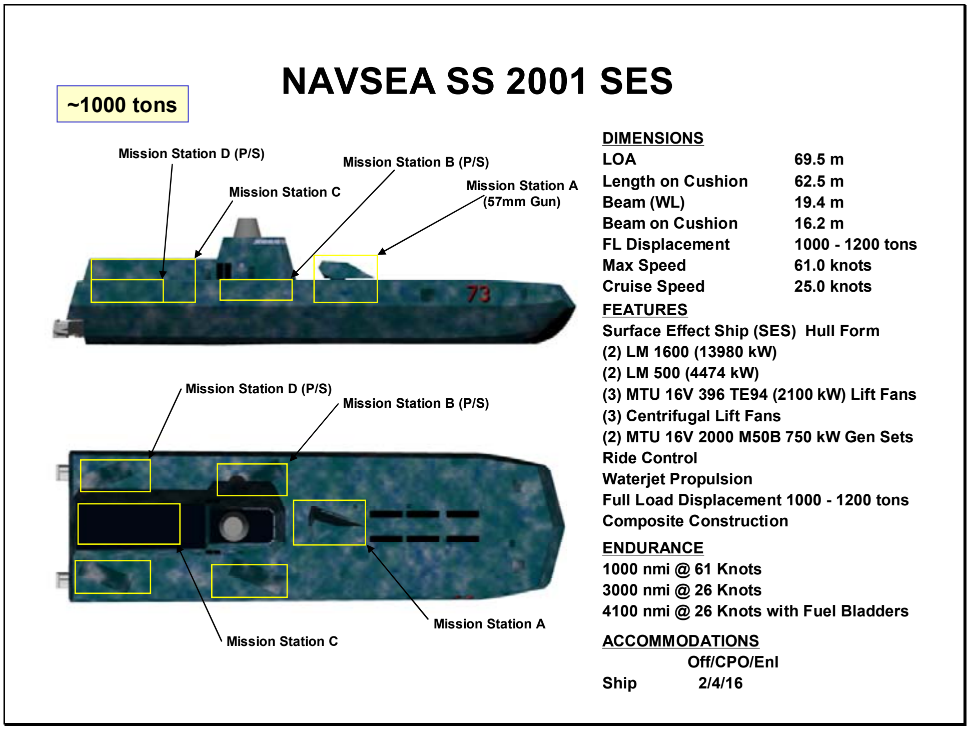


Any of these modules can be accommodated in the VSC-100 craft but only one at a time. The first ASW module consists of a towed array, torpedoes, and an underwater fire control system (UWFCS), while the second ASW module has a variable depth sonar. The first strike module consists of a six-cell concentric canister launcher (CCL) and a TLAM fire control system (FCS), and the second strike module consists of three UAVs.

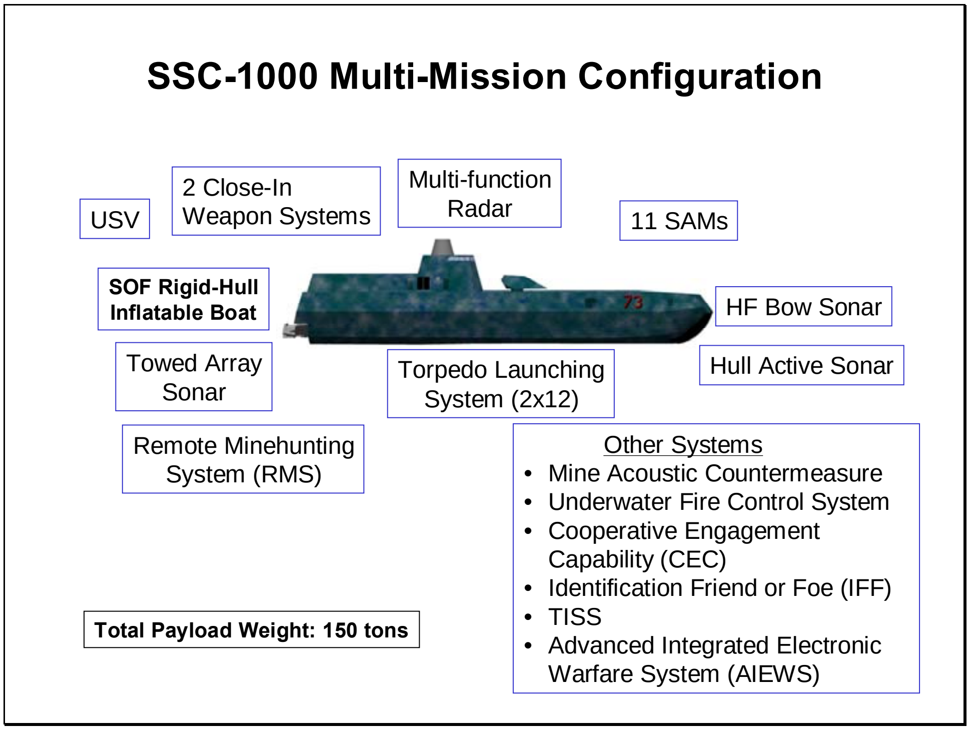
The AAW module consists of 11 SAMs and an MFR. The first SUW module consists of a launcher with eight SSMs, while the second consists of a CIWS-1B cannon.

The MIW module consists of one RMS UUV, MACM, and the Mine Neutralization System (MNS), which is a 25-mm cannon to explode mines on, or near, the water surface. The sensor module consists of 600 sensors representative of the Deployable Acoustic Detection System (DADS) variety.

The UUV module consists of 12 medium-size (smaller than the RMS) UUVs. The USV module consists of two 7-meter RHIB-type USVs, and the SOF module consists of either two 7-meter RHIBs or one 11-meter RHIB.

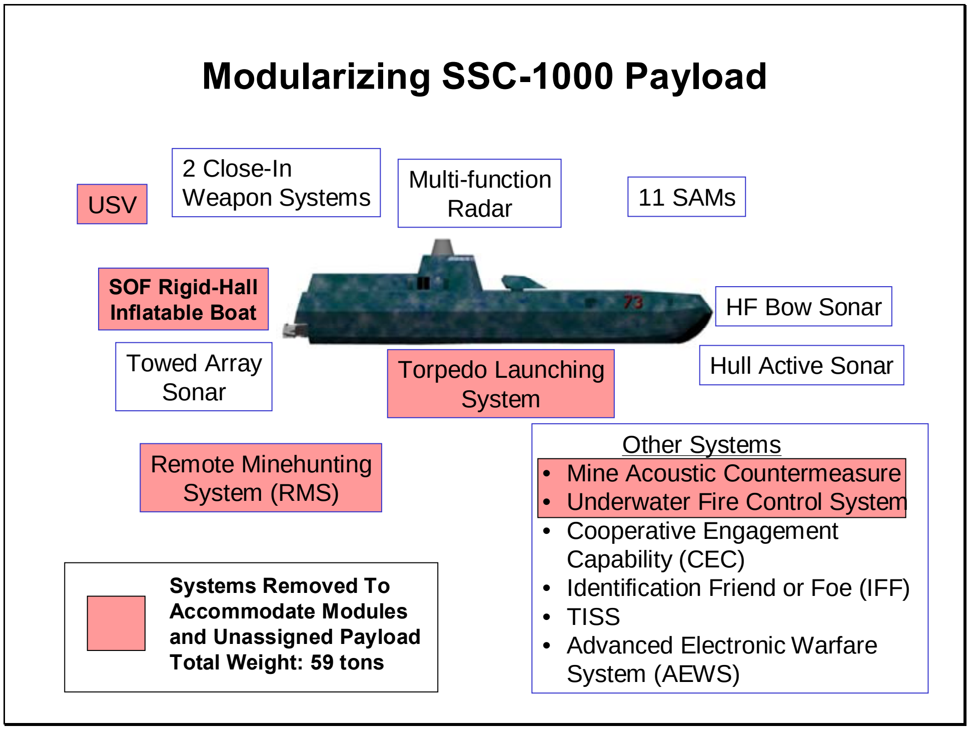


The source concept for the SSC-1000 is a NAVSEA concept design for a 1,000-ton Surface Effect Ship (SES) from the Spring Style Study 2001. The chart shows that it is designed with separate mission station to support modular payloads. The ship's maximum speed is 60 knots, and its endurance is 3,000 nautical miles at 26 knots. The concept has accommodations for 22 men.

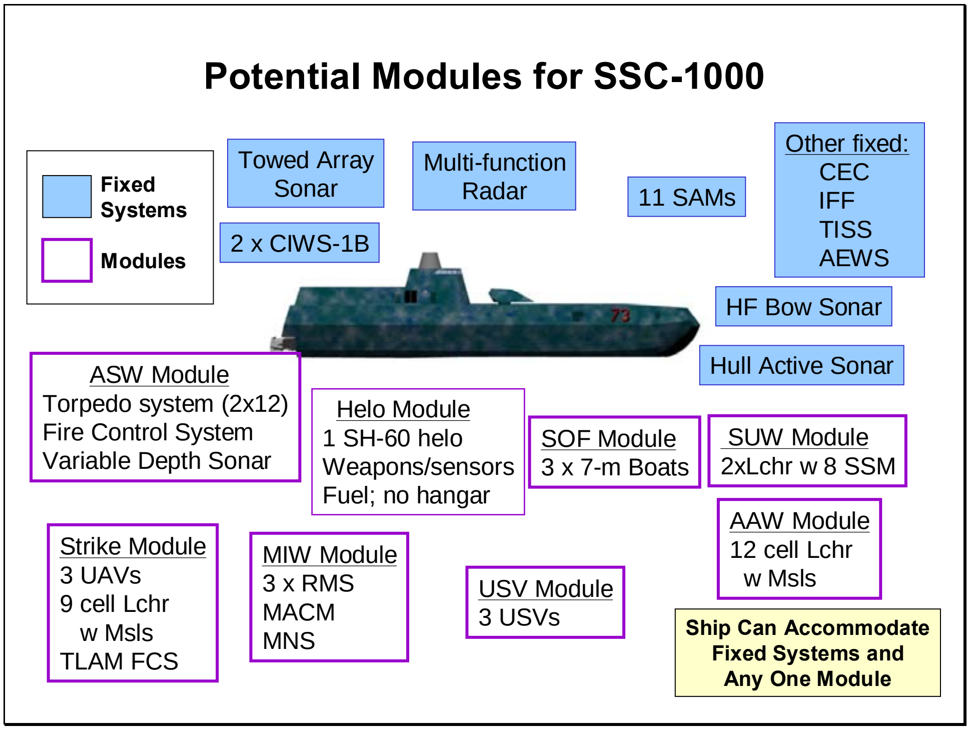


This chart summarizes the multi-mission configuration for the SSC-1000. The ship has capability in air defense, ASW, mine warfare, surface warfare, as well as CEC, IFF, thermal imaging, a SOF RHIB, an AEWS, and a USV that can be configured with a limited number of sensors and weapons.

Air defense capability is provided by a MFR and an 11-cell SAM launcher with missiles. ASW capability is provided by a Multi-Function Towed Array (MFTA), a bow-mounted active sonar, and a torpedo launching system. MIW capability is provided by a bow-mounted high-frequency mine avoidance sonar, one RMS, and a MACM system. SUW capability is provided by two CIWS-1B systems with 1,500 rounds for each system. This configuration represents the capability in a multi-mission SSC-1000, i.e., an SSC that is not modularized. The following charts describe how the study team constructed modules for this ship.



This chart shows the systems removed in order to modularize the SSC-1000. Using the assumptions for modularization, the USV, SOF RHIB, RMS, torpedo launching system, MACM, and the UWFCS are removed. The total weight of the removed systems plus the 16.5 tons not used in the multi-mission configuration is 59 tons. This allows modules weighting up to 59 tons to be accommodated in the modularized version of the SSC-1000.



This chart summarizes the eight modules developed for the SSC-1000 within the 59-ton weight constraint. The modularized version of the SSC-1000 accommodates one of the eight potential modules and the fixed systems that were not removed from the multi-mission configuration of this ship. The fixed systems are the towed array, MFR, two CIWS-1B systems, high-frequency bow sonar, hull active sonar, SAM launcher, CEC, IFF, TISS, and AEWS.

The ASW module consists of a torpedo-launching system with MK-50 torpedoes, an UWFCS, and a Variable Depth Sonar (VDS) that was not in the multi-mission configuration. The helicopter module is the same module defined for the SSC-500 and allows operation of one SH-60 helicopter in a “lily-pad” fashion without hangar or maintenance support.

The strike module consists of three UAVs for targeting, a nine-cell CCL with TLAM and Tactical Tomahawk (TACTOM) missiles, and a TLAM fire control system. The MIW module contains three RMS systems, a MACM system, and a MNS.

The SOF module consists of three RHIBs for delivery of Special Operations Forces. Similarly, the USV module has three RHIBs for sensor and weapons delivery. Since these modules weight only 39 tons, there is 20 tons of margin remaining to outfit them as needed.

The SUW module consists of two launchers and eight Harpoon-like surface-to-surface missiles in each launcher.

The AAW module consists of a 12-cell CCL for Evolved Sea Sparrow Missile (ESSM)–like quad packs.

Due to the availability of the modules on board the large ships in the alternative fleet architectures, one-half of a complete set of modules is bought for each individual small combatant.

Costs of Combat Modules

SSC	Procurement Cost per Combat Ton ($ M)	Average Tons per Module	Procurement Cost per Module ($ M)	Modules per SSC	Modules Bought per SSC	Total Cost ($ M)
100 tons	0.75	23	15	12	6	104
1,000 tons	0.75	48	30	8	4	144
LCS (SSC-3000)	0.75	48	30	5	3	108

The costs for the modules is based on the weight of the module and a procurement cost per ton of $0.75 million. Since several small combatants will be in each formation within which modules will be carried by large ships, less than a complete set of modules is bought for each small combatant. As shown in the chart, the number bought is half the total number of modules defined for each small combatant. The total cost for the modules is determined for the VSC-100, the SSC-1000, and the 3,000-ton SSC that represents the LCS for costing purposes in this study. Details of the cost analysis are contained in the cost chapter of this study.

Outline

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Next we give the alternative fleet architecture development in terms of formations considered and specific configuration of the large platform.

Configuration of Large Ships to Support Alternatives for Non-Traditional Threats

- To develop alternative naval forces to address the non-traditional threats, planned formation types for surface combatants are retained
  - CSG, ESG, and SAG
- Approach provides organization and structure to alternative development and permits direct comparison for each formation relative to the traditional and non-traditional threats
- Capability and cost of the large ships in each formation need to be specified prior to analysis of their performance
  - Review the formations

In order to develop alternative naval forces to address non-traditional threats, the study team retained the planned formation types for surface combatants: CSG, ESG, and SAG. This approach provides structure for alternative development and permits direct comparison between the formations for the traditional and the non-traditional threats. The capability and cost for the large ships in each formation need to be specified prior to the analysis of their performance. The following chart provides a review of the Navy's planned formations.

Formations in the Navy's Global CONOPS

- Carrier Strike Groups (CSG) (12 Programmed)
  - Ships and submarines
    - 1 CVN, 1 T-AOE, 1 SSN, 1 CG, 2 DDGs, 2-3 LCSs
  - Aircraft
    - Fixed wing: 44-46 F/As, 4 AEWs, 6 EWs, 6 TKs
    - Rotary wing: 12 MH-60s
    - Future: 60 JSFs and 12 MV-22s
- Expeditionary Strike Groups (ESG) (12 Programmed)
  - Ships and submarines
    - 1 LHD, 1 LPD, 1 LSD, 1 CG, 1 DDG, 1 DDX, 2-3 LCSs, 1 SSN
  - Aircraft
    - Fixed wing: 6 AV-8B STOVLs
    - Rotary wing: 12 CH-46s or CH-53Es, 4 AH-1s, 2 UH-1s, 6 MH-60s
    - Future: 6 JSFs, 18 MV-22s, and 3 heliplane transport heavy-lift aircraft
- Surface Strike Groups (SSG) or Missile Defense Surface Action Groups (MDSAG) (9 Programmed)
  - Ships
    - 1 CG and 2 DDGs or 3 DDGs

The formations for the Navy's Global CONOPS include 12 CSGs, 12 ESGs, and 9 SAGs. The chart shows the ships and submarines in the CONOPS. Most of the surface combatants are included in these formations, but not all of the submarines, aircraft, and support ships. Submarines have other missions in support of the Unified Commanders and the intelligence community. The next chart shows the submarine missions for SSNs, SSGNs, and SSBNs.

The carrier air wing consists of 44 to 46 F/A-18 fighter and attack aircraft, 4 E-2C AEW aircraft, 6 F-18G EW aircraft, 6 S-3 SUW and tanker aircraft, and 12 MH-60 helicopters for ASW, CSAR, and logistics. We assume that in the future these aircraft could be replaced with 60 JSF-like aircraft and 12 MV-22 tilt-rotor aircraft. This assumes that capabilities like the E-2C and the F-18G could be replicated in a JSF-like aircraft or, alternatively, in an V-22-type aircraft.

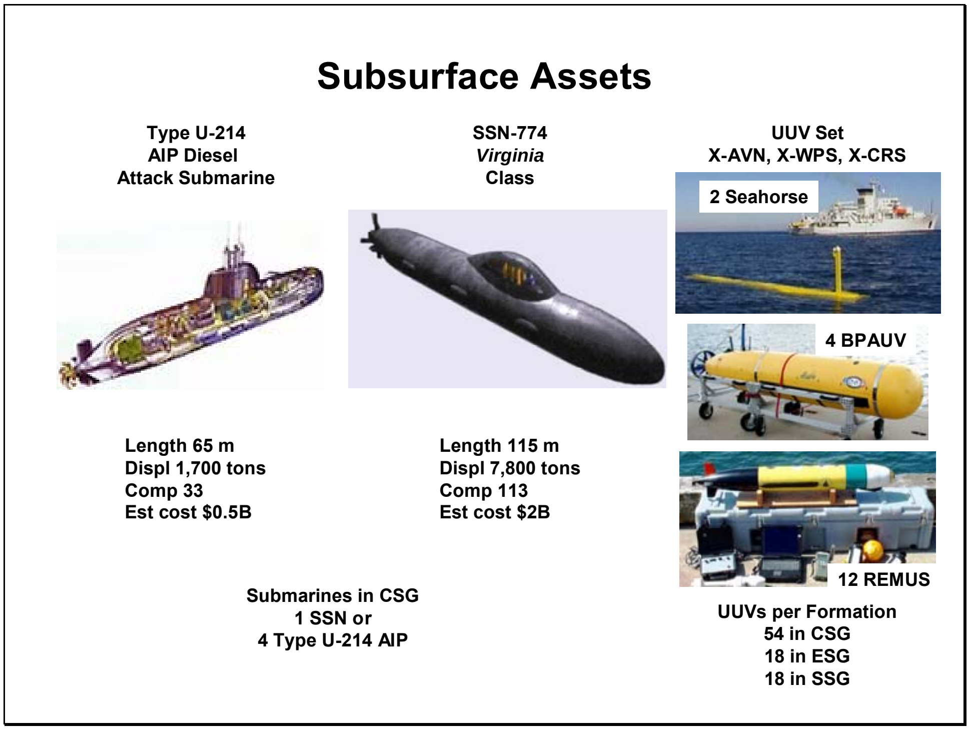
The ESG aircraft include 6 AV-8 aircraft, 12 CH-46 or CH-53E helicopters, 4 AH-1, 2 UH-1, and 6 MH-60 helicopters. We assume that in the future these aircraft could be replaced with 6 JSF-like aircraft, 18 MV-22s, and 3 heliplane transport heavy-lift aircraft.

Future Plans for Submarines

- **SSN**
  - **OPNAV (Submarine Warfare Division) has indicated that 60 to 80 needed to meet requirements of the Unified Commanders and the national intelligence community**
  - **Support operations in the littorals and in "blue water"**
  - **Missions**
    - **Prepare the battle space with data and information**
    - **Support SOF operations**
    - **Land attack with precision strike with TLAM**
    - **ASW and MIW**
    - **Other classified missions**
  - **Programmed to include support to CSGs and ESGs**
- **SSGN**
  - **4 currently planned to provide land attack and precision strike and SOF support**
- **SSBN**
  - **Provide strategic deterrence and presence**

In a briefing to the House Armed Services Committee (HASC) in 2000, the Director, Submarine Warfare Division in OPNAV described the planned force structure. The plan indicated that 60 to 80 SSNs will be needed to meet the submarine requirements of the Unified Commanders and the national intelligence community. SSNs will support operations in both the littorals and in the open ocean or "blue water" operations. The SSN missions include preparation of the battle space with data and information collection, support of SOF operations, land attack with precision strike via TLAM missiles, and MIW and ASW operations. SSNs are programmed to be included in the CSGs and ESGs.

Four SSGNs are planned to provide land attack and precision strike and to support SOF operations. The SSBNs provide strategic deterrence and presence.



In the alternative fleets developed for assessment in this study, we replaced the SSN in the CSG with four smaller, cheaper AIP diesel submarines (SS). In the ESG, we replaced the SSN with sets of unmanned vehicles (UV). This chart shows the SSN-774 flanked by a drawing of an AIP and a set of UUVs.

Several countries are procuring AIPs. Sweden is buying the SSK Gotland class (Type A19) AIP attack diesel submarine shown in the chart. Germany and Italy are buying the Type U-212 AIP SS, which is somewhat larger that the A19. Also, Greece and South Korea are buying the Type U-214 AIP SS, which is somewhat larger than the U-212. We assumed an AIP SS similar to the U-214 for the alternatives in this study. This provides a larger AIP SS so that more range, sensors, weapons, and land attack missiles could be supported. Based on the cost for the Germans to buy four U-212 AIPs, we estimated that four AIPs could be bought and operated for the cost of one SSN. This cost is "ballpark" in that we did not have the same information and details on the AIP as on the other ships in this study. Reported cost for Sweden's A19 is as low as $0.2 billion, which would yield 10 A19s for one SSN. To be conservative about this, we will use four AIPs to one SSN.

Thus, in this study we handled the submarines in the CSG parametrically with either four AIPs or one SSN. This approach was taken to provide an alternative that requires caveats and more analysis. AIP submarines are limited in range and speed in that they can either transit at a low speed for a long time or sprint at a high speed for a short time. Thus, AIPs cannot keep pace with a CVN, and they must be moved into position or forward stationed in anticipation of an operation. This could be a substantial impediment to a fast-moving operation. An SSN does not have any range or speed issue and maintains pace with the CVN.

In the ESG, we replaced the SSN with a set of 18 UVs as shown in the chart: 2 large, 4 medium, and 12 small UUVs. When Marines are landed in a hostile environment, a CSG will be present to form an ESF, so at least one submarine will be in the CSF formation.

SSNs outside the CSG and ESG formations have their own special missions and tasks. This study did not address these SSNs nor the potential to use AIPs in their missions.

Large Ships Using MPF(F) Common Hull for Alternative Development—I

- **X-AVN AVIATION SUPPORT SHIP**
  - 1 X-AVN ship supports 88 aircraft (CH-46 equivalents)
  - Projected future carrier air wing
    - 60 STOVL JSFs + 12 TRs = 150 CH-46 equivalents
  - 2 X-AVN ships support:
    - 60 STOVL JSFs + 12 TRs + 30 VTUAVs
    - Aviation maintenance
    - Accommodations for 4,300
    - Stowage and working area for UUVs, USVs, and modules for SSC-1000s (60K square feet)
    - Integrated Landing Platform (ILP) for launch and recovery of UUV and USV
    - Cranes for changing SSC-1000 modules
- **X-CRS CORSAIR DISTRIBUTED AVIATION SUPPORT SHIP**
  - Supports 8 JSFs, 2 TRs, and 8 UAVs

To support the CSG, the study team traded X-AVN aviation support ships for the CVN and X-WPS for the CGXs using the MPF(F) common hull for both. Using spot factors and aircraft equivalences from the MPF(F) AoA, one X-AVN supports operational spots and parking spots for 88 CH-46 equivalents. The projected airwing of 60 JSFs and 12 MV-22 tilt-rotor aircraft constitute 150 CH-46 equivalents. As a result, we use two X-AVN ships to support this air wing and 30 vertical takeoff and landing unmanned aerial vehicles (VTUAVs). These two ships also provide the space for maintenance, accommodations, UUVs, USVs, and modules for the small combatants, and the cranes for changing the modules.

At 57,000 tons full load displacement, one X-AVN notionally supports 30 JSFs, 6 TRs, and 15 VTUAV air platforms. This is similar to the UK's plans for a new aircraft carrier. This design is evolving but is expected to be between 55,000 and 65,000 tons supporting about 50 VSTOL aircraft.[2] Also, the existing French light aircraft carrier, the *Charles de Gualle*, supports 35 to 40 aircraft at a full load displacement of only 41,000 tons, which is achieved with nuclear power.

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2 Naval Power International, The Fifth Regional Seapower Symposium for the Navies of the Mediterranean and Black Sea countries, Venice, 2004.

In another alternative, 8 X-CRS distributed aviation support ships are used in the CSG formation. The X-CRS, described later in this study, is a very small carrier (13,500 tons full load displacement) supporting 8 JSFs, 2 TR aircraft, and 8 UAVs. The existing UK VSTOL carrier, *Invincible* class, supports 8 VSTOL aircraft and 12 helicopters at a full load displacement of 20,600 tons.

This discussion indicates that the X-AVN is sized in a reasonable manner to support the assigned aircraft. The reasonableness is supported by both existing foreign aircraft carriers and by the plans for the new UK carrier. The X-CRS concept is sized to operate the number of aircraft assigned but may not have the space to provide the level of maintenance currently provided in other aviation capable ships. We will discuss this more when we introduce the X-CRS in the section containing Alternative C.

Large Ships Using MPF(F) Common Hull for Alternative Development—II

- **X-WPS WEAPONS SUPPORT SHIP**
  - 360 VLS cells for strike and fleet defense (AAW, ASW, SUW) or BMD
  - 4 Trainable Rocket Launchers (TRL) (formerly AGS) or 65 MJ EM guns for Naval Fire Support
  - Magazines
  - Aviation support for limited numbers of aircraft or VTUAVs
  - Accommodations for crew
  - Storage and working area for UVs and modules
  - Integrated Landing Platform (ILP) and cranes
  - Weapons systems configuration
    - Weapons, launchers, radar, other equivalent to 3 CGs
    - TRLs for fire support equivalent to 2 DDXs
- **X-SPT IS A MOTHER SHIP FOR VSC-100 COMBATANTS**
  - Transport and support the VSC-100s and crew
  - Carry VSC-100 modules and personnel to support the modules
  - Accommodations for ship and VSC crew members and module support people
- **X-CBO COMBINATION SHIP FOR AVIATION AND WEAPONS SUPPORT**
  - Supports fractional portions of X-AVN and X-WPS

The other large ship used for the CSG is X-WPS, which the team traded for three CGXs and two DDXs. This ship has 360 VLS cells for strike and fleet defense, or ballistic missile defense; four TRLs (formerly the AGS) or EM guns for naval fire support of land forces; magazines; support for a limited number of aircraft or VTUAVs; accommodations for people; space for UUVs or USVs and modules for the small combatants; integrated landing platform for UV operations; and cranes.

X-SPT is another large ship that uses the MPF(F) hull. This ship is the mother ship for the VSC-100 combatants. It transports and supports both the combatants and the modules for the VSCs. It also accommodates the VSC crews and module support personnel. We took a conservative approach with the large ships and did not push the 15-percent load constraint. X-SPT follows this pattern in that by the 15-percent constraint 85 of the VSC-100s could be embarked; however, 24 was the largest number embarked in one X-SPT ship. This allows room to carry the modules for the VSC-100s and to support the cranes to lift the VSC-100s on and off the X-SPT. On board the X-SPT, a system of cranes along with fixed and mobile cradles supports the storage and movement of the VSC-100s on board the X-SPT. A monohull may be the best hull form for the VSC-100 in that it could be cradled and its length could be accommodated in the X-SPT ship. However, this concept is a system of systems that need to be designed together. With our conservative approach, the concept appears to be feasible using the MPF(F) hull as the hull for the X-SPT ship.

Although not used explicitly, the X-CBO is another large ship that could be configured as a combination of X-AVN and X-WPS capabilities.

Large Ships Using MPF(F) Common Hull for Alternative Development—III

- **T-AKX MPF(F) ship**
  - **Used in alternative ESGs to replace programmed amphibious ships**
  - **Supports 30 CH-46 equivalents**
    - **ARG air assets (6 JSFs, 18 MV-22s, 3 heliplane transport heavy-lift aircraft) require about 60 CH-46 equivalents**
  - **Cargo: 150K square and 150K cube**
    - **ARG totals: 80K square and 220K cube**
  - **Accommodations: 1,400**
    - **ARG: 4,000**
  - **2 T-AKXs provide ARG equivalent air, square, cube, and accommodations**
    - **Some excess square traded for accommodations**
    - **Other excess for UVs and modules**

We also used the common MPF(F) hull to replace the programmed amphibious ships in the alternative ESGs. We used two of these ships to provide the support in the current ARG (LHD, LSD, LPD) including the 6 JSFs, 18 MV-22s, and 3 heliplane transport heavy-lift aircraft, LCACs operating off ILPs and embarked with cranes, accommodations, and square and cube storage.

Ship Crew Size

CVN	6,144	Ships company and Air Wing
CGX	374	CG-47
DDX	318	DD-963
LCS	56	Use SSC-3000 below
LHD	2,582	1,582 ship crew plus 1,000 for aviation element
LPD	397	LPD-17
LSD	852	LSD-41
LCS (SSC-3000)	50	NAVSEA design plus 2 each for 3 modules
SSC-1000	22	NAVSEA design plus 2 each for 4 modules
VSC-100	3	
X-WPS	550	50 MSC crew plus 500 for warfighting functions
X-AVN	1,250	50 MSC crew plus 1,200 crew and air wing
T-AKX	550	50 MSC crew plus 500 for warfighting functions
X-SPT	550	50 MSC crew plus 500 to handle cranes and VSC craft
SSN-21	116	
AIP	37	
T-AOE	708	
X-CRS	130	

The study estimated the crew size for each of the ships. The notes indicate the sources including NAVSEA for the concept designs used for the small ships and the MPF(F) AoA for the large ships. Crew to support the capabilities on the large ships are added to the MSC crews of 50 on the large ships. Programmed ship crews are as currently planned. The people supporting the modules for the VSC-100 (two for each of the six modules for each craft) are accommodated in the X-SPT ship.

Ship Speed
(knots)

- CVN 30
- CGX 30
- DDX 30
- LCS 50 Based on SSC-3000
- LHD 20
- LPD 20
- LSD 20
- SSC-3000 50
- SSC-1000 60
- VSC-100 60
- X-WPS 24
- X-AVN 24
- T-AKX 24
- X-SPT 24
- X-CRS 60
- SSN-774 25+
- AIP 20 for limited time periods
- T-AOE 25

The range of speeds includes 20 knots for the amphibious ships, 24 knots for the new large ships, 50 knots for the LCS (based on the SSC-3000 design), and 60 knots for the new small ships (SSC-1000 and VSC-100) and the distributed aviation ship X-CRS. In the alternatives developed, the large ships, X-AVN, X-WPS, X-SUP, and T-AKX (MPF(F)), transit at only 24 knots while the small combatants, SSC-1000 and VSC-100, are capable of 60 knots. It is assumed that forces will continue to be forward deployed to mitigate against the large ship speed, and sufficient warning time is provided to move the other required forces into position prior to conflict start.

UV Set for Large Ships

- **UAV**
  - **Fire Scout (Navy's VTUAV)**
  - **3 per ship**
- **USV**
  - **Spartan Scout**
  - **3 per ship**
- **UUV**
  - **Small (REMUS)**
    - **12 per ship**
  - **Medium (BPAUV)**
    - **4 per ship**
  - **Large (Sea Horse)**
    - **2 per ship**

The set of UV platforms on this chart are used in this study as representative of UAV, USV, and UUV capability platforms for the future fleet alternatives. This set will be included in each of the large ships, X-AVN and X-WPS. One set is distributed over four of the X-CRS ships.

We assumed that these would be replaced in 15 years, so for the 30 years of costing we bought two complete sets of UVs. Cost details are in the cost chapter of this study.

The information on UVs is taken from a previous IDA study.[3]

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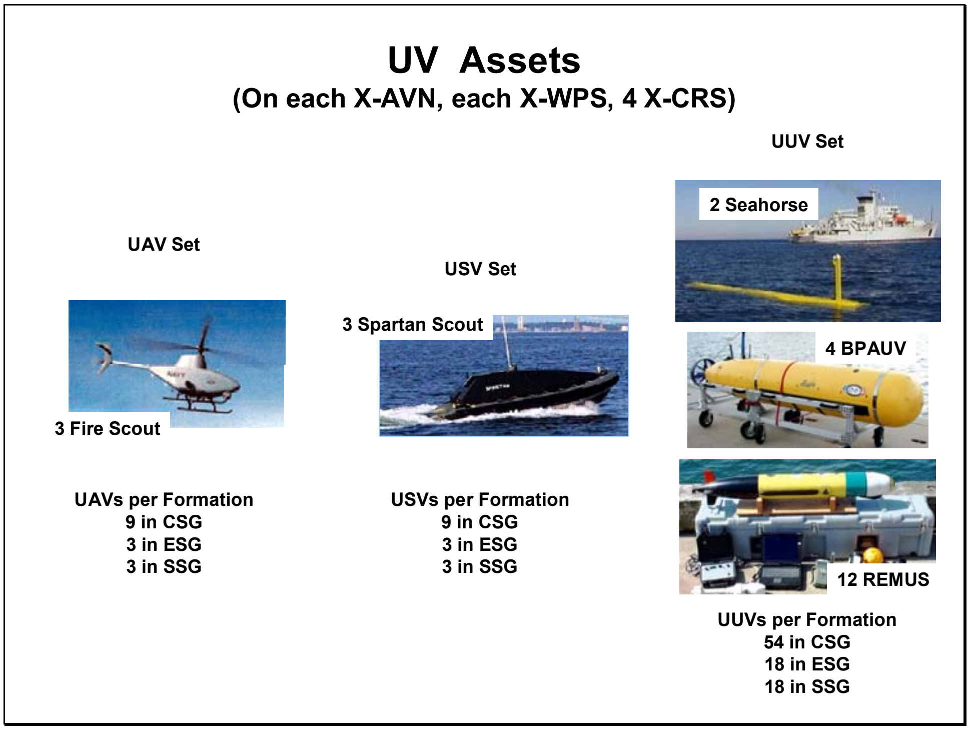
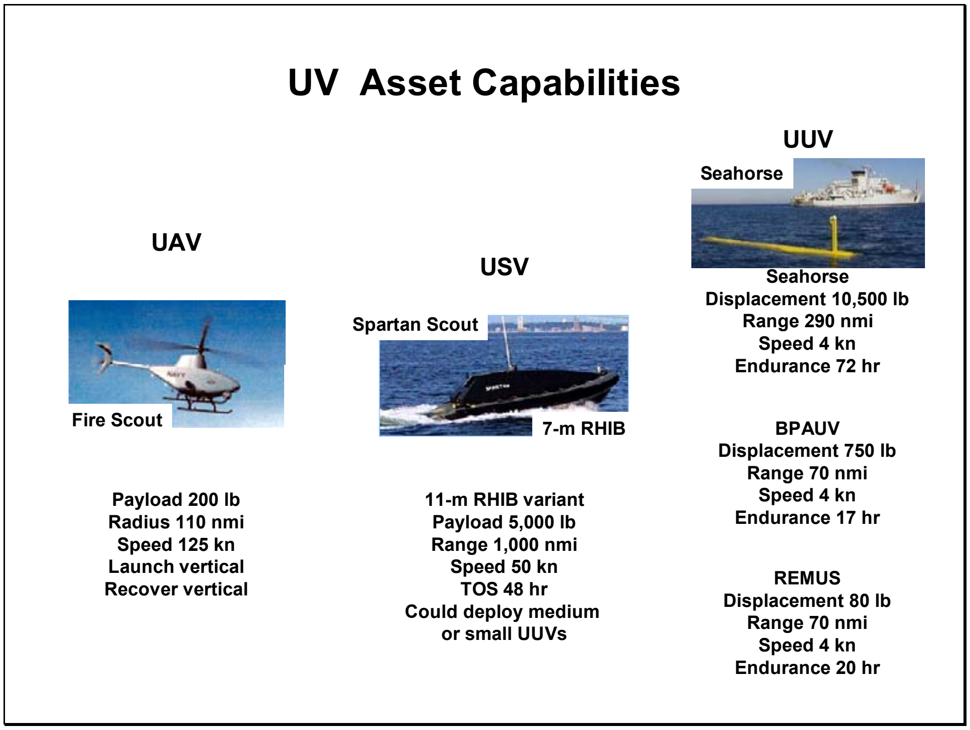
3 *Assessment of the Environmental Battlespace Characterization Capabilities of the Navy's T-AGS 60 Class Ships*, IDA Paper P-3785, July 2003.



A set of UVs is included in each X-AVN and X-WPS ship. For the X-CRS ships, the same set is spread over four X-CRS ships. The UVs are also included in the costs for the alternatives, both procurement and O&S costs. Also, over the 30-year period of the life-cycle costing, the set of UVs is completely replaced at the 15 year point. So, over 30 years, two complete sets of UVs is bought for these ships.

The set consists of three UAVs, included as the VTUAV Fire Scout; three USVs, included as an 11-meter RHIB; two large UUVs, included as the Seahorse; four medium UUVs, included as the BPAUV (Battlespace Profiler Autonomous Underwater Vehicle); and 12 small UUVs, included as the REMUS (Remote Environmental Monitoring Unit System). The chart also shows the number of each type UV in each of the formations.



This chart summarizes the capabilities of each type UV in terms of payload, range, and speed. The endurance of the UUVs is also shown, based on the life of batteries that provide the UUV power. Since the UUVs have a low speed of 4 knots, operationally they will likely be transported, deployed, and retrieved by small combatants, SSC-1000 or VSC-100, UAVs, or USVs.

Outline

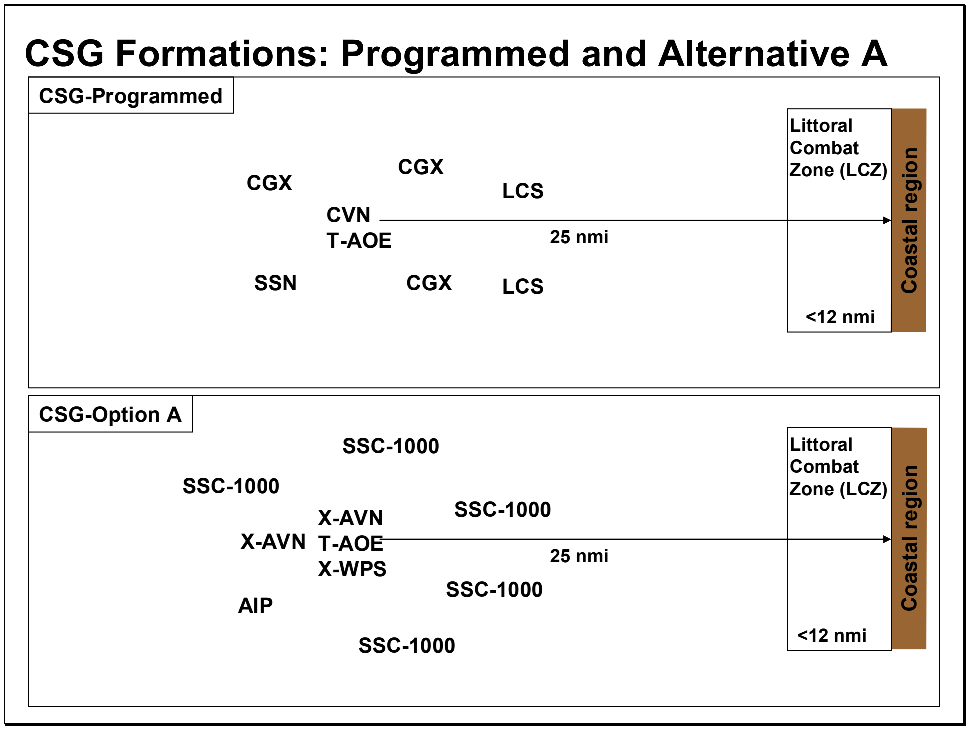
- Background
- Approach to Alternative Fleet Development
- Large Surface Combatant Platforms
- Small Surface Combatant Platforms
- Alternative Fleet Development
  - Formations
  - Large Platform Configuration
- Alternative A
- Alternative B
- Alternative C
- Summary

The first alternative fleet is developed in this section.

Alternative A Formation Development

- **CONCEPT: USE MIX OF LARGE SHIPS (X-AVN AND X-WPS) AND SMALL COMBATANTS (SSC-1000)**
- **CSG**
  - **Programmed: 1 CVN, 1 T-AOE, 1 SSN, 3 CGXs, 2 LCSs**
  - **Option A: 2 X-AVNs, 1 X-WPS, 1 T-AOE, 4 AIP SSs, x SSC-1000s**
- **ESG**
  - **Programmed: 1 LHD, 1 LPD, 1 LSD, 2 CGXs, 1 DDX, 1 SSN, 3 LCSs**
  - **Option A: 2 T-AKXs, 1 X-WPS, y SSC-1000s**
- **SURFACE STRIKE GROUP (SSG) OR MISSILE DEFENSE SURFACE ACTION GROUPS (MDSAG)**
  - **Programmed: 3 CGXs**
  - **Option A: 1 X-WPS, z SSC-1000s**

In order to define an alternative future naval force to deal with the non-traditional threats, we retained the planned formations and made tradeoffs within the formations. For Alternative A, the concept is to use a mix of X-AVNs and X-WPS along with SSC-1000s; the trades for each formation are indicated in this chart. The number of SSC-1000s remains an unknown until the costs are considered. The SSN in the CSG is replaced with four AIP diesel submarines, and the SSN in the ESG is replaced with UVs.



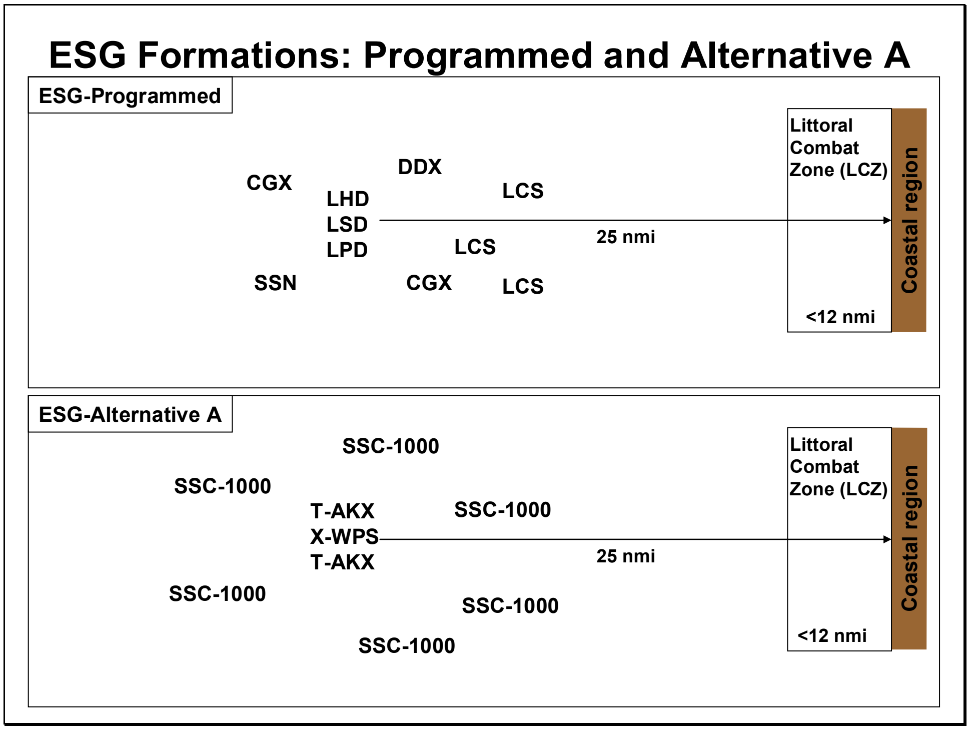
Representative CSG formations for the programmed Navy and for Alternative A are shown for operations off the coast of a Littoral Combat Zone (LCZ). In the programmed case, the CGXs and the SSN can form a screen around the CVN and the T-AOE while the LCSs either operate in the LCZ or support the screen. For Alternative A, the X-AVNs, X-WPS, and T-AOE are screened by SSC-1000s and the AIP submarines. Some of the SSC-1000s and the AIPs along with UAVs, USVs, and UUVs will move into the LCZ to conduct MIW, ASW, or SUW operations.

Alternative A: Comparable Cost CSG Formations

Programmed Carrier Strike Group (CSG)		Alternative A Aviation Strike Group	
Platform Type	12 Formations Number Vessels in each Formation	Platform Type	12 Formations Number Vessels in each Formation
CVN	1	X-AVN	2
Aircraft	60 JSF(CV) and 12 MV-22	Aircraft	60 JSF(STOVL) and 12 MV-22
CGX	3	X-WPS	1
LCS	2	SSC-1000	16
UVs	6	UVs	3 UAV, 3 USV, 18 UUV On each X-AVN and X-WPS
SSN	1	AIP	4
T-AOE	1	T-AOE	1

The programmed CSG and Alternative A Aviation Strike Group, at comparable costs, are compared directly. The savings in the alternative can be used to buy 16 SSC-1000s.

The JSF aircraft are the CVN-based F-35C in the programmed CSG, and the F-35B is the STOVL JSF in the alternatives. The F-35C has about twice the range and payload as the F-35B.



Representative ESG formations for the programmed Navy and for Alternative A are shown for operations off the coast of a LCZ. In the programmed case, the CGXs and the SSN can form a screen around the amphibious ships while the LCSs either operate in the LCZ or support the screen. For Alternative A, the T-AKXs, i.e. MPF(F), and the X-WPS are screened by SSC-1000s. Some of the SSC-1000s will move into the LCZ to conduct MIW, ASW, or SUW operations. The SSN is not retained in the alternative. At least one CSG would augment the ESG(s), in the case of an amphibious assault.

Alternative A: Comparable Cost ESG Formations

Programmed Expeditionary Strike Group (ESG)		Alternative A Expeditionary Strike Group	
Platform Type	12 Formations Number Vessels in each Formation	Platform Type	12 Formations Number Vessels in each Formation
LHD, LPD and LSD	1 each	T-AKX (MPF(F))	2
Aircraft	6 JSF(STOVL) and 24 MV-22	Aircraft	6 JSF(STOVL) 18 MV-22 3 Heliplane Transport Heavy Lift
CGX	2	X-WPS	1
DDX	1		
UVs	9	UVs	3 UAV, 3 USV, 18 UUV On X-WPS
LCS	3	SSC-1000	15
SSN	1		

The programmed ESG and Alternative A ESG, at comparable costs, are compared directly. The savings in the alternative can be used to buy 15 SSC-1000s.

The JSF aircraft are the F-35B STOVL JSF aircraft in both the programmed and alternative ESGs. The heavy-lift aircraft is a heliplane transport.

Alternative A: Comparable Cost SSG Formations

Programmed Surface Strike Group (SSG)		Alternative A Surface Strike Group	
Platform Type	9 Formations Number Vessels in each Formation	Platform Type	9 Formations Number Vessels in each Formation
CGX	3	X-WPS	1
		UVs	3 UAV, 3 USV, 18 UUV On X-WPS
		SSC-1000	5

The programmed SSG and Alternative A SSG, at comparable costs, are compared directly. The savings in the alternative can be used to buy 5 SSC-1000s.

Outline

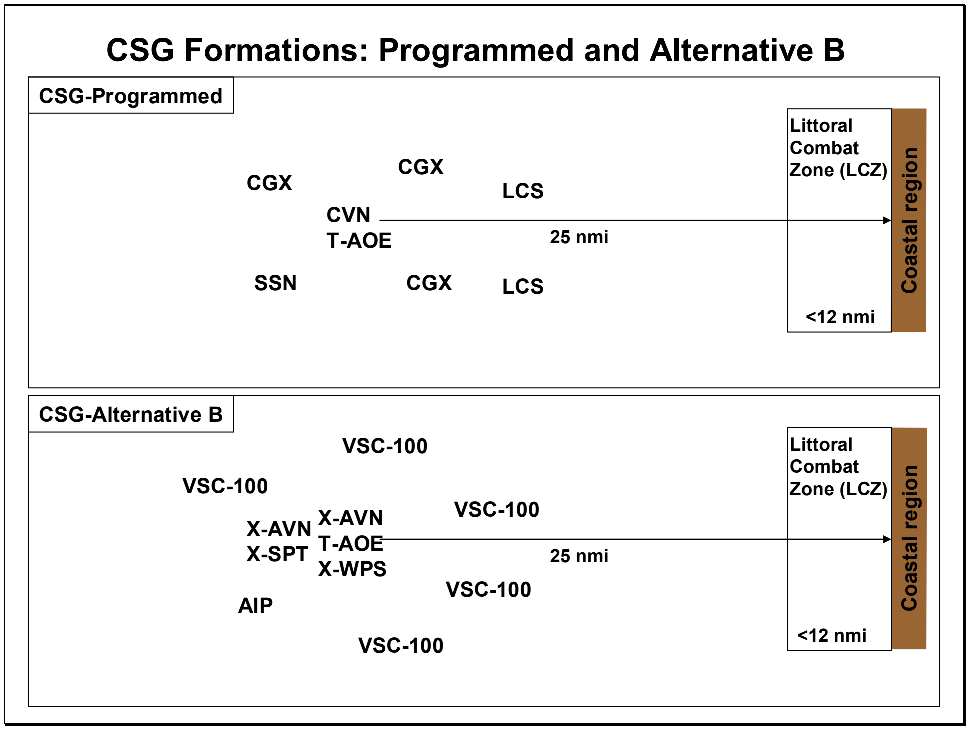
- Background
- Approach to Alternative Fleet Development
- Large Surface Combatant Platforms
- Small Surface Combatant Platforms
- Alternative Fleet Development
  - Formations
  - Large Platform Configuration
- Alternative A
- Alternative B
- Alternative C
- Summary

The second alternative fleet is developed in this section.

Alternative B Formation Development

- **CONCEPT: USE MIX OF LARGE SHIPS (X-AVN AND X-WPS) AND VERY SMALL CRAFT (VSC-100) CARRIED IN A MOTHER SHIP X-SPT**
- **CSG**
  - **Programmed: 1 CVN, 1 T-AOE, 1 SSN, 3 CGXs, 2 LCSs**
  - **Option B: 2 X-AVNs, 1 X-WPS, 1 T-AOE, 1 SSN, 1 X-SPT, x VSC-100s**
- **ESG**
  - **Programmed: 1 LHD, 1 LPD, 1 LSD, 2 CGXs, 1 DDX, 4 AIP SSs, 3 LCSs**
  - **Option B: 2 T-AKXs, 1 X-WPS, 1 X-SPT, y VSC-100s**
- **SURFACE STRIKE GROUP (SSG) OR MISSILE DEFENSE SURFACE ACTION GROUPS (MDSAG)**
  - **Programmed: 3 CGXs**
  - **Option B: 1 X-WPS, z VSC-100s**

For Alternative B, the concept is to use a mix of X-AVNs and X-WPS along with VSC-100s carried in mother ships called X-SPT. The trades for each formation are indicated in this chart. The number of VSC-100s remains an unknown until the costs are considered. Four AIP diesel submarines replace the SSN in the CSG.



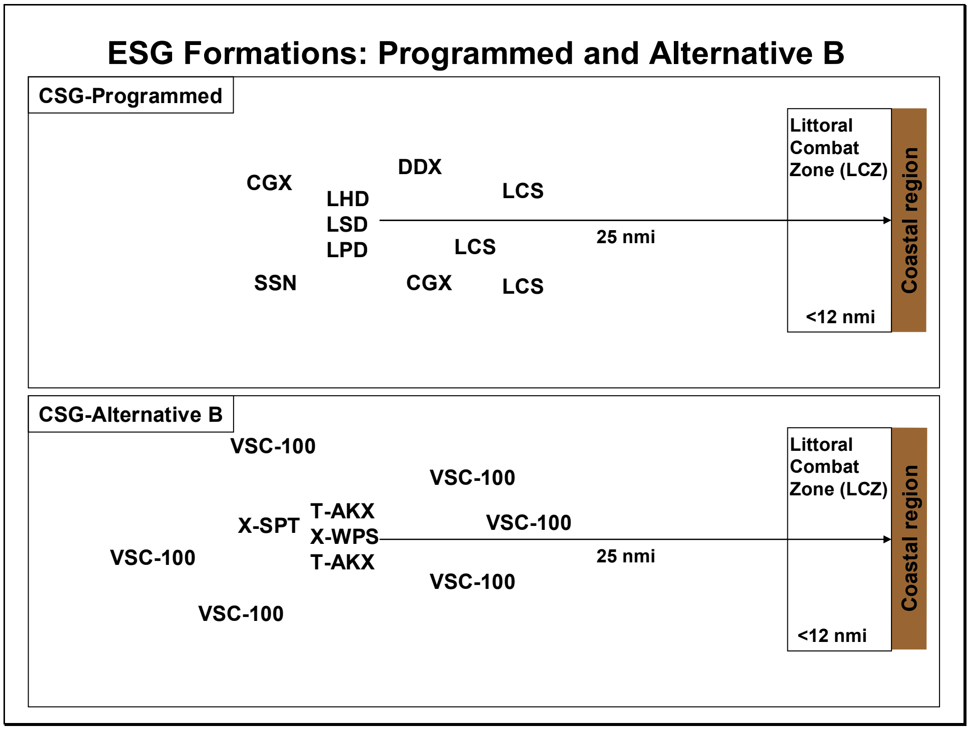
Representative CSG formations for the programmed Navy and for Alternative B are shown for operations off the coast of an LCZ. In the programmed case, the CGXs and the SSN form a screen around the CVN and the T-AOE while the LCSs either operate in the LCZ or support the screen. For Alternative B, the X-AVNs, X-WPS, X-SPT, and T-AOE are screened by VSC-100s and AIP. Some of the VSC-100s and AIPs will move into the LCZ to conduct MIW, ASW, or SUW operations.

Alternative B: Comparable Cost CSG Formations

Programmed Carrier Strike Group (CSG)		Alternative B Aviation Strike Group	
Platform Type	12 Formations Number Vessels in each Formation	Platform Type	12 Formations Number Vessels in each Formation
CVN	1	X-AVN	2
Aircraft	60 JSF(CV) and 12 MV-22	Aircraft	60 JSF(STOVL) and 12 MV-22
CGX	3	X-WPS	1
LCS	2	VSC-100	24
		X-SPT	1
UVs	6	UVs	3 UAV, 3 USV, 18 UUV On each X-AVN and X-WPS
SSN	1	AIP	4
T-AOE	1	T-AOE	1

The programmed CSG and Alternative B Aviation Strike Group, at comparable costs, are compared directly. The savings in the alternative can be used to buy 24 VSC-100s and a mother ship to carry and support them and their modules.

The JSF aircraft are the CVN-based F-35C in the programmed CSG, and the F-35B is the STOVL JSF in the alternatives. The F-35C has a greater range and payload than the F-35B.



Representative ESG formations for the programmed Navy and for Alternative B are shown for operations off the coast of a LCZ. In the programmed case, the CGXs and the SSN can form a screen around the amphibious ships while the LCSs either operate in the LCZ or support the screen. For Alternative B, the T-AKXs, i.e., MPF(F), X-WPS and X-SPT, are screened by VSC-100s. Some of the VSC-100s will move into the LCZ to conduct MIW, ASW, or SUW operations. The SSN is not retained in the alternative. At least one CSG would augment the ESG(s), in the case of an amphibious assault.

Alternative B: Comparable Cost ESG Formations

Programmed Expeditionary Strike Group (ESG)		Alternative B Expeditionary Strike Group	
Platform Type	12 Formations Number Vessels in each Formation	Platform Type	12 Formations Number Vessels in each Formation
LHD, LPD and LSD	1 each	T-AKX (MPF(F))	2
Aircraft	6 JSF(STOVL) and 24 MV-22	Aircraft	6 JSF(STOVL) 18 MV-22 3 Heliplane Transport (H/L)
CGX	2	X-WPS	1
DDX	1		
UVs	9	UVs	3 UAV, 3 USV, 18 UUV On X-WPS
		X-SPT	1
LCS	3	VSC-100	23
SSN	1		

The programmed ESG and Alternative B ESG, at comparable costs, are compared directly. The savings in the alternative can be used to buy 23 VSC-100s and a mother ship to carry and support them and their modules.

The JSF aircraft are the F-35B STOVL JSF aircraft in both the programmed and alternative ESGs.

Alternative B: Comparable Cost SSG Formations

Programmed Surface Strike Group (SSG)		Alternative B Surface Strike Group	
Platform Type	9 Formations Number Vessels in each Formation	Platform Type	9 Formations Number Vessels in each Formation
CGX	3	X-WPS	1
		UVs	3 UAV, 3 USV, 18 UUV On X-WPS
		VSC-100	5

The programmed SSG and Alternative B SSG, at comparable costs, are compared directly. The savings in the alternative can be used to buy 5 VSC-100s that are carried and supported in the X-WPS ship.

Outline

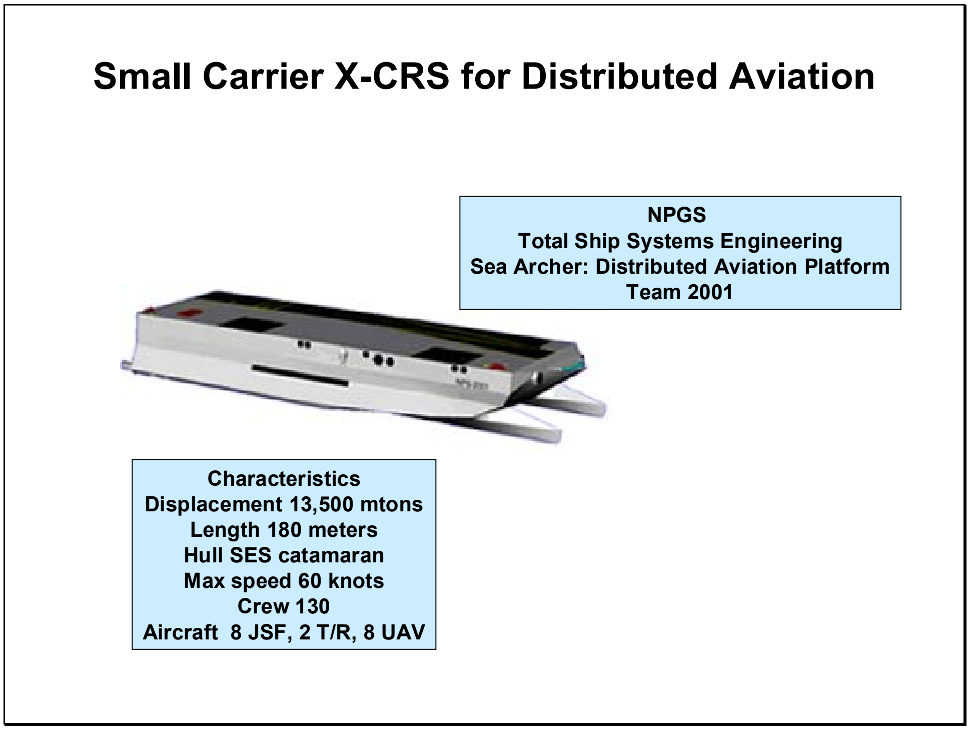
- Background
- Approach to Alternative Fleet Development
- Large Surface Combatant Platforms
- Small Surface Combatant Platforms
- Alternative Fleet Development
  - Formations
  - Large Platform Configuration
- Alternative A
- Alternative B
- Alternative C
- Summary

The third alternative fleet is developed in this section.

Alternative C Formation Development

- **Concept: Distributed aviation on small carriers (8 STOVL JSF aircraft) X-CRS along with the very small craft (VSC-100) carried in a mother ship X-SPT. Alternative C is Alternative B except the X-AVN ships are replaced with corsair type carriers X-CRS in the CSG formations. The ESG and SSG formations are the same as in Alternative B**
- **CSG**
  - **Programmed: 1 CVN, 1 T-AOE, 1 SSN, 3 CGXs, 2 LCSs**
  - **Option C: *8 X-CRSs*, 1 X-WPS, 1 T-AOE, 4 AIP SSs, 1 X-SPT, 24 VSC-100s**
- **ESG**
  - **Programmed: 1 LHD, 1 LPD, 1 LSD, 2 CGXs, 1 DDX, 1 SSN, 3 LCSs**
  - **Option C: 2 T-AKXs, 1 X-WPS, 1 X-SPT, 23 VSC-100s**
- **Surface Strike Group (SSG) or Missile Defense Surface Action Groups (MDSAG)**
  - **Programmed: 3 CGXs**
  - **Option C: 1 X-WPS, 5 VSC-100s**

Alternative C is a variation on Alternative B with the X-AVN ships replaced with small carriers (eight JSFs) in the CSG formations. The other formations are the same as in Alternative B. The cost analysis determined that eight X-CRS ships would replace two X-AVN ships. Since these ships are smaller, the same amount of space for aviation maintenance activities is not achieved. As a result, the aviation support in this alternative is not the same as in Alternatives A and B. However, the speed of the X-CRSs, 60 knots, is much higher than the X-AVN ships.



The distributed aviation platform, designed at the Naval Postgraduate School (NPS) by the 2001 Total Ship Systems Engineering (TSSE) team, provides the aviation capability in the CSG for Alternative C. For a comparable cost, its cost is proportional to the X-AVN ship based on displacement (about 25 percent). This is a lower cost than the NPGS team derived, but we included only the aviation support systems and UVs.

Maintenance capability is an issue with such a small carrier. Other than equivalent displacement, we did not assess the level of maintenance possible in these ships. The intermediate maintenance capability in a CVN would be difficult to replicate in eight X-CRS ships. In the future, new concepts for air operations may see an advantage in trading a heavy maintenance capability in one large ship for distributed aviation capability in several smaller ships.

The Defense Science Board Task Force Report on the Future of the Aircraft Carrier[4] was critical of this ship concept. The report indicated the following issues: current technologies are insufficient for the power plant density required (i.e., the concept is fuel inefficient); the number of aircraft supported is small; conduct of flight operations

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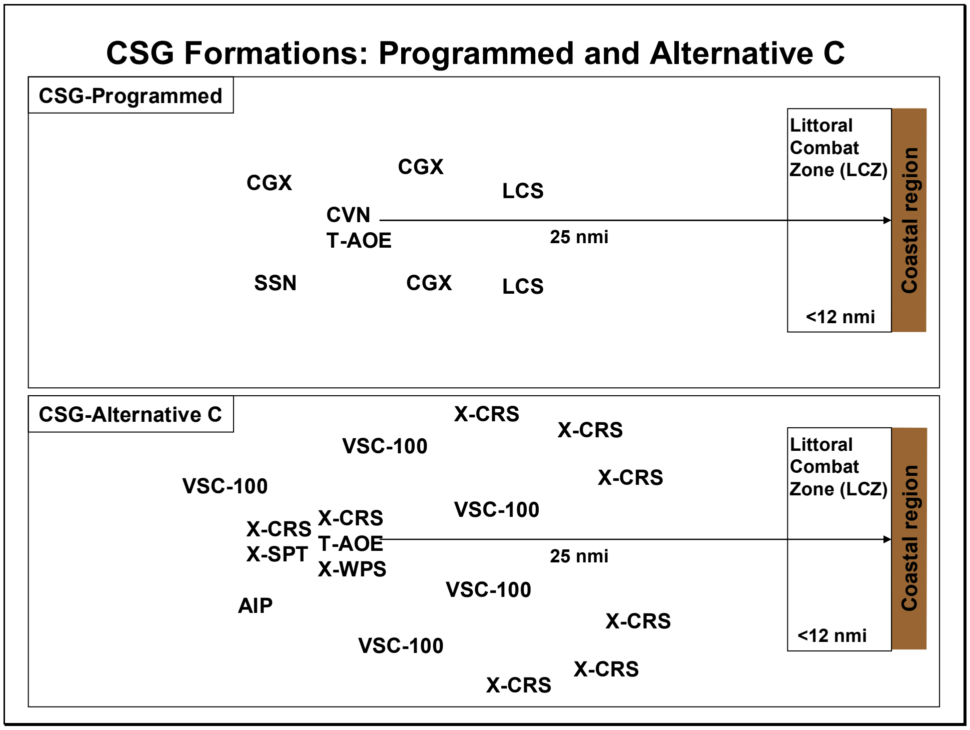
4 *Defense Science Board Task Force Report on the Future of the Aircraft Carrier*, OSD, AT&L, October 2002, Unclassified.

are not clear; sortie rates, seaworthiness, and cost of multiple hulls relative to one large CVN are potential issues; legacy aircraft are not supported; survivability and sustainability are reduced relative to the large carrier but vulnerability is also reduced due to the higher speed of the small carrier; the higher speed also enables the small carrier to close faster.



Representative CSG formations for the programmed Navy and for Alternative C are shown for operations off the coast of an LCZ. In the programmed case, the CGXs and the SSN form a screen around the CVN and the T-AOE while the LCSs either operate in the LCZ or support the screen. For Alternative C, the X-WPS, X-SPT, and T-AOE are screened by VSC-100s and some of the AIPs. Some of the VSC-100s and the AIPs will move into the LCZ to conduct MIW, ASW, or SUW operations. The X-CRS will be distributed to conduct strike operations and to participate in the screen.

Alternative C: Comparable Cost CSG Formations

Programmed Carrier Strike Group (CSG)		Alternative C Aviation Strike Group	
Platform Type	12 Formations Number Vessels in each Formation	Platform Type	12 Formations Number Vessels in each Formation
CVN	1	X-CRS	8
UVs	6	UVs	3 UAV, 3 USV, 18 UUV On X-WPS and on 4 X-CRS
Aircraft	60 JSF(CV) and 12 MV-22	Aircraft	60 JSF(STOVL) and 12 MV-22
CGX	3	X-WPS	1
LCS	2	VSC-100	24
		X-SPT	1
SSN	1	AIP	4
T-AOE	1	T-AOE	1

The programmed CSG and Alternative C Aviation Strike Group, at comparable costs, are compared directly. The savings in the alternative can be used to buy 8 X-CRS distributed aviation ships and 24 VSC-100s and a mother ship to carry and support them and their modules.

The JSF aircraft are the CVN-based F-35C in the programmed CSG, and the F-35B is the STOVL JSF in the alternatives. The F-35C has a greater range and payload than the F-35B.

Outline

- Background
- Approach to Alternative Fleet Development
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- Alternative Fleet Development
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- Alternative A
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- Alternative C
- Summary

The alternative fleets are summarized in this section in terms of numbers of surface and subsurface combatants in the Navy's global CONOPS formations. In addition, the new ship types, both large and small, are summarized with respect to where they are used (alternative and formation) and what their capabilities are.

Finally, we identify some of the challenges for the alternative fleets, defined in this study, that need to be examined further.

Number of Surface and Subsurface Combatants and UVs by Alternative at Comparable Cost

Number / Formation	Formations	Programmed Combatants	Alternative A Combatants	Alternative B Combatants	Alternative C Combatants
CSG	12	96	288	396	468
ESG	12	120	216	324	324
SSG	9	27	54	54	54
Total No.	33	243	558	774	846
Total No. UVs	33	180	1,368	1,368	1,368

When the number of formations is kept the same as programmed, the total number of surface and subsurface combatants increases from 243 for the programmed force to 558 for Alternative A, to 774 for Alternative B, and to 846 for Alternative C. Four SSGNs are counted by the Navy as programmed surface strike assets and included in this list of formations. Since this study did not address any potential change to these assets, they are not included in the count of programmed formations.

The Navy is developing many types of UVs for many applications to include air surface and sea surface. The 180 UVs included under programmed combatants are for the UVs in the mine warfare module for the LCS. In the future, the Navy likely will include more UVs of all types in their formations.

New Surface Ship Types by Formation and Alternative

Alternative \ Formation	CSG	ESG	SSG
A	Large: X-AVN, X-WPS Small: SSC-1000	Large: T-AKX, X-WPS Small: SSC-1000	Large: X-WPS Small: SSC-1000
B	Large: X-AVN, X-WPS, X-SPT Small: SSC-100	Large: T-AKX, X-WPS, X-SPT Small: SSC-100	Large: X-WPS Small: SSC-100
C	Medium: X-CRS, X-WPS, X-SPT Small: SSC-100	Large: T-AKX, X-WPS, X-SPT Small: SSC-100	Large: X-WPS Small: SSC-100

The new ship types defined in this study are the large ships, X-AVN, X-WPS, X-SPT, and T-AKX, all built using a common hull, and the small surface combatants, SSC-1000 and SSC-100. Use of these ships in the three alternative fleets by formation is shown in this table.

Summary of New Large Ships

- **X-AVN**
  - Used in Alternative A and B CSGs
  - Full load displacement 57,000 tons
  - Concept design from MPF(F) AoA Study
  - Supports 88 aircraft (CH-46 equivalents)
    - Used to support 30 STOVL JSFs, 6 MV-22s, and 15 UAVs in CSG
  - Stowage and working space for UUVs, USVs, and modules for small surface combatants (SSC-1000s in Alternative A)
  - Cranes for changing modules
  - Integrated Landing Platform (ILP) for UUV and USV operations
  - Speed 24 knots
  - Crew: 50 civilian for routine ship operations and 500 Navy for warfighting functions
- **X-WPS**
  - Used in all alternatives—CSG, ESG, and SAG
  - Full load displacement 57,000 tons
  - 360 VLS cells
  - 4 Trainable Rocket Launchers
  - Stowage and working space for UUVs, USVs, and modules for small surface combatants (SSC-1000s in Alternative A)
  - Support for limited numbers of VSC-100 combatants (Alternative B SSG) or aircraft or UAVs
  - ILPs and cranes
  - Speed 24 knots
  - Crew: 50 civilian for routine ship operations and 500 Navy for warfighting functions

The characteristics of the large ships are summarized here.

Summary of New Large Ships
-Continued-

- **X-SPT**
  - Used in Alternative B CSG and ESG to support very small combatant craft (VSC-100)
  - Full load displacement 57,000 tons
  - Carries the VSC-100 craft and their modules
  - Stowage and working space for VSC-100 craft and modules
  - Cranes to lift VSC-100 on and off
  - Speed 24 knots
  - Crew: 50 civilian for routine ship operations and 500 Navy to support VSC-100
- **T-AKX**
  - Used in all alternatives in the ESG
  - Full load displacement 57,000 tons
  - Supports 30 CH-46 equivalents
  - Cargo space for square and cube
  - Working space for load configuration
  - Space for UVs and modules for SSC-1000s
  - Speed 24 knots
  - Crew: 50 civilian for routine ship operations and 500 Navy for warfighting functions
- Common hull used for these large ships

Summary of New Small Ships

- **SSC-1000**
  - **Small, fast, modular surface combatant**
  - **Full Load Displacement: 1,000 tons**
  - **Speed: 60 knots; Crew: 22**
  - **Fixed systems**
    - **Multi-function radar**
    - **Surface-to-air missiles**
    - **Close-In Weapon Systems**
    - **Towed array sonar**
    - **Hull-mounted active sonar**
    - **CEC, IFF, EW, thermal imaging system**
  - **Accommodate all fixed systems and one module**
  - **Modules:**
    - **ASW: Variable depth sonar, torpedoes, fire control system**
    - **Helicopter support for SH-60 type: Weapons, sensors, fuel**
    - **Strike: 9-cell launcher, fire control system, 3 UAVs (targeting)**
    - **Mine Warfare: Remote mine-hunting systems, acoustic countermeasure system, mine neutralization system**
    - **SOF: 3 rigid-hull inflatable boats**
    - **USV: 3 unmanned surface vehicles**
    - **SUW: Surface-to-surface missiles**
    - **AAW: 12-cell launcher and missiles**
    - **Modules carried in the large ships in the formations**
    - **Half of a set of modules bought for each SSC-1000 due to number of SSC-1000s and module availability in each formation**

The characteristics of the SSC-1000 are summarized along with the modules defined for this surface combatant.

Summary of New Small Ships
-Continued-

- SSC-100
  - Small, fast, modular surface combatant craft
  - Carried to theater by large X-SPT ship
  - Payload capacity increased as less fuel carried
  - Full Load Displacement: 100 tons
  - Speed: 60 knots; Crew: 3
  - Essentially all modular payload-limited fixed systems—one module at a time
  - Operated as a unit or in flights of two or more craft
  - Modules:
    - ASW-1: Variable depth sonar
    - ASW-2: Towed array, torpedoes, fire control system
    - Strike-1: 6-cell launcher, fire control system
    - Strike-2: 3 UAVs (targeting)
    - Mine Warfare: 1 UUV, acoustic countermeasure system, mine neutralization system
    - SOF: 2 rigid-hull inflatable boats
    - USV: 2 unmanned surface vehicles
    - SUW-1: Surface-to-surface missiles
    - SUW-2: Close-In Weapon System
    - AAW: Launcher, missiles, multi-function radar
    - UUV: 12 medium UUVs
    - Sensors: Small sensors for acoustic detection
    - Modules carried in the X-SPT ship along with the SSC-100s in the formations
    - Half of a set of modules bought for each SSC-100 due to number of SSC-100s and module availability in each formation

The characteristics of the SSC-100 are summarized along with the modules defined for this surface combatant.

Alternative Navy Challenges Requiring Further Assessment

- **How do the alternatives perform relative to the programmed Navy in detailed assessments, or war games, for traditional (specific MCO scenarios) and non-traditional conflicts?**
- **In a Navy with many more combatants, can the programmed combat logistics force (CLF) ships provide the needed support?**
- **Does the lower survivability in the alternative combatants make the alternative Navies too vulnerable?**
- **Are SS (AIP) submarines appropriate for forward-deployed operations?**
- **Will the STOVL JSF aircraft provide the range, payload, and on-station time needed for future conflicts?**
- **Can T/R or STOVL aircraft provide the AEW and EW support required?**
- **Can the smaller carriers (30 or 10 aircraft) provide the maintenance and support needed to keep the aircraft flying?**

Due to the time and resources allocated for this study and the inherent uncertainty in the future threat, we did not assess all aspects of the alternative fleets developed. This chart summarizes some of the challenges for the alternative fleets that need to be examined further. Also, as the first bullet indicates, these alternatives should be included in future detailed analyses and war games for both traditional and non-traditional conflict situations.

IV. METHODOLOGY

A. MODELING FUTURE NAVAL FLEET CAPABILITIES

To understand the relationships between security policy and enemy behavior, on the one hand, and required fleet capabilities, on the other, fleet performance needs quantification. Such quantification is routinely provided by campaign analyses that embed the fleet within specified strategic and tactical situations and then calculate the likely outcomes as a function of inputs describing the enemy, the fleet, and the system that composes them both. Campaign analyses require detailed assumptions, details that can obscure and overwhelm the general characteristics sought. Indeed, a full fidelity engagement model of the naval fleet would be inappropriate for this study since we do not know with sufficient precision the technical characteristics of future naval systems and the concepts of operations for the fleet. Future technological advances in ISR, ship-building methods and weapons systems ultimately need to be evaluated in order to engage a complete fidelity model. A different tack is needed. The way to accomplish this is to step outside the current philosophy for building the nation's Navy to gain a vantage point from which to question the fundamental assumptions that underpin that philosophy, and then to explore alternatives to those assumptions in pursuit of a better way of confronting future enemies. To this end, models that seek to identify and illustrate the critical factors that drive capability are more useful than results of multi-parameter campaign analysis. The models used to support the arguments made in this study are intentionally transparent and straightforward. Furthermore, we make few assumptions about the type of enemy engaged. They are also exceptionally general in order to capture generic situations.

These models are as different from each other as are the naval capabilities they quantify. They do have something in common, however: they all are designed to explicitly capture the enemy's behavior. Since in the foreseeable future, the enemy is likely to try to compensate for its inferior military capability by deception and evasion, it is essential that the models capture this feature of war. The models are also intended to capture a particular characteristic of the naval fleet as appropriate for the capability. For example, the speed of the naval forces is a major characteristic in assessing the ability to promptly bring forces to bear where needed but is not as relevant for the ability to fight from the sea. T he size and nature of the theater of combat is another parameter that is incorporated into the models. Overall, the models consider the major features of the enemy and naval forces as described by Table 8.

Table 8. Aspects With Which the Model Captures Enemy Characteristics, Navy Characteristics, and Theater of Combat

Enemy Features Considered	Navy Features Considered	Theater of Combat
Elusiveness, the ability to avoid targeting Evasiveness, the ability to quickly flee the area Ability to deny access to littorals with anti-access weapons	Quality and coverage of ISR Density of naval platforms and shooters in the theater of combat Number of elements in naval network Speed of combatants	Operational area size Nature of combat area – littorals or open ocean

B. QUANTIFICATION OF CAPABILITIES

The six capability models used in the study are described comprehensively next. As the models were developed, the intent was to reveal the trends concerning the fleet capabilities as well as to compare the relative capabilities of the programmed fleet with its alternatives. We began each model with a general description of the warfare situation under consideration and then developed a mathematical model to describe it. From the models, we were able to better understand the relationship between naval fleet capabilities and the essential features of warfare such as enemy behavior, our policies regarding the enemy, and the features of the naval fleet. For the purpose of this study, the models are then intended as a development tool to understand the important features concerning the naval fleet capabilities rather than provide an accurate numerical value to assign fleet capability.

1. Develop and Communicate Knowledge of Forces and Situation

Since the fleet's capability to develop and communicate knowledge of forces and situation reflects the degree of networking that exists among its elements, this model quantifies the increase in situational awareness provided by the network. It assumes that the mechanism by which a network of elements gains more information than is available to the elements themselves is similar to a Bayesian process: the information provided by each element changes the prior state of information available to the network into a posterior state. Consequently, the larger the number of contributing elements, the higher is the state of information about the battlefield available to the network. In particular, if the information sought is the location of some battlefield entity, the accuracy with which the network can determine that location is larger than the accuracy that each contributing element could attain, and the average location will be closer to the actual location.

Ultimately, a networked naval fleet could significantly increase the combat capability of the fleet above that provided by the individual entities acting alone. The increase in performance derives from the collective sharing of information about the battlefield, thereby providing the commander with a comprehensive picture of the battlefield situation. The capability of developing and communicating knowledge requires the fleet to maintain (1) a persistent intelligence and surveillance, (2) a tactical common operating picture, (3) communications and data networks, and (4) a command of the naval and joint forces. The relevant metric is change in combat capability in terms of the increase in accuracy with which we know the battle situation. The model considers the following to evaluate fleet networking capability: (1) the number of elements in the network, (2) the quality of our indications and warning, and (3) the quality of our intelligence and surveillance.

a. The Networked Naval Force

As depicted in Figure 8, each naval force is represented as a node in a network connected to a network center or manager. The nodes relay information to the network manager concerning a battlefield object or objects. The manager, with sufficient information gained, then directs the elements to perform a particular duty. The network manager starts with some prior knowledge of the theater of combat, also known as indications and warnings. The probability distribution of the assumed state of knowledge is Gaussian with standard deviation σ_{iw}. The individual nodes have sensors that collect data concerning the battlefield situation. The data collected by the sensors are stochastic in nature. The probability distribution of the individual observer's state of knowledge is also assumed to be Gaussian with standard deviation of σ_{io}. Once the forces are deployed, each element in the network subsequently relays its observations to the network manager. After each successive input from the element, the manager gradually develops a more accurate image of the battlefield. This increase in accuracy aids the network manager in gaining a better understanding of the situation in the battlefield and increases confidence in the decisions reached.

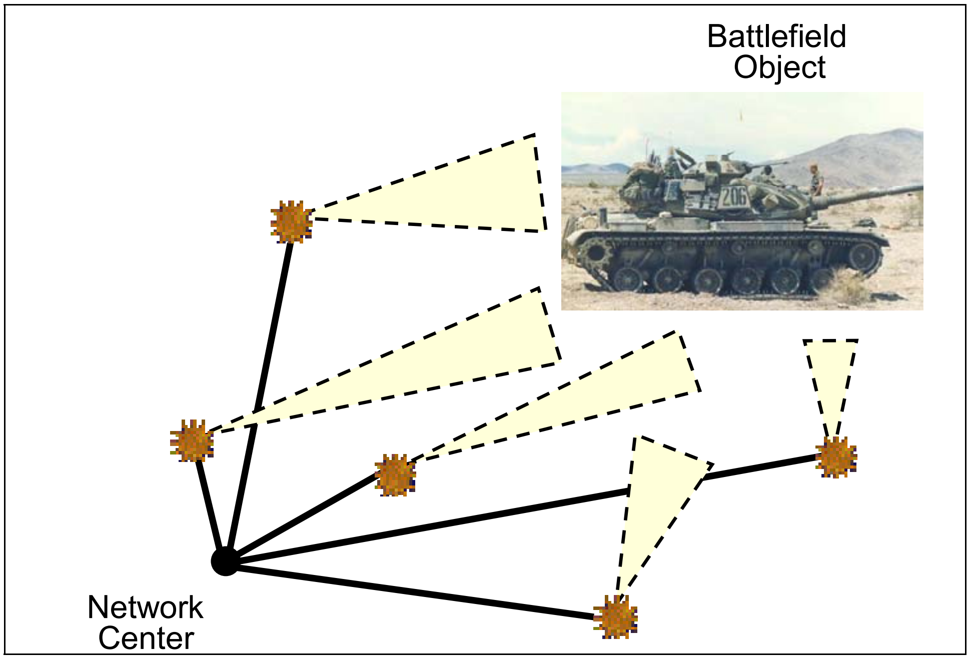

Figure 8. Elements of Naval Network Provide Information to the Network Center

b. Increase in Accuracy Afforded by Networking

The network manager starts with some prior state of knowledge of the theater of combat. These indications and warnings are developed through a combination of previous battlefield experiences and past ISR information on the enemy. Assume the probability distribution of this initial state is a Gaussian distribution with mean I_0 and standard deviation σ_{iw}. We then have for the probability distribution of the prior information available to the network,

$$\varphi(I) \propto \exp\left(\frac{-(I-I_0)^2}{2\sigma_{iw}^2}\right)$$

The network manager receives *n* calls from the network elements, communicating their state of knowledge, designated $i_1, i_2, \ldots i_k$, of the battlefield from their unique perspective. The state of knowledge of each element in the network is a distributed Gaussian with standard deviation σ_{io} according to,

$$\varphi(i_k|R) \propto \exp\left(\frac{-(i_k-R)^2}{2\sigma_{io}^2}\right)$$

where *R* is the true or real value of the location of the battlefield object.

The probability distribution of the posterior information available to the network given that one observation has been made and its value is *i* is defined as,

$$\varphi(I|i) = \frac{\varphi(I)\varphi(i|I)}{\varphi(i)} = \frac{\varphi(I)\varphi(i|I)}{\int dI\varphi(I)\varphi(i|I)}$$

from which it follows that

$$\varphi(I|i) \propto \exp\left(\frac{-(I-m(1))^2}{2S^2(1)}\right)$$

where

$$m(1) = \frac{\sigma_{iw}^2 i_1 + \sigma_{io}^2 I_0}{\sigma_{iw}^2 + \sigma_{io}^2}$$

$$S(1)^2 = \frac{\sigma_{iw}^2 \sigma_{io}^2}{\sigma_{iw}^2 + \sigma_{io}^2}$$

This result can be generalized for the case of *n* observers to give:

$$\varphi(I|i_1,...,i_n) \propto \exp\left(\frac{-(I-m(n))^2}{2S^2(n)}\right)$$

where

$$m(n) = \frac{\sigma_{iw}^2 \sum_{k=1}^{n} i_k + \sigma_{io}^2 I_0}{n\sigma_{iw}^2 + \sigma_{io}^2}$$

and

$$S^2(n) = \frac{\sigma_{iw}^2 \sigma_{io}^2}{n\sigma_{iw}^2 + \sigma_{io}^2}$$

Since the *m*(*n*) depends upon the specific observations i_1, i_2,…i_k, it is not a very useful measure of network effectiveness. We, therefore, average over the number of observations to get a Gaussian distribution of the same variance but with the following mean:

$$m(n) = \frac{n\sigma_{iw}^2 R + \sigma_{io}^2 I_0}{n\sigma_{iw}^2 + \sigma_{io}^2}$$

Illustrated in Figure 9, measurements conducted by each element in the network change the prior location distribution provided by indications and warnings into a posterior distribution whose mean is closer to the actual location *R* than the prior and is significantly sharper. In fact, the standard deviation of the posterior distribution decreases in inverse proportion with the square-root of the number of elements.

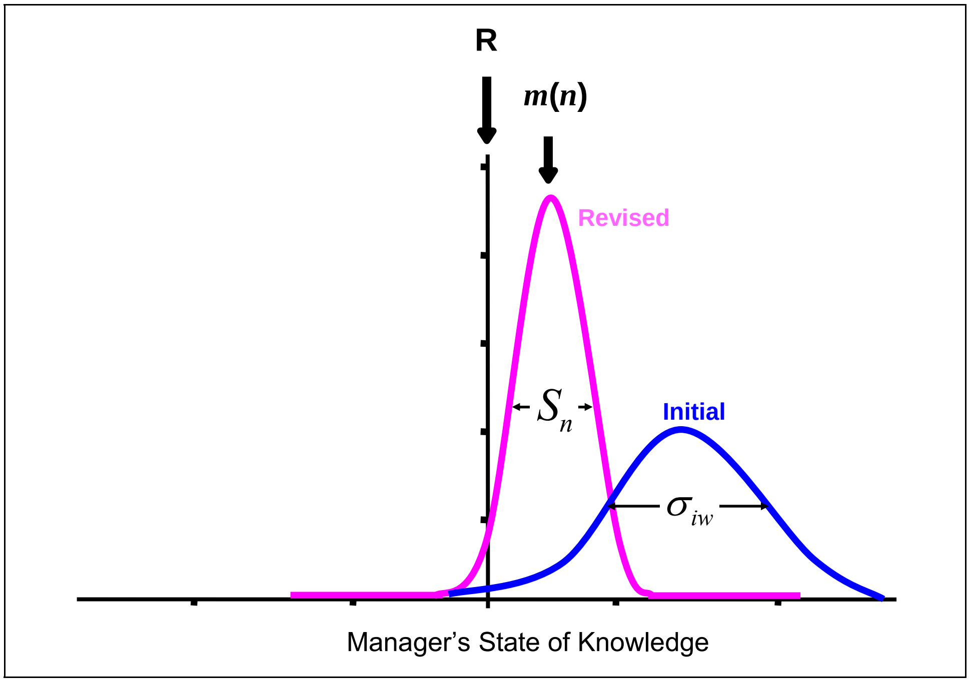

Figure 9. Increase in Accuracy Afforded by Network of *n* Elements

The relative increase in accuracy $\xi(n)$ afforded by a network with *n* elements is then calculated as,

$$\xi(n) = \frac{[I_0 - R] - [m(n) - R]}{[I_0 - R]} = \frac{n\sigma_{iw}^2}{n\sigma_{iw}^2 + \sigma_{io}^2}$$

The increase in accuracy $\xi(n)$ is dependent on the number of elements *n* in the network, increasing to unity as the number of elements increases to infinity, $\xi(n) \to \infty = 1$.

Figure 10 shows the increase in accuracy afforded by networking as a function of the number of networked elements for various values of σ_{io}. For small values of σ_{io}, we find the accuracy increases significantly with just one element; with each subsequent element in the network added, we find little additional increase in accuracy. For large/values of σ_{io}, we no longer observe diminishing returns but instead find that the increase in accuracy depends almost linearly on the number of elements in the network.

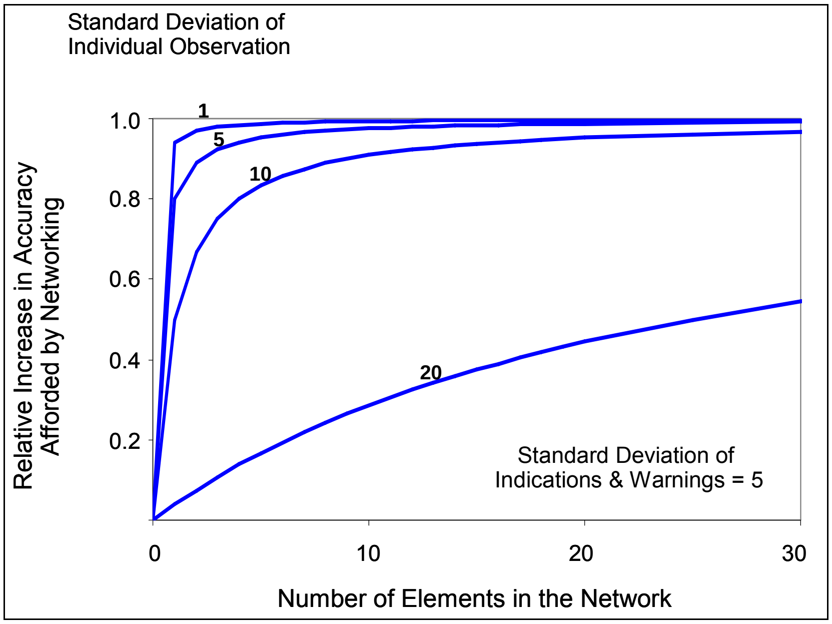

Figure 10. Increase in Accuracy Due to Networking

2. Control Operational Domain

Since the fall of the Soviet Union, the focus of the U.S. Navy has shifted from open-ocean competitions with a first class naval opponent to power projection in the littorals. The littorals are areas where naval influence and power have the greatest effect and where forces are needed most often. We consider a model of control of the littoral area for a future naval fleet. The model determines the probability of survival of power projection forces while moving into operating position. The enemy has initially placed generic anti-access threats to prevent our forces from accessing the littorals. These threats could range from passive forces, such as underwater mines, to active forces, such as submarines or small watercraft. We are then required to first remove these anti-access forces. Next, the naval fleet proceeds to move into position. Control then has two major parts: the first is the removal of anti-access threats and the second determines the time-dependent probability of survival for a naval power projection force that moves into position to conduct operations in support of the land battle.

When applying this model to the strategic advantage policy case, the portion of the model comprising the movement of the power projection force into position was removed since under that policy the emphasis is on sea control and not on intervening into any land operations.

a. Removal of Enemy Anti-Access Forces

Imagine that an enemy has populated the approaches to his shores with a selection of anti-access systems designed to discourage U.S. power projection forces from operating there. The systems they may employ range from passive threats such as underwater mines, through active threats such as submarines and small watercraft, to air, land, and sea-based missiles. Since we are taking a general rather than specific view of things, we will not focus on the specific nature of these systems but rather will describe the anti-access threat as a generic field of threat distributed uniformly over the area of strategic interest to our forces, much like butter is spread over a slice of bread. To confront this generic threat, U.S. naval forces will conduct equally generic "removal" operations intended to eliminate it. For that purpose, the U.S. fleet deploys generic removal platforms of as yet unspecified type, size, speed, and removal capability and then has them operate in the area covered by the enemy field; much like a scraper would be used to remove the aforementioned butter. Figure 11 depicts this operational arrangement. The anti-access threat is shown as a pink planar surface; the removal units are depicted as a blue planar surface. The yellow rectangular box indicates the area the removal forces can scrape away with operating speed v and removal width w in a unit time. After the removal period, the power projection force takes path Γ to arrive at its final destination.

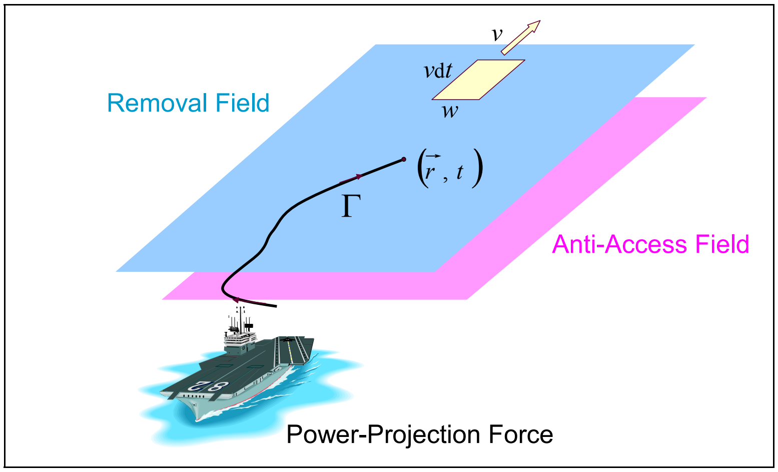

Figure 11. The Removal and Deployment Operation

The anti-access threats are assumed to uniformly cover a given area of operation with a time-dependent density $\rho(t)$. We counter these threats by using a time-dependent removal field with density $\beta(t)$. To characterize the ability of our removal forces to eliminate these enemy threats, we define a removal rate μ, which is the rate at which our forces eliminate enemy anti-access threats. We similarly define a loss rate λ, defined as the rate at which our removal forces are lost from anti-access threats. We determine the density of enemy anti-access forces ρ and our removal forces β as a function of time. The time dependent rate equations for the anti-access threats and removal units are given by the following:

$$\frac{d\rho(t)}{dt} = -\mu\rho(t)\beta(t)\,,$$

$$\frac{d\beta(t)}{dt} = -\lambda\rho(t)\beta(t)\,.$$

From the two differential equations above, we then have,

$$\frac{d}{dt}\left(\frac{\beta}{\lambda} - \frac{\rho}{\mu}\right) = 0\,.$$

This then implies,

$$\frac{\rho}{\mu} - \frac{\beta}{\lambda} = k\,,$$

where k is a constant whose value is set by the initial conditions of ρ and β. From the above set of equations, we can then determine the ρ and β as a function of time, under the assumption that μ and λ are constant in time.

$$\beta(t) = \beta_0 \frac{(\lambda\rho_0 - \mu\beta_0)e^{-(\lambda\rho_0 - \mu\beta_0)t}}{\lambda\rho_0 - \mu\beta_0 e^{-(\lambda\rho_0 - \mu\beta_0)t}}\,,$$

$$\rho(t) = \rho_0 \frac{(\lambda\rho_0 - \mu\beta_0)}{\lambda\rho_0 - \mu\beta_0 e^{-(\lambda\rho_0 - \mu\beta_0)t}}\,,$$

where ρ_0 and β_0 are the initial anti-access force densities and removal force densities respectively. After a sufficiently long time, we expect some number of our forces to remain and the enemy forces to be removed. Since we require that $\rho(t)$ decrease to zero for a sufficiently long time and $\beta(t)$ does not, we require that

$$\lambda\rho(0) - \beta(0)\mu > 0 .$$

Figure 12 shows the anti-access force density and the removal unit force density as a function of time. We use as our initial parameters, an anti-access threat density which is orders of magnitude larger than the removal force density. However, with a sufficiently high removal rate, the removal units are able to overcome this discrepancy in numbers. After a certain period of time, the density of anti-access threats eventually decreases to a value less than the removal force density.

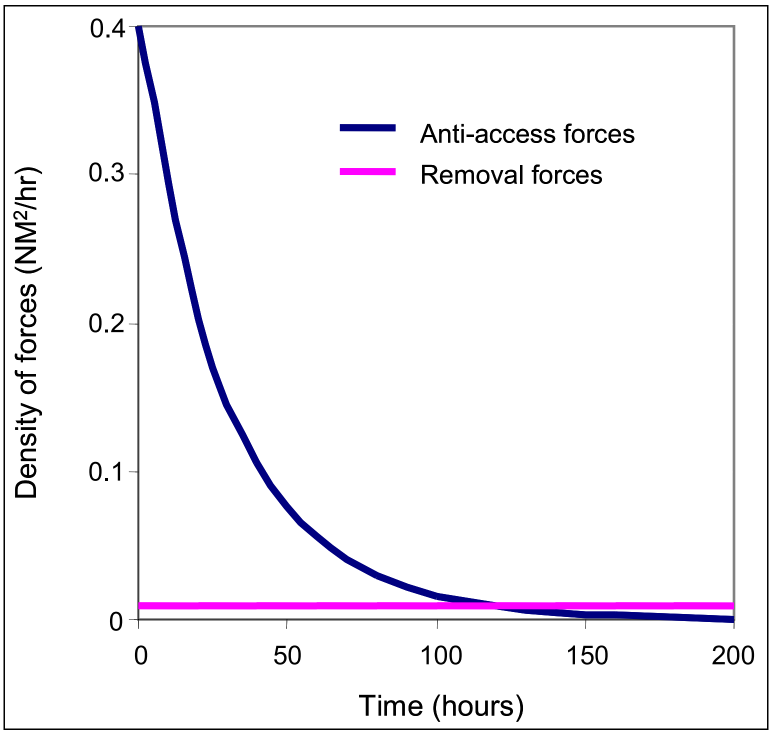

Figure 12. Density of Anti-Access Forces (Blue) and Removal Forces (Pink) as Time Progresses

b. Survivability in Operational Area

Imagine further that a projection force was ordered to sail to the littoral, deploy itself through the threat field to a specified location, arrive there at a specified time, and then start power projection operations in support of the land campaign. Shown in Figure 13, the power projection force takes path Γ, through the anti-access threat area, to arrive at its desired final destination. We specify the paths as a set of straight lines starting at some point on the *x*-axis $(x_0,0;t_0)$ and arriving at the final point of destination

(0,ζ;*t*) which is located on the *z*-axis. With sufficient time and resources, the removal units are able to eliminate most of the anti-access threats thus ensuring the survivability of the power projection forces.

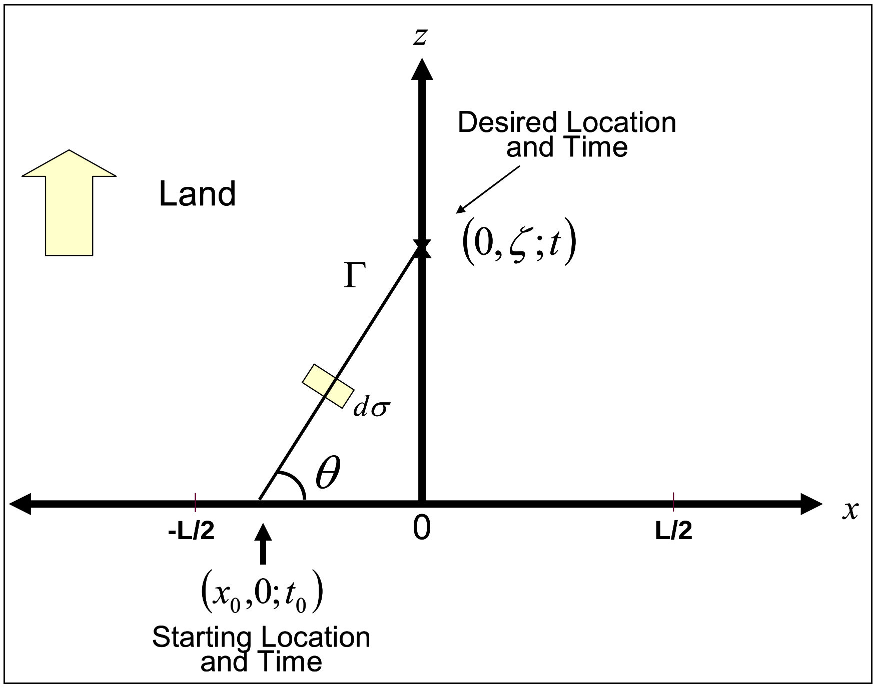

Figure 13. The Deployment Path of the Power Projection Force

We begin with the probability of survival *S*(σ+Δσ) that the projection force will survive as it moves between σ and σ+Δσ. It can be written as the probability the force survived up to location σ multiplied by the probability it survived its way from σ to σ+Δσ.

$$S(\sigma+\Delta\sigma) = S(\sigma)(1-\alpha\rho(\sigma)W\Delta\sigma),$$

where α is the probability of survival of a power projection ship if struck by anti-access forces and *W* is the sweep width of that ship. From the above equation, we obtain,

$$\frac{dS(\sigma)}{d\sigma} = -\alpha\rho(\sigma)WS(\sigma).$$

We solve for *S* to obtain,

$$S(\sigma) = \exp\left[-\alpha W \int_{\Gamma} d\sigma\rho(\sigma)\right]$$

Let us assume the anti-access threat density is constant with value $\rho(t_0)$ as the power projection force moves to its final location. The integral in the exponential term above can then easily be evaluated. The survivability is calculated to be,

$$S(t) = \langle S(t;\theta) \rangle = \left\langle \exp\left(-\alpha V W \rho \left(t - \frac{\zeta}{V \sin\theta} \right) (t - t_0) \right) \right\rangle ,$$

where the total time to remove enemy anti-access threats is given by,

$$t_0 = t - \frac{\zeta}{V \sin\theta} .$$

The probability that such a force would have survived the journey depends upon the time at which the journey begins. In Figure 14, we show that the later the power projection force starts deployment, the smaller the density of anti-access threat that survived the ongoing removal operation and therefore the larger the survival probability. For a specified time at which the power projection force is called upon to act, the probability of survival depends upon the initial density of the anti-access field and the density of the removal field we are able to deploy. For the given initial parameters indicated, we find that within 1 day after the removal operation has begun, the survivability of the fleet is less than one-half. However, if the removal operation has taken place for several days or more, the survivability increases to greater than 0.8. Under the reasonable assumption that the U.S. fleet would try to interdict deployment of anti-access assets if it knew that it was taking place, the density of anti-access threats reflects the enemy's ability to conduct covert deployment of its anti-access forces and therefore measures the enemy's ability to deceive. The density of removal units is directly related to the number of removal platforms the fleet employs in the given operation.

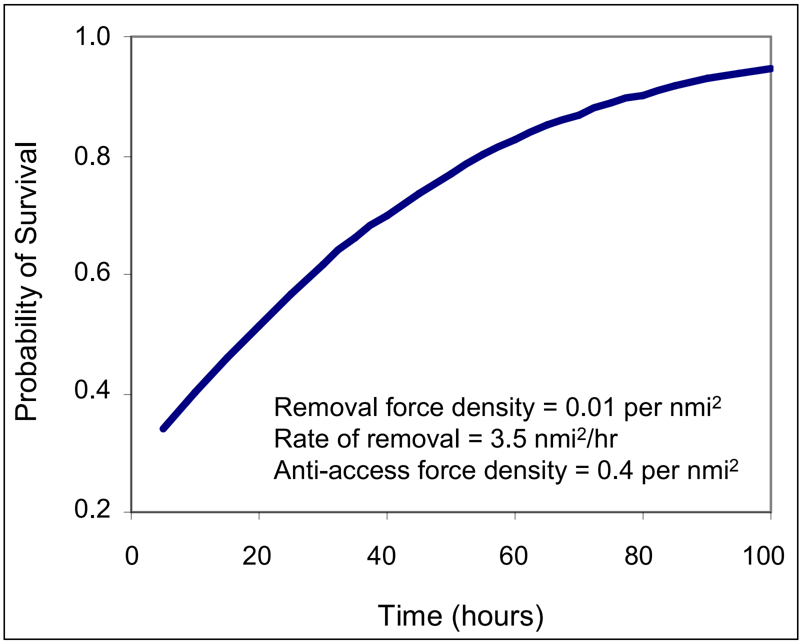

Figure 14. The Power Projection's Probability of Survival as a Function of Time

3. Promptly Bring Forces to Bear Where Needed

The next model quantifies the capability to promptly bring forces to bear. The model envisions that U.S. naval forces detect an enemy formation that they wish to engage. They, therefore, proceed in a direction that their intelligence and surveillance systems tell them they should follow to make this happen. However, errors in intelligence and in surveillance information lead to errors both in their estimates of the location and of the direction of the enemy's advance. The attempted engagement will be successful if the actual enemy location at the time at which the intercept was to have occurred is found to be within an acceptable strike radius from U.S. forces.

Clearly, the better the information, the better the capability to promptly engage the enemy. However, how much can be learned about enemy intentions is limited, particularly if the enemy is intent on deception. The model allows this limit to be explored by explicitly including the variance of the stochastic process describing the knowledge of enemy speed. Specifically, the model determines the probability of being at the right place at the right time to engage the enemy by accounting for the density of our naval forces, speed of deployment, our capacity to detect and track the enemy, and the enemy speed and deception capability. In order to be agile, the naval fleet must be able to (1) maintain wide geographic coverage, (2) deploy joint forces rapidly, (3) maneuver forces, and (4) provide strategic mobility to joint forces.

a. Engage Enemy with Precise Position Established

Let us first consider the case where enemy location and velocity are known with precision. Figure 15 illustrates the area of operation with enemy and naval force positions given. Initially, our naval forces are located at position *a*. We then detect an enemy target at position *b***,** moving with velocity v_b. We wish to engage the enemy at some final location of intercept. We subsequently advance our forces with maximum velocity v_a toward the intercept location.

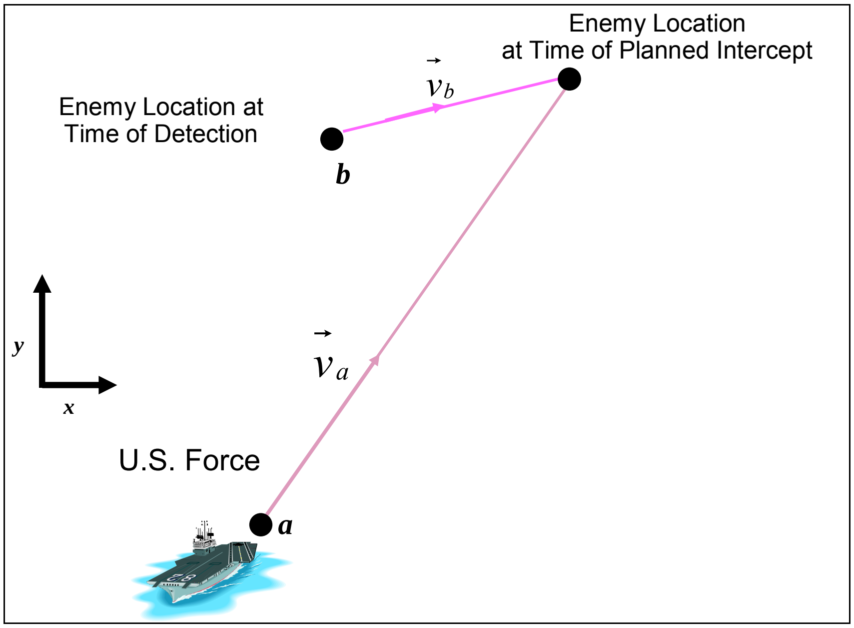

Figure 15. Engaging the Enemy with Precise Enemy Location and Velocity Known

In order for the naval fleet to seize the enemy target, we need maximum speed to be greater than enemy maximum speed, $|v_a| > |v_b|$. The magnitudes of the velocities are:

$$|v_a| = \sqrt{v_{ax}^2 + v_{ay}^2} \qquad |v_b| = \sqrt{v_{bx}^2 + v_{by}^2}$$

Using the following equations to determine the position of U.S. forces and the enemy as a function of time,

$$x = x_0 + v_x t$$

$$y = y_0 + v_y t$$

We expect to encounter the enemy at position (x_{final}, y_{final}) at time τ.

$$x_{final} = a_x + v_{ax}\tau = b_x + v_{bx}\tau$$

$$y_{final} = a_y + v_{ay}\tau = b_y + v_{by}\tau$$

$$\Rightarrow \frac{a_x - b_x}{a_y - b_y} = \frac{v_{bx} - v_{ax}}{v_{by} - v_{ay}}.$$

We need to solve for the fleet's velocity components. Substituting in the velocity components of v_{ax} (where $v_{ax} = \sqrt{v_a^2 - v_{ay}^2}$) into the above equation, we obtain

$$\begin{aligned}&[(a_x - b_x)^2 + (a_y - b_y)^2]v_{ax}^2 + [2v_{by}(a_x - b_x)(a_y - b_y) - 2v_{bx}(a_y - b_y)^2]v_{ax} + \\ &[(v_{by}^2 - v_a^2)(a_x - b_x)^2 - 2v_{bx}v_{by}(a_x - b_x)(a_y - b_y) + v_{bx}^2(a_y - b_y)^2] = 0\end{aligned}.$$

Similarly, we substitute the components of v_{ay} (where $v_{ay} = \sqrt{v_a^2 - v_{ax}^2}$) into the equation to obtain:

$$\begin{aligned}&[(a_x - b_x)^2 + (a_y - b_y)^2]v_{ay}^2 + [2v_{bx}(a_x - b_x)(a_y - b_y) - 2v_{by}(a_x - b_x)^2]v_{ay} + \\ &[(v_{bx}^2 - v_a^2)(a_y - b_y)^2 - 2v_{bx}v_{by}(a_x - b_x)(a_y - b_y) + v_{by}^2(a_x - b_x)^2] = 0\end{aligned}.$$

The components of the fleet's velocity (v_{ax}, v_{ay}) are then calculated to be,

$$v_{ax} = \frac{-[2v_{by}(a_x - b_x)(a_y - b_y) - 2v_{bx}(a_y - b_y)^2]}{2[(a_x - b_x)^2 + (a_y - b_y)^2]} \pm$$
$$\frac{\sqrt{[2v_{by}(a_x - b_x)(a_y - b_y) - 2v_{bx}(a_y - b_y)]^2 - 4[(a_x - b_x)^2 + (a_y - b_y)^2][(v_{by}^2 - v_a^2)(a_x - b_x)^2 - 2v_{bx}v_{by}(a_x - b_x)(a_y - b_y) + v_{bx}^2(a_y - b_y)^2]}}{2[(a_x - b_x)^2 + (a_y - b_y)^2]}$$

$$v_{ay} = \frac{-[2v_{bx}(a_x - b_x)(a_y - b_y) - 2v_{by}(a_x - b_x)^2]}{2[(a_x - b_x)^2 + (a_y - b_y)^2]} \pm$$
$$\frac{\sqrt{[2v_{bx}(a_x - b_x)(a_y - b_y) - 2v_{by}(a_x - b_x)^2]^2 - 4[(a_x - b_x)^2 + (a_y - b_y)^2][(v_{bx}^2 - v_a^2)(a_y - b_y)^2 - 2v_{bx}v_{by}(a_x - b_x)(a_y - b_y) + v_{by}^2(a_x - b_x)^2]}}{2[(a_x - b_x)^2 + (a_y - b_y)^2]}$$

For simplicity, we designate the fleet's position components to be at the origin $(a_x,a_y) = (0,0)$ and we choose appropriate coordinates such that $(b_x,b_y) = (0, b_y)$ such that there is only a distance y between fleet and enemy forces. The x-direction is then defined as the direction perpendicular to the line connecting the initial enemy location to our initial location. We then have for the velocity components,

$$v_{ax} = v_{bx} .$$

We are simply matching the *x*-component of the enemy's velocity.

$$v_{ay} = \sqrt{\left|(v_{bx}^2 - v_a^2)\right|} .$$

We then maximize the *y*-component of velocity to seize the enemy. We note that the velocity components are now calculated for this rotated coordinate system. The time to engage the enemy τ is then,

$$\tau = \frac{b_y}{\sqrt{\left|v_{bx}^2 - v_a^2\right|} - v_{by}} .$$

We equate b_y to the average distance from the naval fleet to enemy target. The derivation of the average distance from target to shooter is given in Appendix A. This distance from the forces to the target is determined by the total number of forces in the fleet and the overall area of operation. As the area of combat increases and/or the number of platforms decrease, we expect the average distance from our forces to the enemy target to increase, i.e., the density of forces is decreasing.

b. Engage Enemy with Known Probability Distribution of Enemy

In a real combat situation, the exact enemy location and velocity cannot be determined with precision. We next consider the case where the imprecision of the ISR assets are taken into consideration. As in the previous case, we wish to engage the enemy at some final intercept location after determining the location and initial fleeing velocity of the enemy target. We initially detect an enemy target with ISR sensors**,** however due to the inaccuracy of our surveillance system, there is an inherent uncertainty in the determined enemy location. The enemy leaves the location at velocity v_b. We then advance the enemy with our maximum velocity $v_{a.}$ The enemy has the ability to evade us by changing their initial velocity. The overall final standard deviation in the probability distribution of the enemy location depends on the quality of our ISR assets and the enemy's ability to swiftly avoid confrontation.

Shown in Figure 16, we detect an enemy target at position *T*(0) with our surveillance system, but the target's actual location is *E*(0). The probability distribution of the detected or estimated location is assumed to be Gaussian with mean value *E*(0). The enemy then attempts to leave with detected velocity ω. We deploy our forces to intercept the enemy target at a predetermined location based on the estimated enemy location and velocity. The enemy, in turn, may seek to evade and flee with an actual velocity Ω. We have as the initial mismatch $m(0)$ between detected enemy location and actual enemy location as:

$$\vec{m}(0) = \vec{E}(0) - \vec{T}(0) .$$

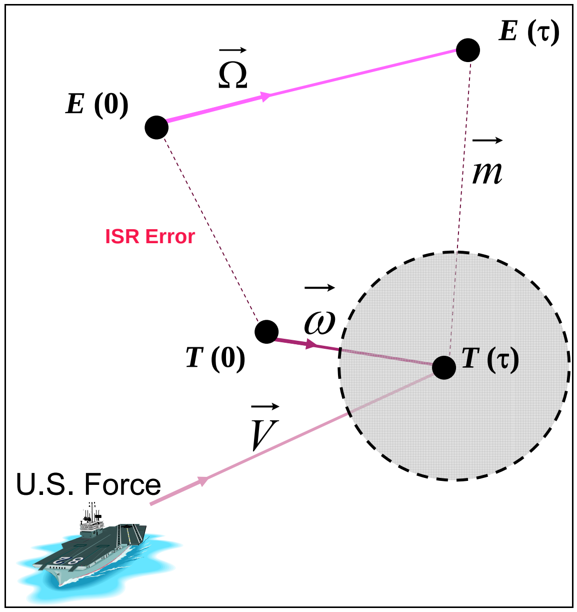

Figure 16. Intercepting Enemy Forces with Estimated Enemy Location and Velocity

The deception of the enemy is then the mismatch in actual versus detected fleeing velocity multiplied by the time τ needed to engage the enemy.

$$\vec{\delta} = (\vec{\Omega} - \vec{\omega})\tau .$$

The final mismatch between the location of our intercepting forces to the actual final location of the enemy is $m(\tau)$, which is the addition of the final mismatch with the initial ISR error:

$$\vec{m}(\tau) = \vec{E}(\tau) - \vec{T}(\tau) = \underbrace{\vec{E}(0) - \vec{T}(0)}_{\vec{m}(0)} + \underbrace{(\vec{\Omega} - \vec{\omega})\tau}_{\vec{\delta}} .$$

We assume a Gaussian probability distribution function for the final estimated position of the enemy

$$\Pi(T(\tau)) = \frac{1}{(2\pi\sigma^2)^{3/2}} \exp\left(\frac{-[T(\tau) - (E(0) + \omega\tau)]^2}{2\sigma^2} \right),$$

where σ is the standard deviation of the ISR assets. Similarly, we assume a Gaussian probability distribution function for the final actual position of the enemy. We expect probability distribution of the enemy velocity to also be Gaussian with standard deviation μ. We then have as the probability distribution of the final actual enemy location to be,

$$\Pi(E(\tau)) = \frac{1}{[2\pi(\mu\tau)^2]^{3/2}} \exp\left(\frac{-[E(\tau) - (E(0) + \omega\tau)]^2}{2(\mu\tau)^2} \right).$$

The normal difference distribution of the estimated probability distribution and of the actual probability distribution is another Gaussian distribution given by,

$$\Pi(\vec{m}(\tau)) = \frac{1}{(2\pi\Sigma^2)^{3/2}} \exp\left(\frac{-m^2(\tau)}{2\Sigma^2} \right),$$

where the mean mismatch distance <*m*> is expected to be zero and the standard deviation Σ is given as,

$$\Sigma^2 = \sigma^2 + (\mu\tau)^2 .$$

Finally, we calculate the agility of our naval force, measured by how much of a mismatch probability lies within a specified attack area. We define an acceptable mismatch area as one in which the enemy is within our vicinity to attack. The dotted area in Figure 16 represents the acceptable area within which our forces are able to strike. The agility *N* of our forces is determined by integrating the probability distribution of the enemy location over an acceptable square area A_Δ,

$$N(A_\Delta;\Sigma) = \int_{A_\Delta} \Pi(\vec{m})dm = \int_0^{L_{x\Delta}} \frac{1}{[2\pi\Sigma_x^{\ 2}]} \exp\left(\frac{-m_x^{\ 2}(\tau)}{2\Sigma_x^{\ 2}} \right) dm_x \int_0^{L_{y\Delta}} \frac{1}{[2\pi\Sigma_y^{\ 2}]} \exp\left(\frac{-m_y^{\ 2}(\tau)}{2\Sigma_y^{\ 2}} \right) dm_y$$

Figure 17 illustrates the relationship between enemy deception and the standard deviation of our surveillance system. The graph shows constant agility curves as a function of the standard deviation in enemy deception and the standard deviation in our surveillance system. Clearly, if the enemy deception capability and the standard deviation in our surveillance are small, which is the case for a symmetric enemy, the probability of being at the right place at the right time is high. This probability decreases as the enemy's speed and position become increasingly uncertain.

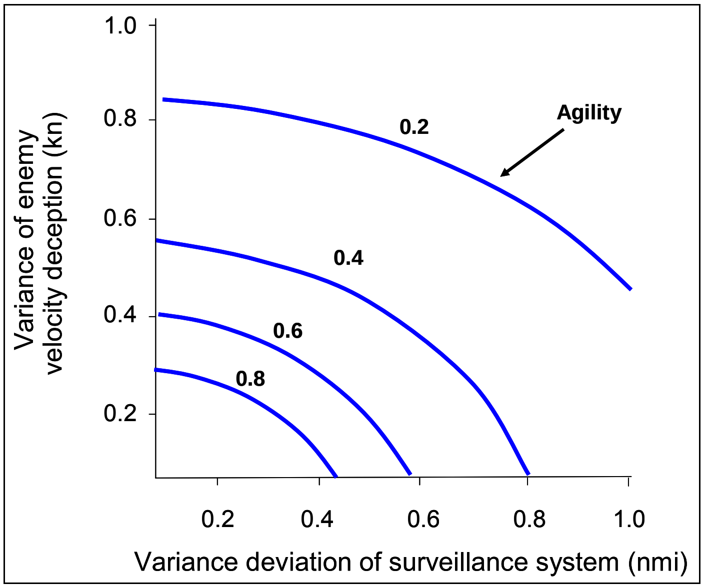

Figure 17. Agility Dependence on Enemy Deception and U.S. Surveillance Quality

4. Fight From the Sea

Figure 18 illustrates the general concept behind the fourth model, which evaluates a fleet's capability to fight from the sea. To model this capability, imagine that the fleet is confronted with a given number of enemy targets operating in a given area and that two systems are deployed: sensors and weapons. The sensors are an information-generating system designed to detect and localize as many of the targets as possible, and the weapons represent a killing system designed to destroy any target that has been detected and localized by the information-generating system. The model assumes that the number of targets to attack is much smaller than the number of weapons at the fleet's disposal. This is a reasonable assumption given technical increases in fire-power in recent years and given that an asymmetric enemy would provide a target poor environment.

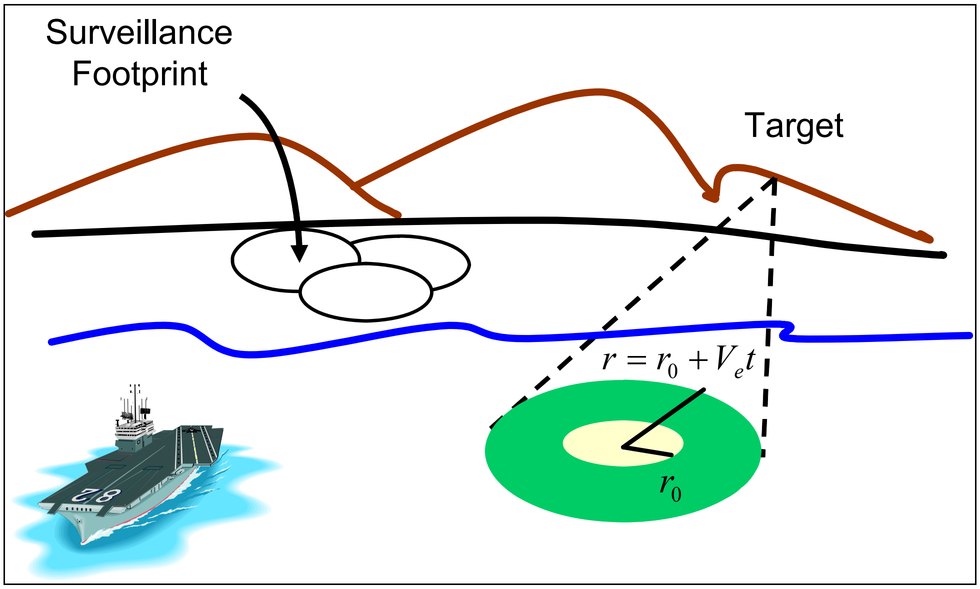

Figure 18. Theater of Combat Situation for Strike Model

We further assume that the targets have the ability to react to the information-gathering system's attempt to detect and localize them. Consequently, at any given time, targets can be partitioned into two classes: those that are under active localization and could be attacked with the higher precision corresponding to a well localized target, and those that are no longer under active localization but could still be attacked with the much lower precision corresponding to a fleeing target. The weapon kill radius has associated radius r_0 and for a fleeing target encompasses a larger radius r, which is effectively r_0 plus the distance the enemy can cover with speed v_{escape}, $r = (r_0 + v_{escape}\ t)$. The model adds results of these two kinds of kills and evaluates the fleet's overall capability to fight from the sea as the fraction of targets it can destroy as a function of the enemy's ability to escape from the first class into the second. This ability to evade our track is a reflection of an asymmetric enemy.

We have created a model of strike effectiveness for a current and future naval fleet. Our model captures (1) the number and quality of our ISR assets, (2) the probability that the weapon kills the target, (3) the enemy's ability to break trail, and (4) the effect time has on the ability to kill a fleeing target. We initially deploy an information-gathering or surveillance system designed to detect enemy targets. The surveillance system consists of a combination of a satellite system, unmanned aircraft from the naval fleet, etc. We then confront the enemy targets in a given theater of combat. The targets have the ability to react to the detection system and, therefore, attempt to evade attack. The targets are in either of three states: the *tracking* state in which the surveillance system is actively tracking it, the *undetected* state, or the *fleeing* state in which the target managed to break trail but has not yet moved far enough to enter the undetected state. During battle there is a constant transition rate between the enemy states. We ultimately determine the measure of strike effectiveness in terms of the fraction of land targets that we can destroy in the given operating area.

a. Determining Strike Effectiveness *F*

Initially, we have a number of targets *N,* which are found in either of the three states: *tracking*, *undetected*, or *fleeing*. The total number of targets *N* is then simply the addition of all numbers in the target states,

$$N = N_t + N_f + N_u,$$

where N_t are the tracked targets, N_f are the fleeing targets, and N_u are the undetected targets.

We characterize the states of the enemy as a three-level system, similar to the quantum levels of an atom. Figure 19 shows the three-level system of enemy states, where the enemy has the ability to transition from one state to another just as electrons can transition between energy levels in an atom. We simplify the scenario by assuming the enemy can only transition between certain states. Let us assume the enemy has the ability to transition from the undetected state to the tracking state with constant rate λ_t, from the tracking state to the fleeing state with rate μ_f, and from the fleeing state to the undetected state with rate γ_u. For simplicity, we assume the enemy does not have the ability to transition from the tracking to undetected state since the enemy cannot flee so quickly as to instantaneously become undetected. We also simplify the scenario by assuming that once the enemy is in his fleeing state, he can transition to the undetected state and not back into the tracking state. The time-dependent rate equations of the three enemy states are given by the following:

$$\frac{dN_t}{dt} = -\mu_f N_t + \lambda_t N_u$$

$$\frac{dN_f}{dt} = \mu_f N_t - \gamma_u N_f$$

$$\frac{dN_u}{dt} = \gamma_u N_f - \lambda_t N_u$$

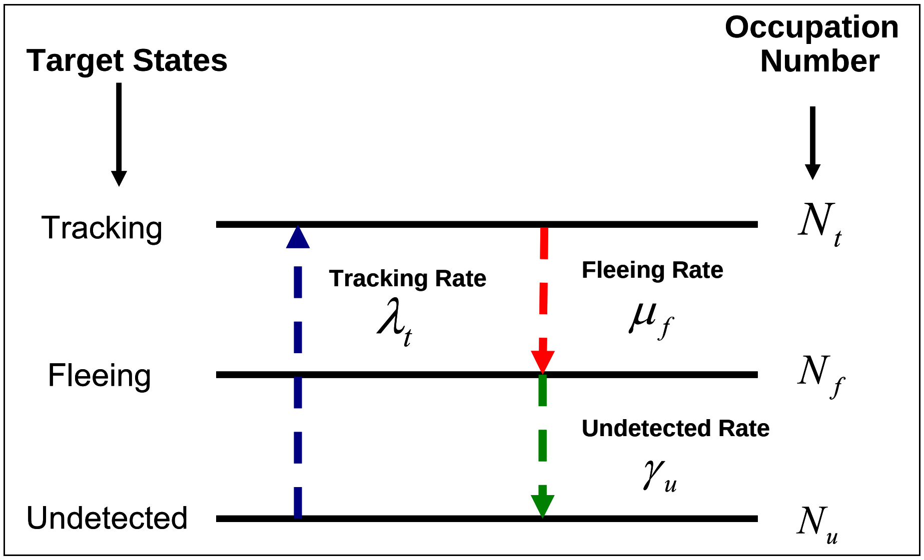

Figure 19. Transitions Can Occur Between Three Target States

For simplicity, we consider the steady-state solution ($d/dt = 0$). We then have for the steady-state rate equations,

$$-\mu_f N_t + \lambda_t N_u = 0$$

$$\mu_f N_t - \gamma_u N_f = 0$$

$$\gamma_u N_f - \lambda_t N_u = 0$$

Solving for the number of tracked targets N_t and the number of fleeing targets N_f, we obtain

$$N_t = \left[\frac{\lambda_t \gamma_u}{\lambda_t \gamma_u + \mu_f \gamma_u + \lambda_t \mu_f} \right] N$$

$$N_f = \left[\frac{\lambda_t \mu_f}{\lambda_t \gamma_u + \mu_f \gamma_u + \lambda_t \mu_f} \right] N$$

The average number of killed targets n is then,

$$n = N_t P + N_f p = \left[\frac{\lambda_t \gamma_u}{\lambda_t \gamma_u + \mu_f \gamma_u + \lambda_t \mu_f} \right] NP + \left[\frac{\lambda_t \mu_f}{\lambda_t \gamma_u + \mu_f \gamma_u + \lambda_t \mu_f} \right] Np$$

where P is the probability of kill for a tracked target and p is the probability of kill for a fleeing target. We naturally assume eliminating a fleeing target is more difficult than eliminating a detected target and therefore, $p < P$. The probability P is the acknowledged numerical value of the probability to kill for a given detected target. The probability p is related to P as the ratio of the kill target area πr_0^2 to the area that the target can cover with given speed v_{escape} in a time t_0 $(\pi(r_0+v_{\mathrm{escape}}\, t_0)^2)$,

$$p = \frac{\mathrm{Pr}_0^{\ 2}}{(r_0 + v_{\mathrm{escape}} t_0)^2}.$$

We note the time t_0 is the time required for the weapon to reach its target. Given the speed of the weapon v_{weapon} and the average distance $\rho_{distance}$ from shooter to target, we can then determine the weapon time of flight t_0.

$$t_0 = \frac{\rho_{dis\tan ce}}{v_{weapon}},$$

where $\rho_{distance}$ is derived in Appendix A. The fraction of targets killed (n / N) in a given subarea a is then,

$$f = \left[\frac{\lambda\gamma}{\lambda\gamma + \mu\gamma + \lambda\mu}\right] P + \left[\frac{\lambda\mu}{\lambda\gamma + \mu\gamma + \lambda\mu}\right] p .$$

Depending on the fleet architecture, the surveillance coverage may be increased and the number of surveillance areas m can increase indefinitely. Illustrated in Figure 20, each surveillance system can view an area of footprint area a with the total theater of operation of area A. We note that the surveillance areas may overlap, therefore m can be infinite. Surveillance of the operational area is then an inefficient process; we may survey the same area with several different surveillance platforms. The fraction of surveillance area α considered is then,

$$\alpha = \left(1 - \exp\left(\frac{-ma}{A}\right)\right).$$

For small ma/A, the fraction is simply the fraction covered. For large m (surveillance of the area a large number of times), the fraction becomes 1, as expected.

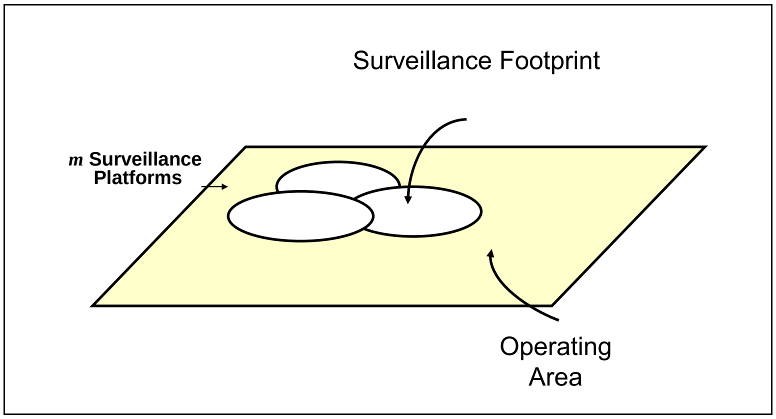

Figure 20. Surveillance Footprints Cover a Portion of the Operating Area

We then determine the total fraction F eliminated (taking into account surveillance system of fleet architecture) as

$$F = P\left[\left[\frac{\lambda\gamma}{\lambda\gamma + \mu\gamma + \lambda\mu}\right] + \left[\frac{\lambda\mu}{\lambda\gamma + \mu\gamma + \lambda\mu}\right]\frac{{r_0}^2}{(r_0 + v_{escape}t)^2}\right]\left[1 - \exp\left(\frac{-ma}{A}\right)\right].$$

5. Sustain Joint Forces

The situation modeled is one in which ground forces are in immediate need of resupply. Forces may be engaged in combat and need ammunition or repair parts, for example. They can be Marines, Army units, or allies. The sea base from which joint logistics is extended is either an amphibious ship for the programmed forces or the X-WPS ship in the alternatives. For programmed forces, MV-22s are used for prompt resupply; for alternatives, the new-design heliplane transport is used.

The time at which a resupply aircraft is launched is treated as a random variable, drawn from a probability distribution with a mean delay time after a call for help before aircraft are airborne and a standard deviation in the response time about the mean delay time. Since it is assumed that each aircraft travels at an average maximum speed until it reaches the embattled ground forces, the probability distribution also propagates over the same space at the same speed. This satisfies a traveling wave equation, the conservation equation:

$$\frac{\partial}{\partial x}P(x,t) + \frac{1}{v}\frac{\partial}{\partial t}P(x,t) = 0\,.$$

In this expression, *P(x,t)* represents the probability distribution at position *x* and at time *t*. The aircraft (and the distribution function) move at a constant speed *v*. If we assume a Gaussian distribution, the expression for *P(x,t)* is a function of *x-vt*, representing a traveling wave that satisfies the conservation equation above. It is

$$P(x,t) = (2\pi\sigma^2)^{-2} e^{-[(x-vt-\mu)/\sigma]^2/2} .$$

This distribution function moves without losing its basic shape and without spreading. It maintains a constant standard deviation throughout its propagation. Different aircraft will be characterized by different values of v and σ, and different information processing systems will have different reaction delays μ. Schematically, the relative pulse movement looks as shown in Figure 21. Initially the two pulses look similar and are almost the same. They differ only by the initial delay in getting aircraft airborne after the call for resupply goes out and the width of their distributions, a measure of the efficiency with which each force can respond. After several minutes, the distributions have separated significantly since the heliplane transport flies at 450 knots and the MV-22 at 250 knots. The distributions continue to separate further in proportion to the distance flown to the objective.

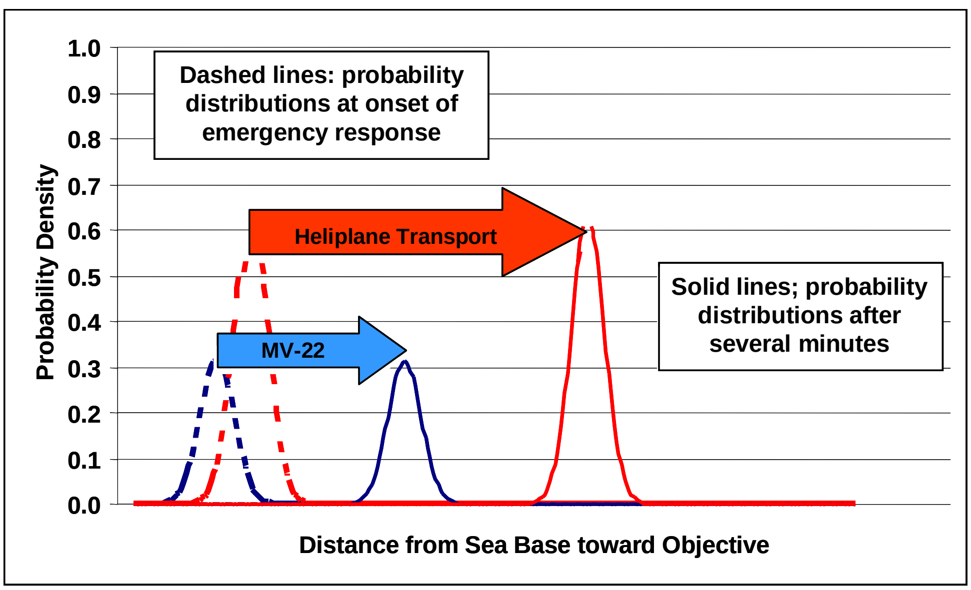

Figure 21. Schematic Comparison of Emergency Resupply Probability Pluses for Programmed and Alternative Fleets

The cargo is delivered when there is a 90-percent probability that the needed cargo has arrived where needed. This is the same as calculating the time when 90 percent of the probability pulse has passed over the required position. Since the programmed fleet and the alternative fleets have different statistical parameters, the time delay in the MV-22s arriving from the amphibious ship relative to the heliplane transports from the X-WPS ships is

$$\Delta t = \Delta \tau + L \frac{\Delta v}{v_{alt} v_{prog}} + z\Delta(\frac{\sigma}{v}) \ ,$$

The parameters are defined as follows. The term Δt is the difference in arrival times for the programmed and alternative fleets, while $\Delta\tau$ is the difference in processing time of the request for help. The term L is the distance from the sea base to the ground units needing help, and Δv is the difference between the speed v_{alt} of the alternative heliplane transport delivery aircraft and the speed v_{prog} of the programmed MV-22. The term z is the number of standard deviation units when 90-percent of the resupply cargo has arrived (i.e., 90 percent of the area under the curve). This value is 1.645, from standard statistics tables. If a more demanding 95-percent arrival were used instead, z = 1.96. In our example, we use the less demanding 90-percent arrival figure where $z = 1.645$.

6. Deny Enemy Ability to Hold Homeland at Risk

The role of the U.S. Navy in homeland defense is illustrated in two ways in this report. One is dynamic, serving to interdict suspicious shipping in support of coastal ands port defense. The second is static, providing a ballistic missile defense shield along selected coastlines. We treat the interdiction analyses first.

a. Interdiction at Sea

The interdiction model is that employed in several earlier studies.[1,2] The concept is that naval ships form a linear barrier to interdict any ships trying to penetrate. This is illustrated in Figure 22. These ships could pose a problem as drug smugglers or as agents determined to do harm once nearer the shore or ports.

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1 *Small Combatants: Implications for the Effectiveness and Cost of Navy Surface Forces*, IDA Paper P-3716, September 2002, Classified.

2 *Mark VI (MK VI) Analysis of Alternatives (AoA)*, IDA Paper P-3886, May 2004, Classified.

The SSG is used in this mission to illustrate differences between programmed and the more numerous and faster craft in the three alternatives. The programmed fleet uses LCSs. Alternative A has the smaller and faster SSC-1000s. Alternatives B and C are identical in this case, both with the very small, very fast and most numerous VSC-100s.

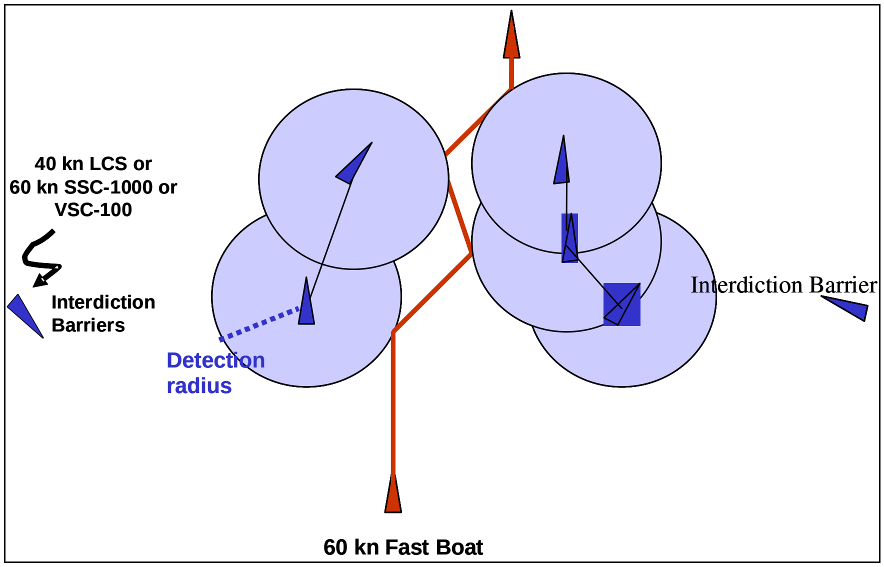

Figure 22. Interdiction Concept

When the fast boat is first detected by surface radar on one of the barrier ships (LCS, SSC-1000, or VSC-100), the intruder makes a sharp turn away to elude capture while still moving forward. The radar reach is illustrated by the blue circles in Figure 22. The intruder recognizes that he has been detected and is credited with the knowledge of distance and relative speeds and so selects an oblique evasion route that guarantees escape while maintaining as much of forward velocity as possible. He knows other ships are stationed somewhere in the barrier and doesn't want to run into one accidentally by veering too far away from the forward direction. Through networked data communications, a picture of the intruder's position and velocity is immediately transmitted to all other ships in the barrier. The nearest defender plots and moves on an interception course using this information. As the second ship detects the intruder, the intruder maneuvers again to elude both pursuers while still moving forward, if possible, using its knowledge of the range and speeds of the two pursuers to best advantage. In this zigzag evasive pattern the intruder reacts to each new detection in order to avoid capture. By coordination, the barrier defenders try to pin down the intruder and prevent passage. The intruder is either intercepted or it penetrates. No weapons are fired—this is straight interdiction at sea.

b. Ballistic Missile Defense (BMD)

The SSGs are assumed to be deployed to assist in missile defense along selected coastline areas or near ports. They would be protecting against ballistic or other missiles launched at sea toward U.S. facilities ashore. The ballistic missile defense is the most challenging, requiring the use of space-search and active-guidance radars to cue interceptor missiles launched from Navy ships. For programmed forces, the *Aegis*-class ships with SPY-1 radars and BMD interceptors serve in this mission. For alternative fleets examined here, the X-WPS provides the search and guidance radar, as well as interceptor missiles, although the SSC and VSC craft could also carry interceptors launched on cue from the X-WPS.

The coverage implied schematically by a programmed SSG with three CGXs (the BMD forces of the fleet) and one of the alternative SSGs (with a single X-WPS in the formation) is shown in Figure 23. The trapezoidal areas are illustrative of relative area coverage against a flying missile. The X-WPS is a larger ship than the CGXs and can carry a larger radar and larger, faster interceptor missiles, hence the somewhat larger engagement envelope depicted.

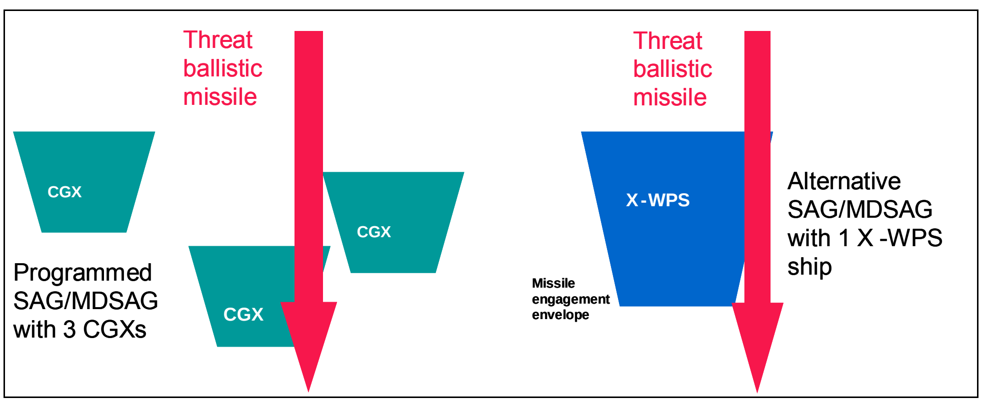

Figure 23. Concept for Ballistic Missile Defense of the Homeland

C. ANALYSIS OF ALTERNATIVES

Next the question of fleet capability against an uncertain future is addressed by using these models for the four sets of circumstances identified previously in Table 8. For each set of policy and enemy behavior, we have explored the major factors affecting fleet capability such as the speed of naval forces, the number of units in the operational area, or the enemy anti-access threat density. We then identified their dependencies on these factors, observing how varying them affects fleet capability. Once the underlying behavior of these capabilities is investigated, we compared the programmed fleet with its alternatives and identified the most capable fleet within the specified policy and enemy behavior.

Since current warfare has shifted toward an intervention policy/asymmetric enemy situation, our analyses have emphasized this particular scenario over other scenarios. Future enemies cannot, of course, be accurately predicted, but we are forced to predict the type of enemy we are likely to engage in order to properly design the future naval fleet. The future fleet should be capable in any scenario; however, the alternatives were designed to consider the intervention policy/asymmetric enemy situation more likely to occur than the other scenarios. Although the analyses of the other scenarios are discussed, the main focus of this section is on the intervention policy/asymmetric enemy situation.

1. Intervention Policy/Asymmetric Enemy

We begin with the case in which U.S. security policy is interventionist. Under these circumstances, the needed capabilities are agility, access and control of operational domains, and the ability to fight from the sea (power projection). This is because, in an intervention setting, the Navy is mainly focused upon supporting the land battle from the sea, and it must therefore tailor its operations to the dynamics of that battle. Agility, measured by the fleet’s ability to quickly get to the proper location, is thus important. In a similar fashion, since supporting land operations requires the Navy to be positioned within striking distance of land targets, a fleet participating in an intervention action would have to gain access to the enemy’s littorals to guard against the anti-access forces that the enemy deploys there. Finally, since the whole reason for using the fleet in an intervention war is to affect the battle on land, the fleet must be able to deliver a sizable power projection strike once it accesses the littorals.

In an intervention war, the enemy could behave asymmetrically, implying that enemy action will be aimed more at exploiting the fleet's weaknesses than at confronting it head on. Consequently, the enemy would be driven to deceive rather than confront U.S. forces. Deception could significantly affect all our needed capabilities. Thus, a deceptive enemy would go to great lengths to ensure that we do not know either the right place or the right time at which the fleet should act. Similarly, the fleet must be able to remove the various anti-access assets the enemy will deploy against it. This fleet ability could be significantly reduced by enemy tactics designed to hide from surveillance when and where those assets are deployed. Finally, enemy targets could choose to operate in an environment in which the surrounding objects provide them with an ability to escape tracking before we can launch weapons against them. Therefore, the most important critical factor to all the relevant capabilities is the enemy's ability to deceive.

a. Driving Capabilities

To control the operational domain, we intuitively recognize that fleet survival depends on the number of removal forces and the density of the enemy anti-access threat. Fleet survivability should increase with increasing number of removal units but decrease with increasing enemy anti-access threats. Shown in Figure 24, we find that the probability of surviving a power projection force after 48 hours once the removal operation begins, does, in fact, increase with the number of removal units. For small numbers of removal units, this trend is observed to have an almost linear dependence but, if we increase the number of ships beyond 50 or more units, we observe diminishing returns. However, if the enemy initially has a large density of anti-access forces in the operational area, our ability to survive diminishes significantly. Figure 25 shows constant probability of survival curves as a function of enemy anti-access density and the numbers of removal units. Clearly, increasing the number of removal units bolsters survivability, but a more effective method of ensuring survivability is to deny the enemy from situating in the operational area in the first place.

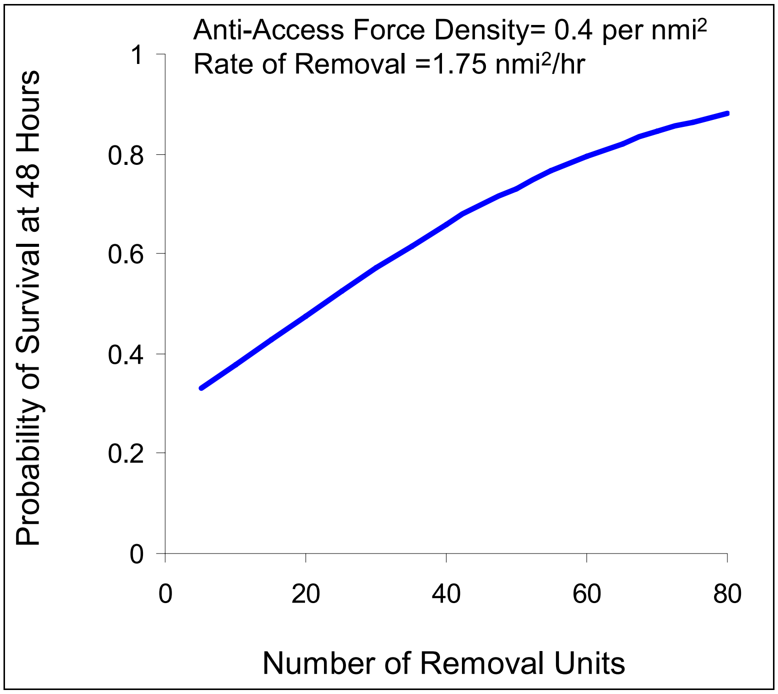

Figure 24. Probability of Survival Depends on the Number of Removal Units

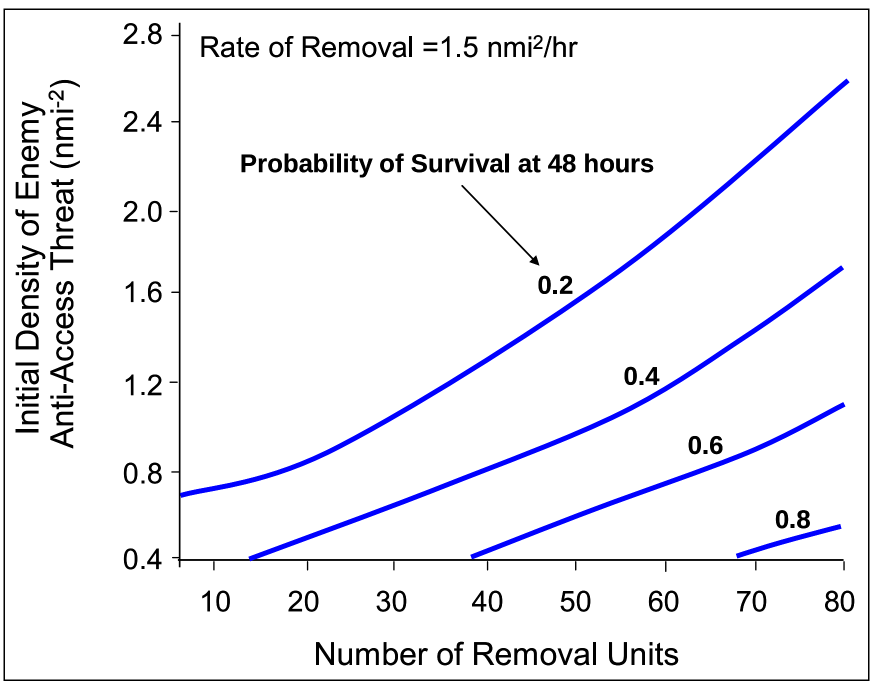

Figure 25. Constant Probability of Survival Curves for Varying Enemy Anti-Access Density and Varying Number of Removal Units

In order to be at the right place at the right time, we must have forces readily situated to engage the enemy at a moment's notice. This requires a large number of quick forces to cover the operational area. In this case, more is clearly better, but at some point we expect diminishing returns whereby increasing the numbers by one unit has little effect in improving agility. The question of how agility depends on the number of forces is answered in Figure 26. If we are to engage an asymmetric enemy, associated with a large uncertainty in our ability to identify his location, we find that agility depends almost linearly with the number of naval units. Since information about the enemy is unclear, each additional increase in the number of platforms significantly improves the fleet's agility because it decreases the average distance between the enemy's location and our own forces. However, if we are to engage a more symmetric enemy, which is associated with a small uncertainty in our ability to identify his location, we find that agility depends little on the numbers of units once the number of naval forces stationed in the operational area reaches about 5 units. The intervention scenario engaging a symmetric enemy will be discussed further in the following section.

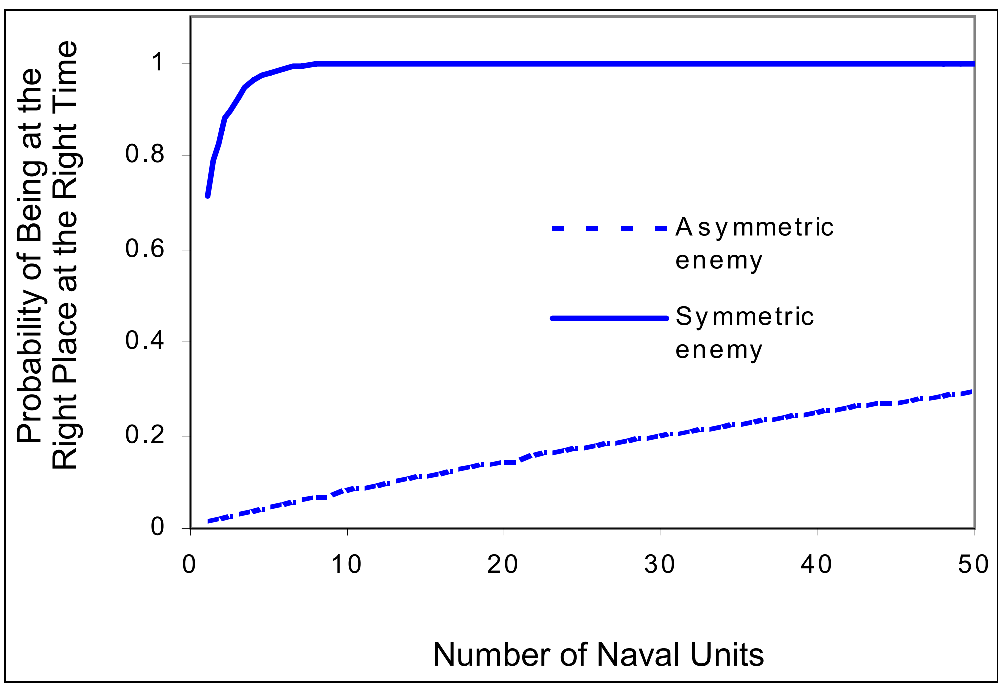

Figure 26. Agility Dependence on the Number of Units

Now let us observe how agility depends on enemy deception capability. Figure 27 shows constant agility curves for varying enemy deception and varying number of forces. Indeed, decreasing enemy deception capability has a greater effect in improving agility than increasing the number of forces. We would also like to understand how ship speed affects the ability to be at the right place at the right time. Shown in Figure 28, we find that both the naval speed and the number of forces affect agility approximately equally; a unit increase in speed or number of forces has a roughly similar effect in increasing agility. However, it may not be as easy to obtain a unit increase in speed as opposed to increasing, by one unit, the number of platforms. If we disregard the ease with which these can be accomplished, we show that ship speed and number of units should have equal weight in determining the probability of being at the right place at the right time.

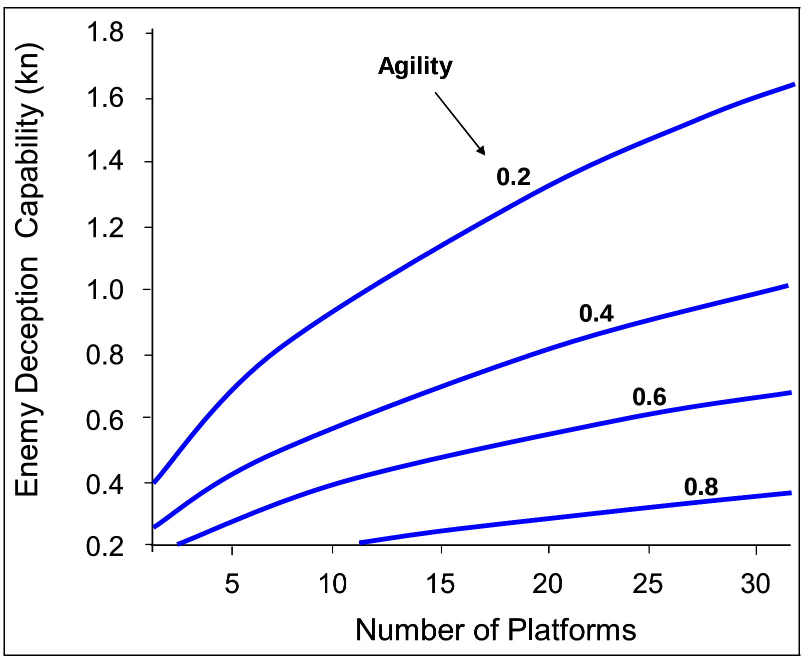

Figure 27. Constant Agility Curves for Varying Enemy Deception Capability and Varying Number of Platforms

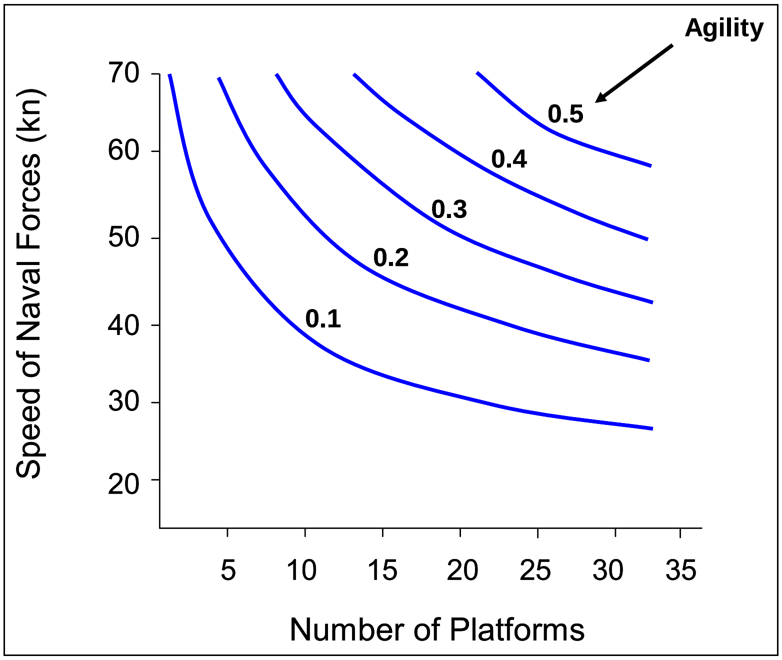

Figure 28. Constant Agility Curves for Varying Naval Speed Capability and Varying Number of Platforms

Next, we look at the ability of the programmed fleet and its alternatives to fight from the sea. Since we assume the fleets do not have limited weapons, increasing the number of shooters shows little improvement in the fraction of targets killed as shown in Figure 29. The figure shows strike capability as a function of the number of shooters when engaging a symmetric and asymmetric enemy. Engaging a more symmetric enemy will significantly increase strike capability but increasing the number of units will not. The major factors in determining strike capability are then the ability to track enemy targets and the ability of the enemy to escape getting hit. Figures 30 and 31 show constant strike effectiveness curves for the programmed fleet and Alternative A respectively. The figures show that, to improve strike capability, the fleet must improve tracking capability and/or prevent the enemy from fleeing. However, limiting the enemy's ability to evade is far more effective in aiding strike capability than improving our tracking capability.

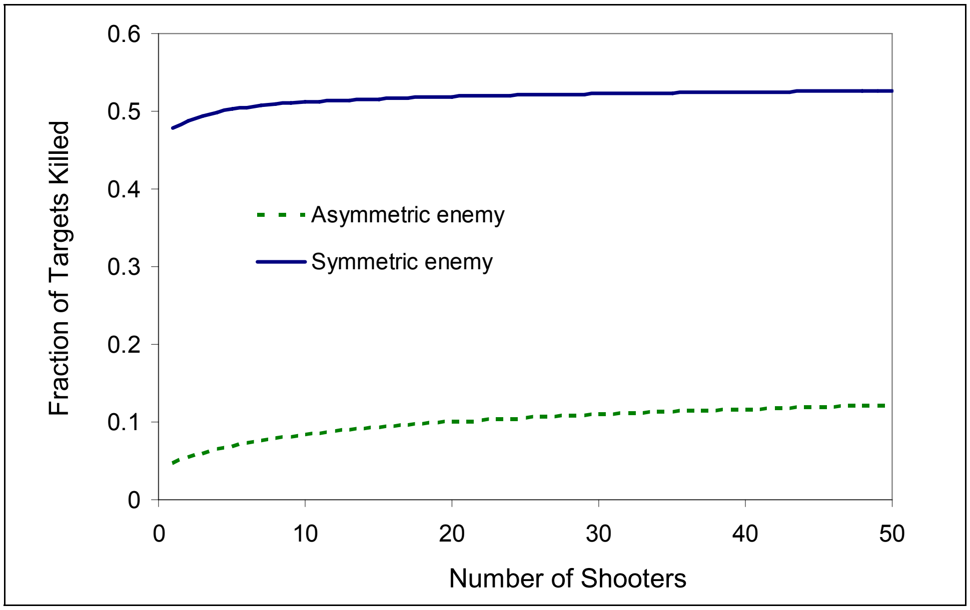

Figure 29. The Fraction of Targets Killed Dependent on the Number of Shooters

Figure 30. Constant Fight from the Sea Effectiveness Curves for Varying Fleeing and Tracking Rates for the Programmed Fleet

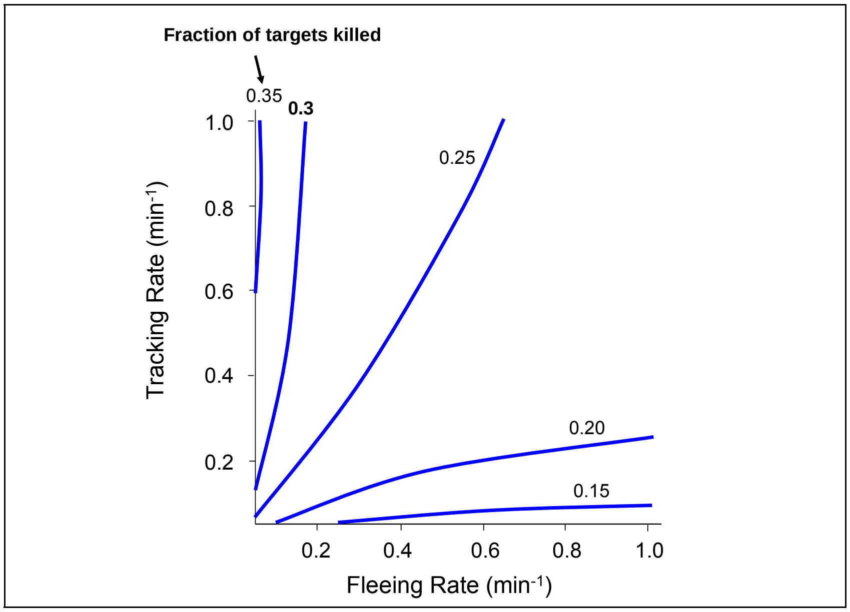

Figure 31. Constant Fight from the Sea Effectiveness Curves for Varying Fleeing and Tracking Rates for the Alternative A Fleet

b. Comparison of Fleets

A reasonable way to control enemy deception is to network many platforms. Networking, made possible by rapidly developing information technologies, promises to deliver two kinds of benefits. First, by distributing information, networking may enhance the effective performance capability of each platform despite the fact that each of them would be smaller and hence individually less capable. The capability of the network, not the capability of each individual element, ultimately matters in a networked force. For instance, by using information made available to the network by all ships, each individual ship in the network could launch weapons at targets located beyond their own detection range. This improvement in capability as a result of the technological power of the network is the technical benefit of networking. Second, by allowing free information flow among military personnel, the network could enable, though spontaneous self-organization, a more cohesive behavior out of which focused, relevant action could emerge.

A networked fleet consisting of many platforms offers the promise of being not only more capable but also more relevant to fighting an asymmetric enemy in an intervention setting. By inculcating cohesive behavior, networking could more efficiently deny an asymmetric enemy the powerful lever of deception. Indeed, a networked force should be able to operate faster, have significantly more tactical options, and generate a more fluid picture of its instantaneous posture and subsequent intentions. This new flexibility and complex array of possibilities should make it difficult for any enemy to ascertain exactly what action would generate deception; it may not be able to determine what will happen next, to set up an appropriate deception plan, and to adapt rapidly enough to changes confronting it.[3]

In the analysis, we wish to compare the programmed fleet with its alternatives quantitatively as well as qualitatively. Using appropriate input parameters for engaging an asymmetric enemy in an intervention setting, given in Tables 9-11 for the appropriate capability, the value of the driving capabilities are determined for the programmed fleet and for its alternatives. Since we used general capability models rather than specific campaign analyses, we sought to employ approximate values for our input parameters. Our main goal was not to use exact historical or projected figures for input parameters but rather, our analyses required approximate values to highlight trends and comparisons. Some values were general order of magnitude approximations, such as the area of operation, weapon lethal radius, and weapon flight speed. Since we cannot accurately predict the future area of operations and specific weapon characteristics, we employed values that were representative of current technologies. When possible, we used future projected values for our inputs, such as the speed of naval forces in the future and the density of naval forces derived from the number of projected platforms. Finally, some values are highly dependent on specific operational conditions, such as the rate at which platforms are lost, enemy deception capability, and enemy tracking, fleeing, and undetected rate to name a few examples. To consider these, it was best to employ a parametric analysis whereby these values were varied in order to explore the full range of input values. Although direct comparison of the fleets required specific input values, more insight can be found by looking at the trends emphasized through these parametric analyses.

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3 We term this capability to confound enemy deception attempts as relevancy, by analogy to the use of this term by OFT.

Table 9. Control the Operational Domain Parameters for the Intervention Policy/ Asymmetric Enemy Incorporating Technical Benefits of Networking
Parentheses Indicate Values With Relevancy Benefits of Networking Incorporated

Parameter	Programmed CSG	Alternative A	Alternative B	Alternative C
Average velocity of removal platform *v* (kn)	35	53	54	57
Removal platform sweep width *w* (nmi)	0.1	0.025	0.025	0.025
Rate at which removal platforms are lost to anti-access threat λ (nmi^2/hr)	0.05	0.35 (0.05)	0.35 (0.05)	0.35 (0.05)
Density of removal forces β_0 (number/nmi^2)	0.0032	0.0096	0.0128	0.016
Density of enemy anti-access threat ρ_0 (number/nmi^2)	0.4	0.4	0.4	0.4
Velocity of power projection force *V* (kn)	35	53	54	57
Power projection sweep width *W* (nmi)	0.1	0.025	0.025	0.025
Prob. of antiaccess assets killing power projection forces α	0.3	1 (0.5)	1 (0.5)	1 (0.5)
Perpendicular Distance from Operating Location to Starting Point ζ (nmi)	15	15	15	15
Dimension of Operating Area along the Shore *L* (nmi)	100	100	100	100
Depth of Operating area *d* (nmi)	25	25	25	25
Arrival Time t_0 (hr)	48	48	48	48

Table 10. Being at the Right Place at the Right Time Parameters for the Intervention Policy/Asymmetric Enemy Incorporating Technical Benefits of Networking
Parentheses Indicate Values With Relevancy Benefits of Networking Incorporated

Parameter	Programmed CSG	Alternative A	Alternative B	Alternative C
Operating area *A* (nmi^2)	50,000	50,000	50,000	50,000
Number of platforms in the area *n*	8	24	33	39
Average velocity of own forces v_a (kn)	35	53	54	57
Velocity of enemy forces v_b (kn)	10	10	10	10
Accuracy of networked surveillance system $\sigma_{network}(n)$ (nmi)	0.33	1.5	1.3	1.2
Enemy deception in intent μ (kn)	1	1 (0.1)	1 (0.1)	1 (0.1)
Acceptable radius strike distance (nmi)	0.5	0.5	0.5	0.5

Table 11. Fight from the Sea Parameters for the Intervention Policy/Asymmetric Enemy Incorporating Technical Benefits of Networking
Parentheses Indicate Values With Relevancy Benefits of Networking Incorporated

Parameter	Programmed CSG	Alternative A	Alternative B	Alternative C
Operating area *A* (nmi^2)	50,000	50,000	50,000	50,000
Number of platforms in the area *n*	8	24	33	39
Transition rate from undetected state to the tracking states λ (min^{-1})	0.3	0.1	0.117	0.126
Transition rate from the tracking state to the fleeing state μ (min^{-1})	1 (0.5)	1 (0.2)	1 (0.2)	1 (0.2)
Transition rate from the fleeing state to the undetected state γ (min^{-1})	0.115	0.115	0.115	0.115
Probability of killing a target which is under active tracking *P*	0.6	0.6	0.6	0.6
Weapon lethal radius r_0 (nmi)	1	1	1	1
Weapon speed v_{weapon}(kn)	550	550	550	550
Enemy fleeing velocity v_{escape} (kn)	10	10	10	10
Surveillance area (*ma/A*)	1	1	1	1

To compare the alternatives against the programmed fleet, the value of the driving capabilities for the programmed fleet was normalized to unity and the relative values of the alternatives were then determined. Comparisons are made between the fleets for three capabilities: Control the Operational Domain, Promptly Bring Forces to Bear, and Fight from the Sea. Two cases are shown in the figures below, one that incorporates the technical benefits of networking, the other incorporates both the technical and relevancy benefits of networking. We apply a similar comparison method for the other three scenarios.

The models we use to quantify fleet capabilities against such enemies reflect this by explicitly displaying enemy ability to deceive as an input parameter and by showing how fleet capability would increase if networked behavior would reduce that ability. In Figures 32-34, the three driving capabilities of the fleets are compared, incorporating only the technical benefits of networking. The results indicate that, in an intervention operation against an asymmetric enemy, the programmed fleet could out-perform some of the alternatives despite the fact that all of them sport larger numbers of platforms. Alternative A is shown to be less capable than the programmed fleet for all capabilities whereas Alternative B is measured to be only marginally better than the programmed fleet except in the case of promptly bringing forces to bear. Due to its significantly larger number of platforms, Alternative C is shown to be the only fleet better than the programmed fleet for all three capabilities.

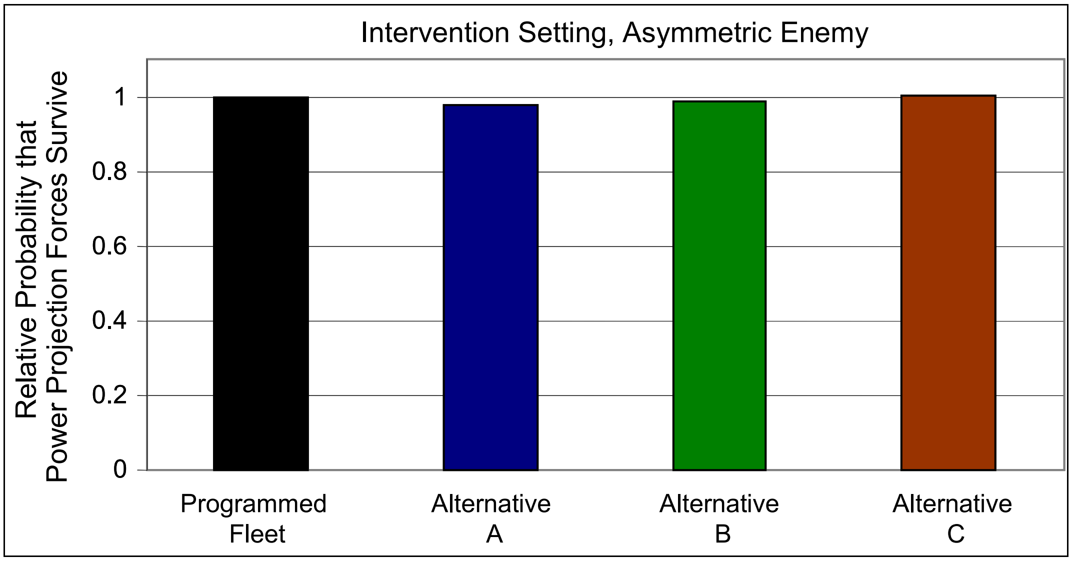

Figure 32. Comparing Programmed and Fleet Alternatives Ability to Control Operational Domain, Incorporating Technical Benefits of Networking

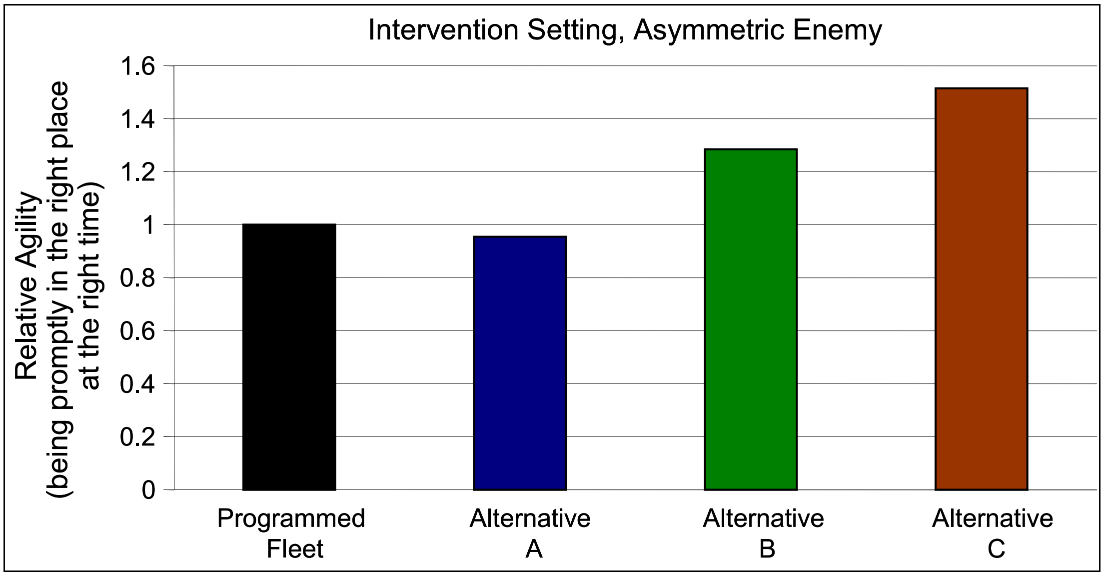

Figure 33. Comparing Programmed and Fleet Alternatives Ability to Promptly Bring Forces to Bear, Incorporating Technical Benefits of Networking

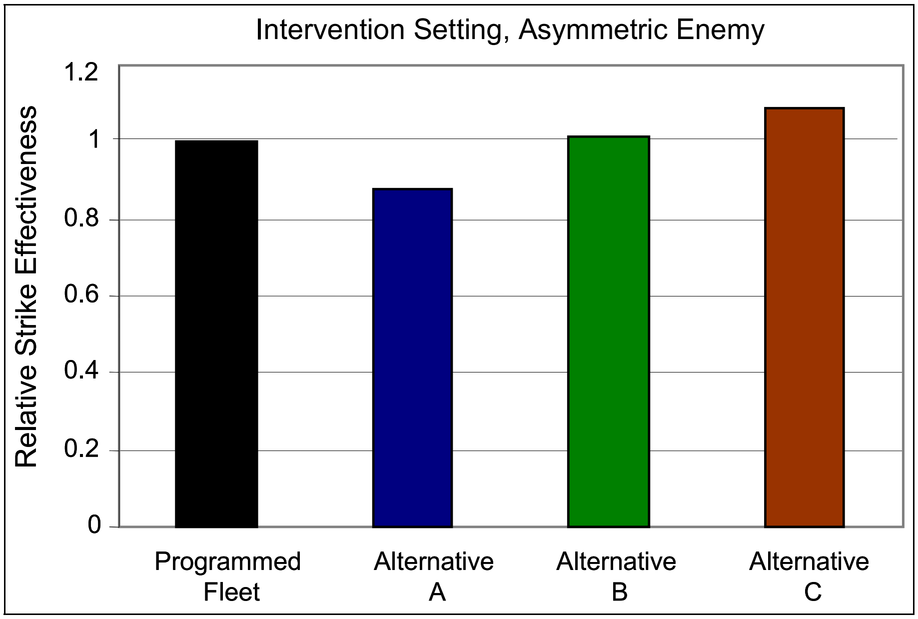

Figure 34. Comparing Programmed and Fleet Alternatives Ability to Fight from the Sea, Incorporating Technical Benefits of Networking

This trend stops being true if fleet capabilities were made more relevant by networking since the programmed fleet, being less numerous, would benefit relatively less from networking. Figures 35-37 show the comparison between the fleets for the three driving capabilities, incorporating both technical and relevancy benefits of networking. While both the programmed fleet and the alternatives could reduce the enemy's ability to deceive, the alternatives would do so more efficiently because the effects of networking grow with the number of elements in the network. Indeed, the analysis shows the benefits of networking clearly enhance the alternative fleets significantly more than the programmed fleet. The comparison charts show that if networking were to make a fleet more relevant to fighting an asymmetric enemy, each alternative fleet, by virtue of its size, would develop into a better fleet than the programmed one.

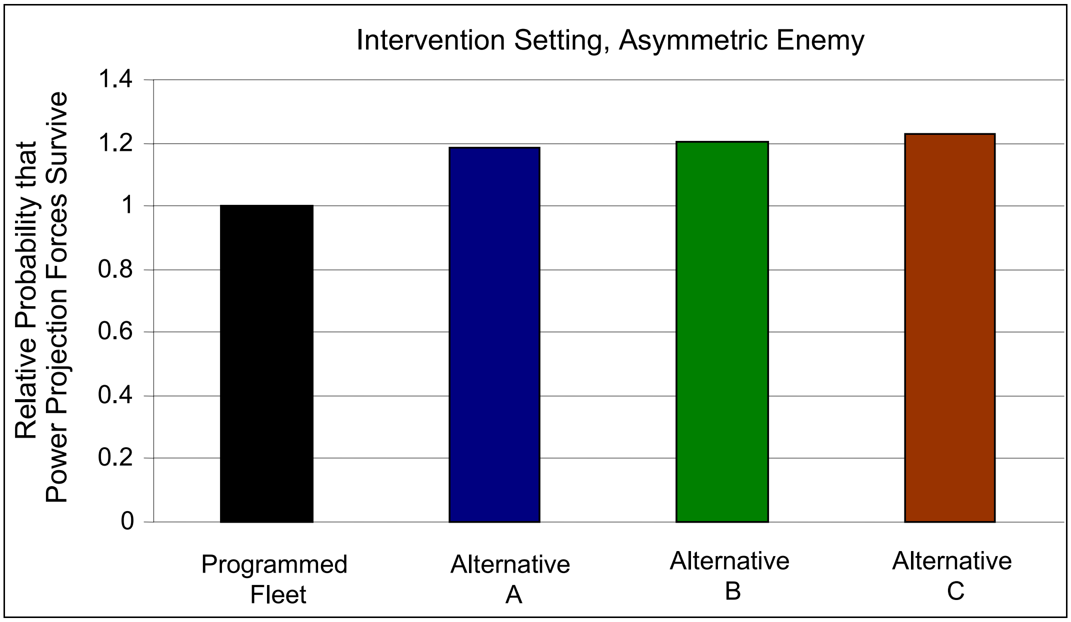

Figure 35. Comparing Programmed and Fleet Alternatives Ability to Control Operational Domain, Incorporating Technical and Relevancy Benefits of Networking

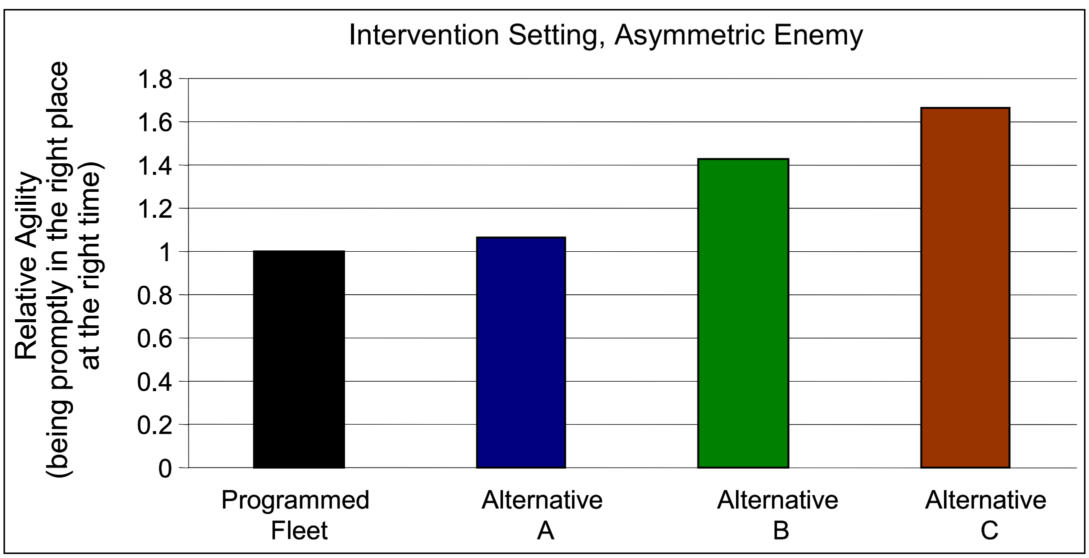

Figure 36. Comparing Programmed and Fleet Alternatives Ability to Promptly Bring Forces to Bear, Incorporating Technical and Relevancy Benefits of Networking

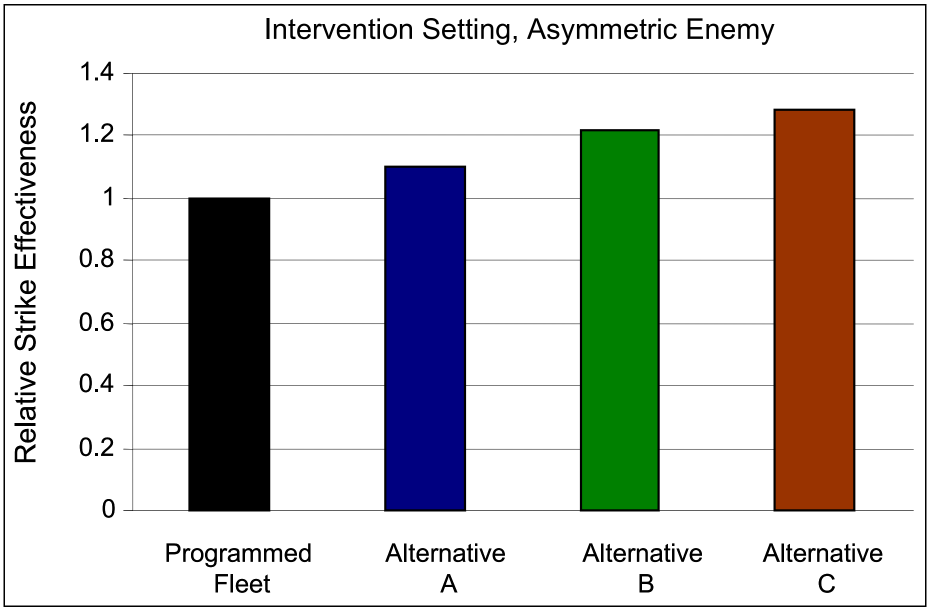

Figure 37. Comparing Programmed and Fleet Alternatives Ability to Fight from the Sea, Incorporating Technical and Relevancy Benefits of Networking

2. Intervention Policy/Symmetric Enemy

Let us now move on to the intervention case in which, much like in the Operation Desert Storm, the enemy behaves symmetrically. Under these circumstances, deception ceases to be an important consideration and networking helps all the fleets correspondingly less. Therefore, the ability of the programmed fleet to out-perform the smaller alternatives survives the introduction of networking.

a. Driving Capabilities

For the case of an intervention policy/symmetric enemy, the driving capabilities are control the operational domain, agility, and strike from the sea. Much like the analysis in the previous section, we envision this type of warfare to involve a relatively small operational area near the littorals. Since enemy position and speed are well known, increasing the number of ships does little to improve either agility or strike capability against a symmetric enemy. Controlling the operational domain is not influenced as much by his ability to deceive our tracking system as it is in the case of agility and strike from the sea. Therefore, for this case, let us assume that controlling the operational domain against a symmetric enemy is similar to controlling the operational domain against an asymmetric enemy within the intervention policy. One can argue that the initial density of anti-access forces for the two enemy behaviors is different, but it is unclear as to how different they truly are.

b. Comparison of Fleets

For this particular situation, where we are engaging a symmetric enemy, our analysis confirms the suspicion that networking aids little to improve the overall capabilities of the fleets. Stated differently, since enemy position and speed are well known, networking does little to improve our already accurate surveillance information on the enemy. Since the model for controlling the operational domain is not dependent on enemy behavior, we refer to Figures 29 and 32 to illustrate the comparison of the fleets for this capability. In comparing agility and the ability to strike from the sea, however, we find that the four fleets are approximately equally effective in these capabilities. Shown in Figures 38-39 we have compared the programmed fleet with its alternatives, incorporating only the technical benefits of networking. We find that the alternatives are roughly as capable as the programmed fleet, with little or no discernable difference among the four fleets. In the case of agility, the alternatives possess faster and more numerous ships, but the benefits this provides are overshadowed by the increase in surveillance information. Similarly for the case of strike from the sea, the effects of a larger number of ships for the alternatives does little in improving strike capability over the programmed fleet.

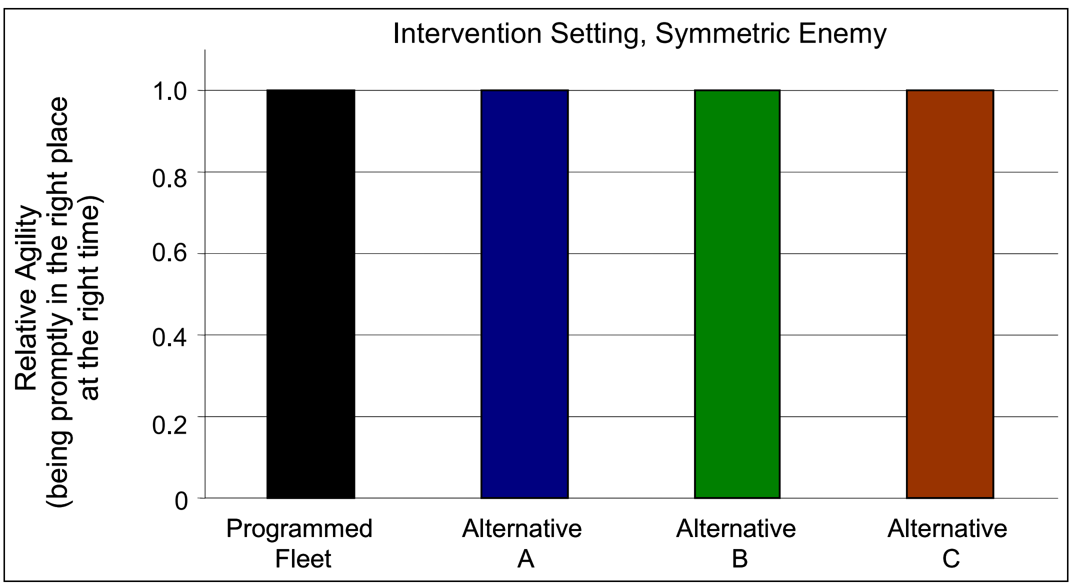

Figure 38. Comparing Programmed and Fleet Alternatives Ability to Promptly Bring Forces to Bear, Incorporating Technical Benefits of Networking

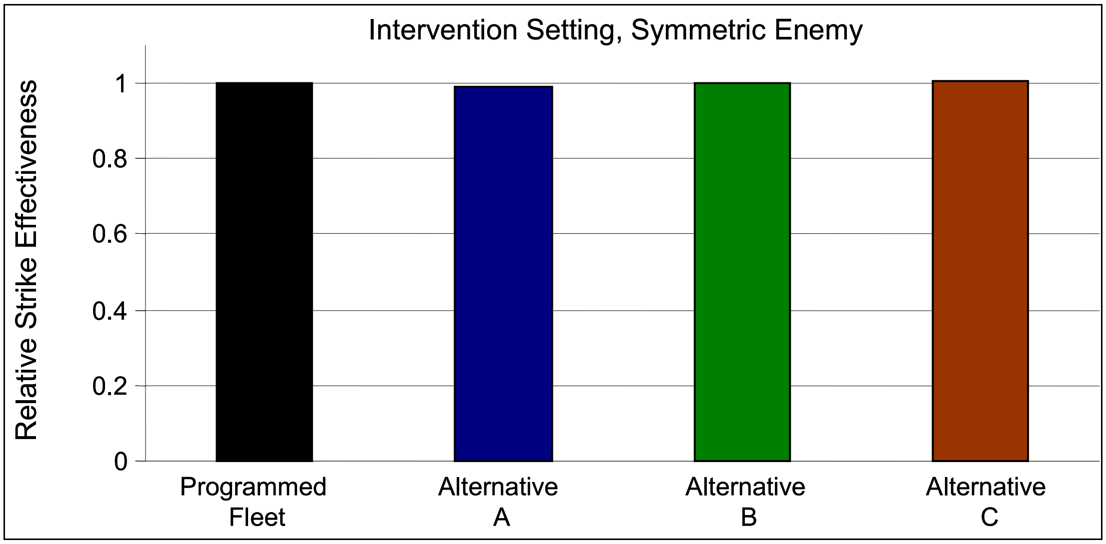

Figure 39. Comparing Programmed and Fleet Alternatives Ability to Fight from the Sea, Incorporating Technical Benefits of Networking

We next compared the four fleets as shown in Figures 40-41, incorporating the technical and relevancy benefits of networking. Even with the added relevancy benefits of networking, we again find that networking does little to enhance the relative ability to be in the right place at the right time or strike from the sea.

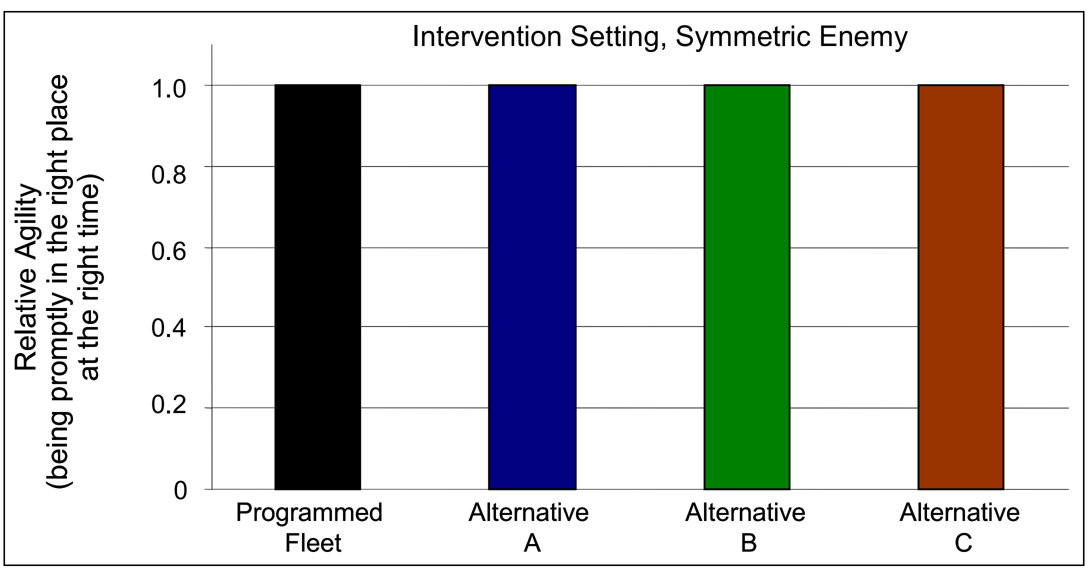

Figure 40. Comparing Programmed and Fleet Alternatives Ability to Promptly Bring Forces to Bear, Incorporating Technical and Relevancy Benefits of Networking

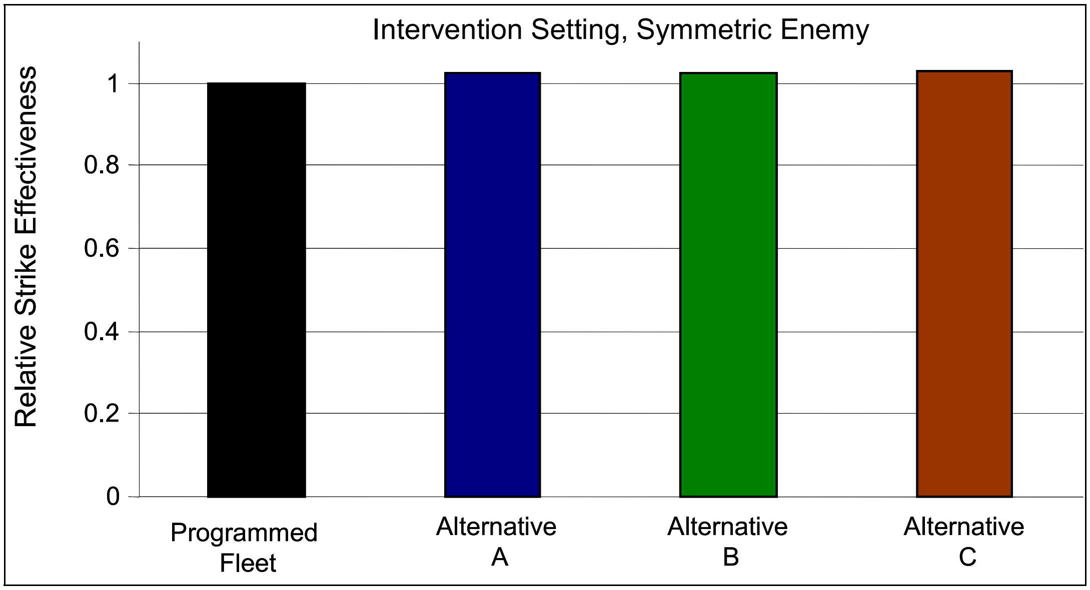

Figure 41. Comparing Programmed and Fleet Alternatives Ability to Fight from the Sea, Incorporating Technical and Relevancy Benefits of Networking

3. Strategic Advantage Policy/Symmetric Enemy

a. Driving Capabilities

Now we will examine the case in which a security policy seeks strategic advantage against a symmetric enemy determined to deny such advantage. The ability to operate in the commons despite an enemy threat is enhanced by the increased number of ships in the alternatives (whether or not they are networked). This offsets what the force would lose from the decreased survivability of a small platform under attack from a symmetric enemy. While large ships would probably survive an enemy hit, small ships such as those contained in the alternatives, would essentially be out of action when hit. The only way to maintain the advantages provided by any of the alternatives is to sufficiently reduce the enemy's ability to target, track, and then hit the small removal ships involved in sea control operations. Whether that can be accomplished in any of our alternatives is an unanswered question. Indeed, the only degrees of freedom are platform speed and the operational flexibility that would come from networking. If the enemy used submarines to deny free use of the commons, speed would not gain much survivability. The decrease in enemy search due to the reduced exposure time that characterizes a fast ship would be compensated by the increase in that ship's encounter rate with the enemy. Similarly, in a game as lonely as anti-submarine warfare, numbers are not likely to gain very much. If the enemy used surface or air launched missiles, on the other hand, numbers could help because networking might provide a large fleet of removal platforms with the capability to confuse the enemy's surface picture enough to make our alternative fleets harder to hit than the programmed fleet.

b. Comparison of Fleets

The capabilities of the programmed fleet and its alternatives to control the operational domain were compared in the case in which the United States is pursuing a policy of strategic advantage against a symmetric enemy. For this particular scenario, we looked at the density of anti-access forces as a function of time for the programmed fleet and its alternatives (the 2-week period is indicated by a gray line). Shown in Figure 42, we find that the density of enemy forces decreases with time, and Alternative C decreases more sharply compared to the other fleets. The considerable ability of Alternative C to remove enemy anti-access threats is mainly due to its greater number of removal units. However, the programmed fleet, with its greater removal ability and survivability (discussed next), shows a greater ability to remove enemy forces after a 2-week period compared with Alternatives A and B.

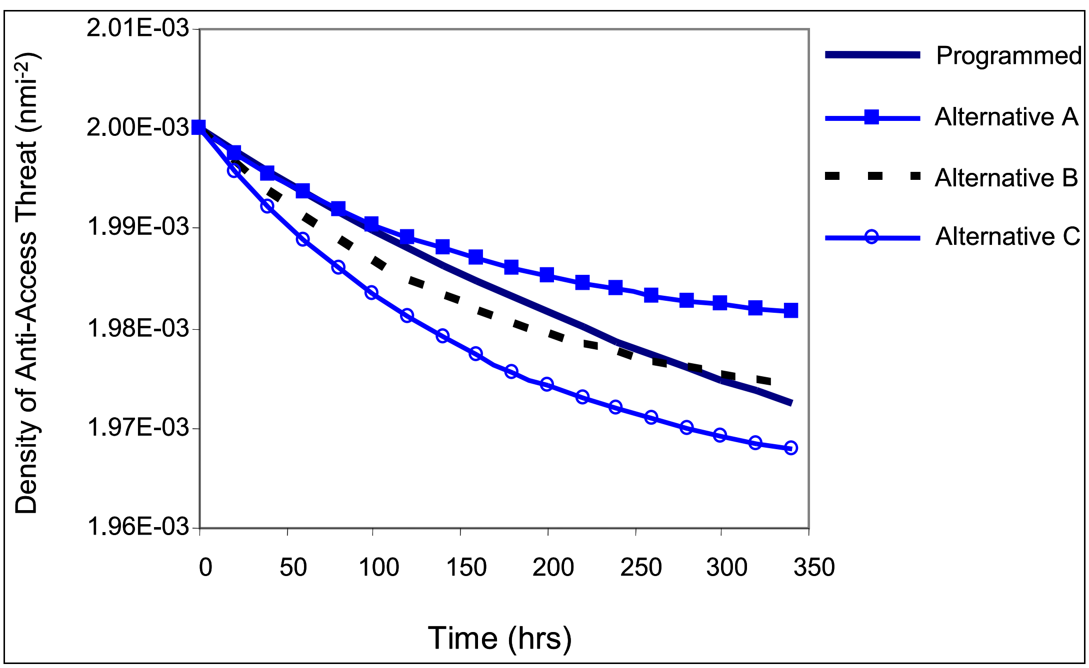

Figure 42. The Density of Anti-Access Threats as a Function of Time for the Programmed Fleet and Its Alternatives

The comparisons of the fleets, incorporating only the technical benefits of networking, are shown in Figure 43. The relevant parameters for this situation are given in Table 12. For this case, the programmed fleet is significantly better than Alternatives A and B because of its greater ability to survive when hit. Although ships in Alternative C may be less survivable than the programmed fleet, the fleet's advantage over the programmed fleet lies with its larger quantity of ships.

However, with the increased relevancy provided by networking, the fleet alternatives may turn out to better deny the enemy's ability to correctly read the battlefield, effectively making it harder for him to locate and track the small fast ships in the alternatives. As shown in Figure 44, we find that, similar to the intervention/asymmetric enemy scenario, these relevancy benefits greatly improve the alternatives compared to the programmed fleet.

Table 12. Control the Operational Domain Parameters for the Strategic Advantage Policy/Symmetric Enemy Incorporating Technical Benefits of Networking

Parentheses Indicate Values with Relevancy Benefits of Networking Incorporated

Parameter	Programmed CSG	Alternative A	Alternative B	Alternative C
Average velocity of removal platform *v* (kn)	35	53	54	57
Removal platform sweep width *w* (nmi)	0.1	0.025	0.025	0.025
Rate at which removal platforms are lost to anti-access threat λ (nmi^2/hr)	1	3 (1)	3 (1)	3 (1)
Density of removal forces β_0 (number/nmi^2)	0.000016	0.000048	0.000066	0.000078
Density of enemy anti-access threat ρ_0 (number/nmi^2)	0.002	0.002	0.002	0.002
Removal operation period (hr)	340	340	340	340

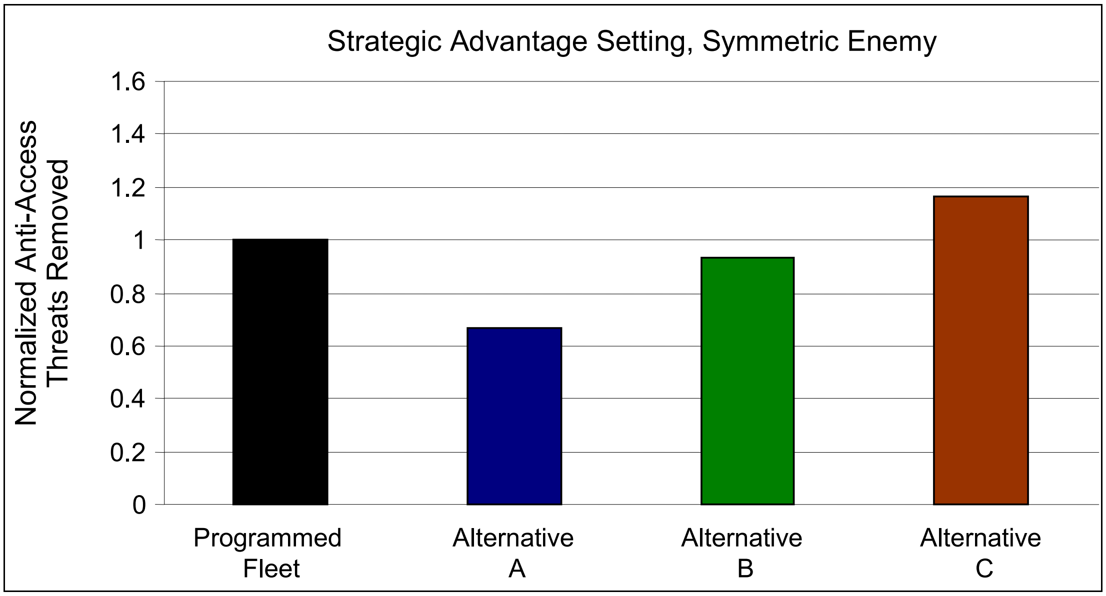

Figure 43. Comparing Programmed and Fleet Alternatives Ability to Control Operational Domain, Incorporating Technical Benefits of Networking

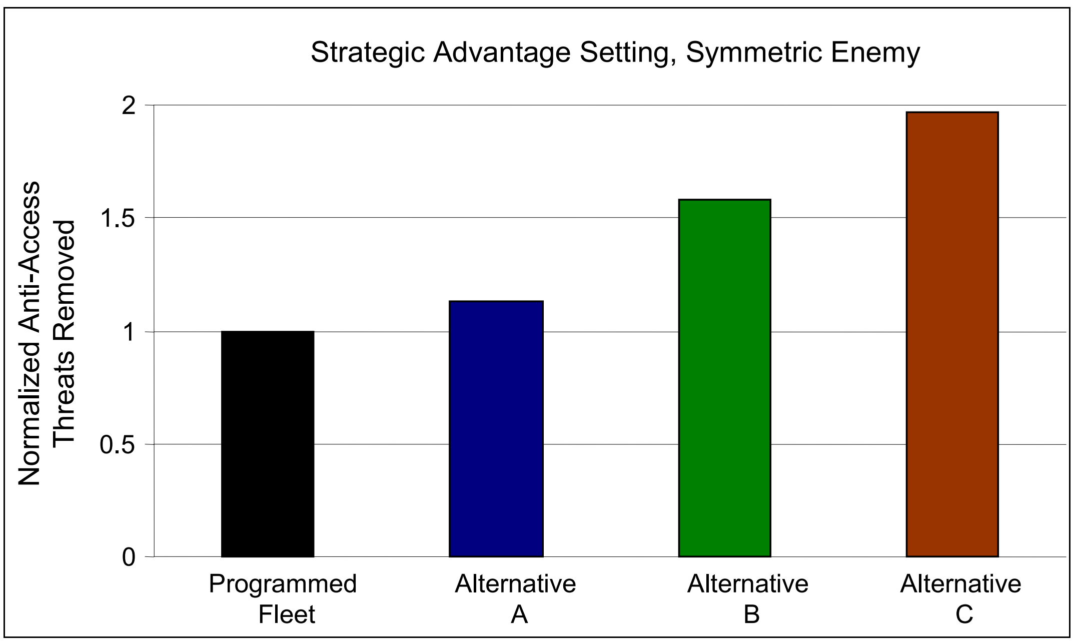

Figure 44. Comparing Programmed and Fleet Alternatives Ability to Control Operational Domain, Incorporating Technical and Relevancy Benefits of Networking

The analyses we have shown previously do not address the potential differences in survivability of the surface craft. The previous scenarios considered an enemy lacking the ability, due to technological immaturity and/or an insufficient number of units, to destroy a significant fraction of our forces. However, in the case of a symmetric enemy in a strategic advantage scenario (such as China developing into a superpower), survivability becomes a critical issue in comparing the fleets. Craft survivability is important to consider because the double hull designs of the alternative fleet ships do not have the same level of single-ship survivability as do the triple-hull designs of the programmed fleet. The speed and smaller size of the alternative fleets might make them harder to target than the larger programmed counterparts, but once hit they are likely to be less survivable. Does this consideration alter the images developed to this point?

Figure 45 compares the strike effectiveness of the programmed fleet and the alternatives in the intervention policy setting against an asymmetric enemy. Losses to the fleet are included this time, namely 50 ships lost. The approach does not model *how* these ships might be lost but is offered to show the consequences of losses. A fixed number of losses is usually associated with a fixed number of weapons or tracking systems. An example might include losses from mines or losses from a single barrage of a fixed number of ballistic missiles at the approaching fleet. Even with losses, the alternative fleets outperform the programmed fleet, even if it suffers no losses under these same circumstances because of greater individual ship survivability or greater defenses.

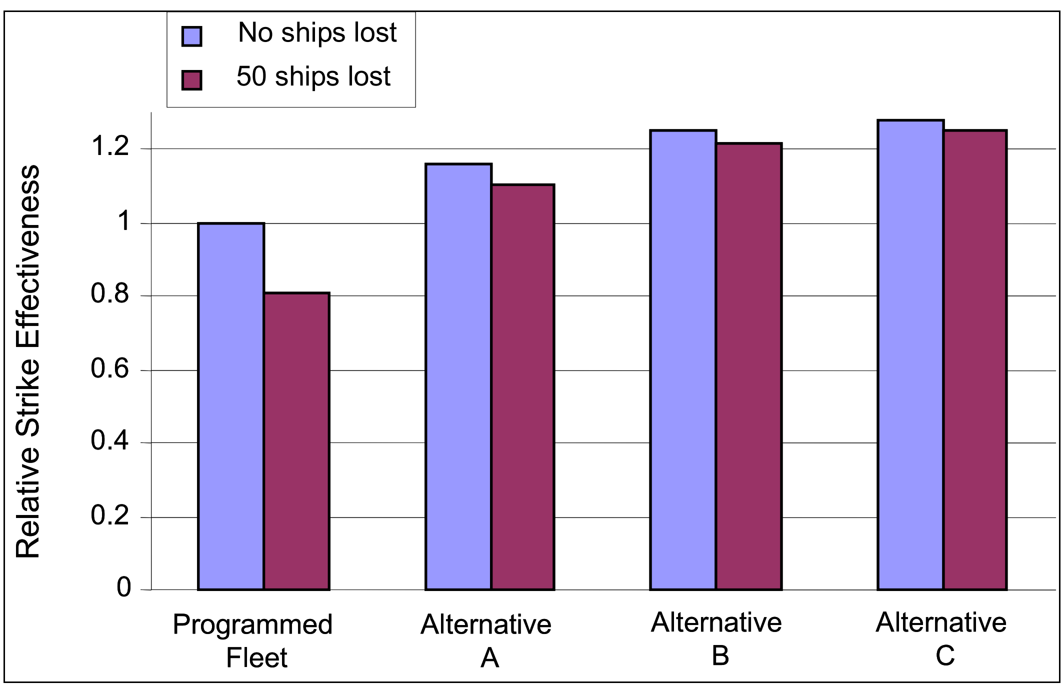

Figure 45. Comparing Programmed and Fleet Alternatives Ability to Fight From the Sea, Including Ship Losses in the Alternatives

Figure 46 shows the consequences to being able to promptly bring forces to bear if the fleet loses 50 ships from a 4 CSG formation sent to engage a symmetric enemy under strategic advantage circumstances. The figure compares all results to the case in which no programmed ships are lost. Note that all the alternatives continue to provide greater agility than the programmed fleet, even after suffering high losses. Alternative C, which has more ships to start, suffers the least percent of degradation.

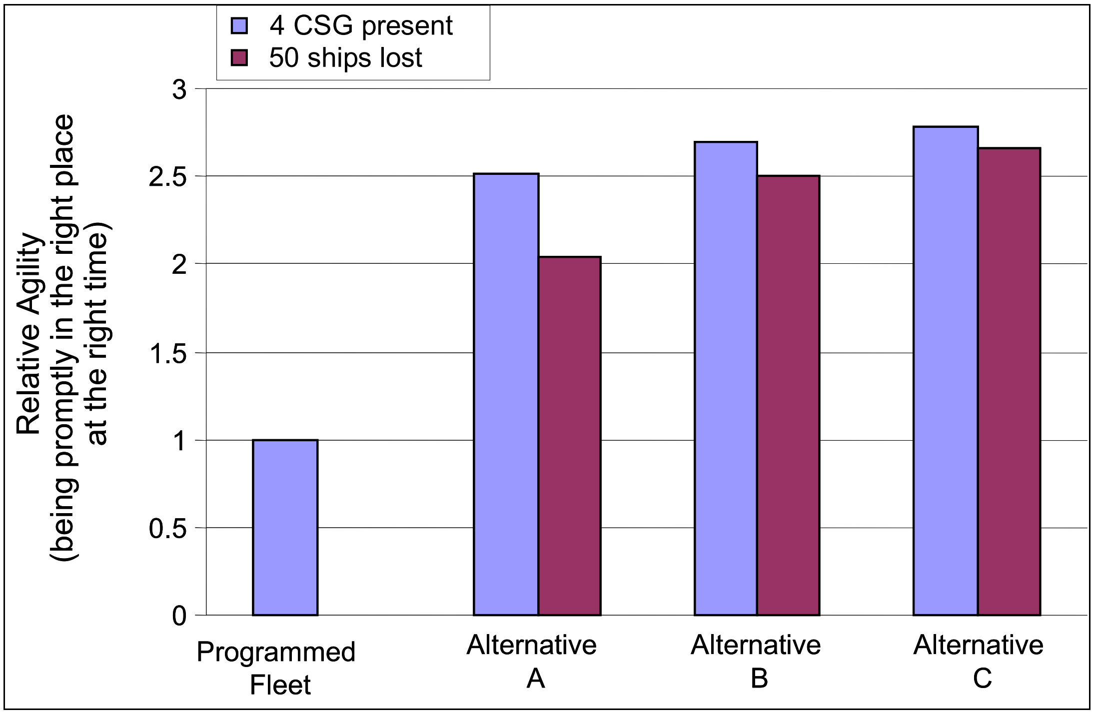

Figure 46. Comparing Programmed and Fleet Alternatives Ability to Promptly Bring Forces to Bear, Including Ship Losses in the Alternatives

4. Sustain Joint Forces and Homeland Defense

a. Sustain Joint Forces

For resupplying joint forces, all the alternatives are equal to each other but different from the programmed fleet. The basic difference is the use of MV-22s in the programmed fleet and the faster and larger heliplane transports in all the alternatives. To illustrate results, Table 13 summarizes assumptions made.

Table 13. Assumptions for Time Delays in Arranging Resupply (Δ*t*)

Parameter	Value (minutes)	
	Programmed Fleet	**Alternative fleets**
Situational awareness	2	1
Reporting time	4	2
Log processing time	10	5
Time to ready aircraft	30	25
Aircraft loading time	5	5
Aircraft unload time	2	2
total	53	40
Δ*τ*	13	

For a 300-mile resupply mission, the delay associated with distance is

$$L\frac{\Delta v}{v_{alt}v_{prog}} = \frac{450-250}{300(250)(450)} = 0.5\,hour = 30\min.$$

Finally, the time due to differences in dispersion is

$$z\Delta(\frac{\sigma}{v}) = 1.645 * 5\min = 8\min.$$

Thus the total time delay in the programmed fleet relative to the alternative fleets is

$$\Delta t = \Delta\tau + L\frac{\Delta v}{v_{alt}v_{prog}} + z\Delta(\frac{\sigma}{v}) = 51 \text{ min.}$$

This can be seen graphically in Figure 47. The total times are shown using the information in this illustration. In this case, 117 minutes is required for the programmed fleet vice 66 minutes for any of the alternative fleets.

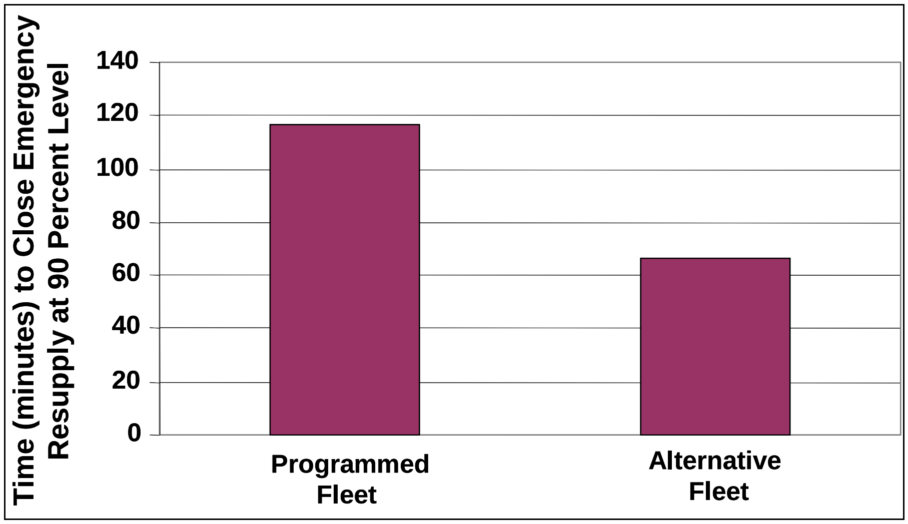

Figure 47. Comparison of Times Needed To Resupply Joint Forces Ashore

b. Homeland Defense

Interdiction at Sea. The results of the interdiction analyses are illustrated in Figure 48. In a case in which the programmed SSG would be able to interdict a 60-knot fast boat 15 percent of the time before it eluded its pursuers, the SSG of Alternative A would interdict 75 percent of the time, and Alternatives B and C would interdict every single time (100 percent).

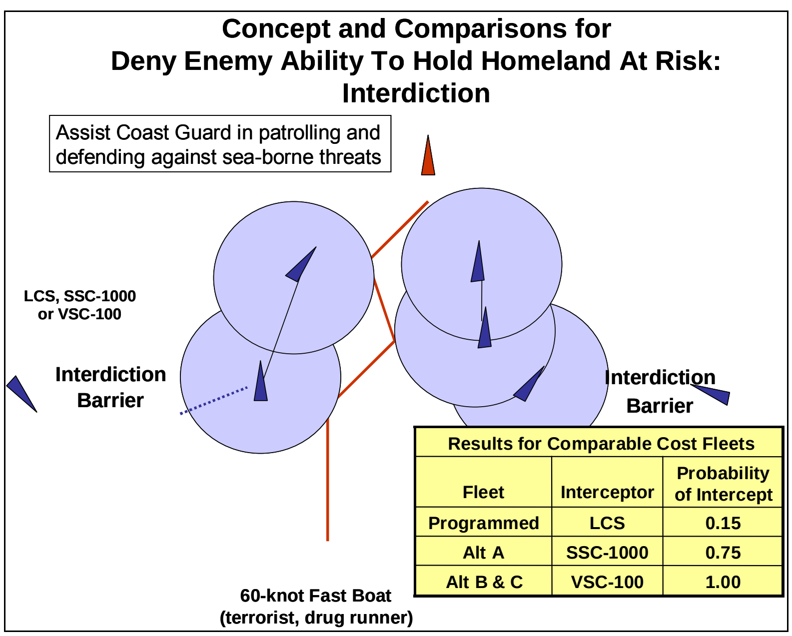

Figure 48. Interdiction Comparison

Ballistic Missile Defense. The ballistic missile analyses are qualitative but the advantage goes to the fleet with the greater number of TBMD platforms. Such a fleet provides a order barrier against TMs. This would favor the programmed fleet.

5. Excursions with Lesser Capability

Most of the analyses here have emphasized the results of layer numbers of ships, with a capability comparable to the programmed ones. On some contexts this can be true, but in others, not so. If range of weapons and surveillance sensor capabilities prove crucial, the results can be different. This sector explores such an excursion.

a. Firepower Considerations

We address the greater firepower capability of the programmed fleet, exploring both its greater weapon range and weapon lethal radius. Firepower is a significant parameter for two capabilities: promptly bring forces where needed and fight from the sea. Shown in Figure 49, we plot the probability of being at the right place at the right time as a function of the weapon range for the alternatives and programmed fleet. From the analysis, we observe that the larger the weapon range, the greater the ability to be at the right place at the right time to strike the enemy. This suggests that even if we are unable to precisely identify the enemy intercept location, a large weapon range compensates for this inaccuracy if still within range of the target. Shown in the figure, we consider that the alternatives, mainly composed of small ships, have a smaller weapon range than the programmed fleet, mainly composed of larger combatants. Since both the programmed and alternative fleets are composed of a varying proportion of small and large combatants, we do not define the exact weapon range of these systems but give some notional range of small and large combatant weapon range indicated by the gray area. From this analysis, the alternative fleets generally have a lower probability of being at the right place at the right time, even with its significant advantage in the number of ships.

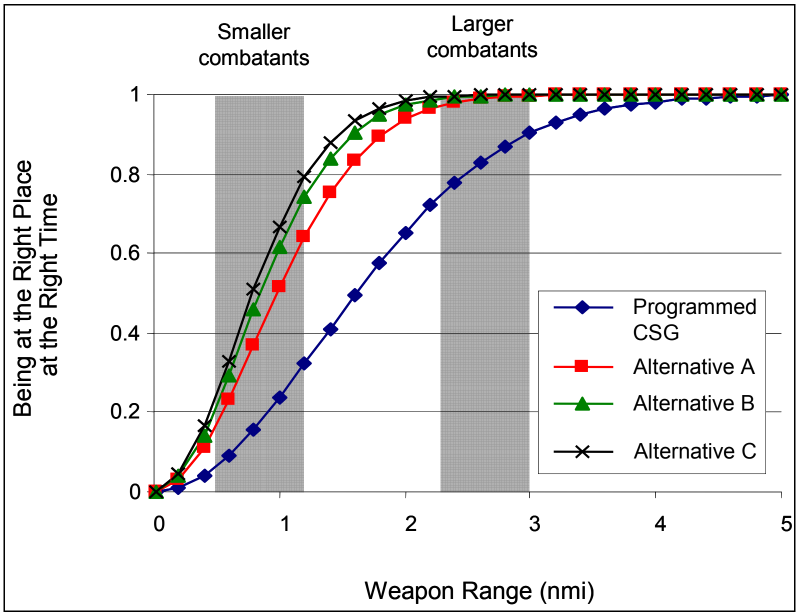

Figure 49. Firepower Comparison for Being at the Right Place at the Right Time

Next, we analyze the fraction of targets killed as a function of both the probability of killing a tracked target and the weapon lethal radius. Previously we defined the probability of killing a tracked target as the likelihood of destroying a target, under track, that is fired upon. The weapon lethal radius is defined as the effective radius upon which a weapon is detonated. As shown in Figure 50, we find that within the intervention/asymmetric scenario, the fraction of targets killed is enhanced by both aspects. Due to their enhanced firepower, both in tracking a target and weapon kill radius, the larger combatants have a significant lead in the fraction of targets killed compared to smaller combatants. However, as shown in Figure 51, against a symmetric enemy, we discover that increasing weapon lethal radius has little effect in improving the fraction of targets killed. For this type of enemy, his location is well established and, therefore, enlarging the effective kill area of the weapon does not significantly improve kill capability.

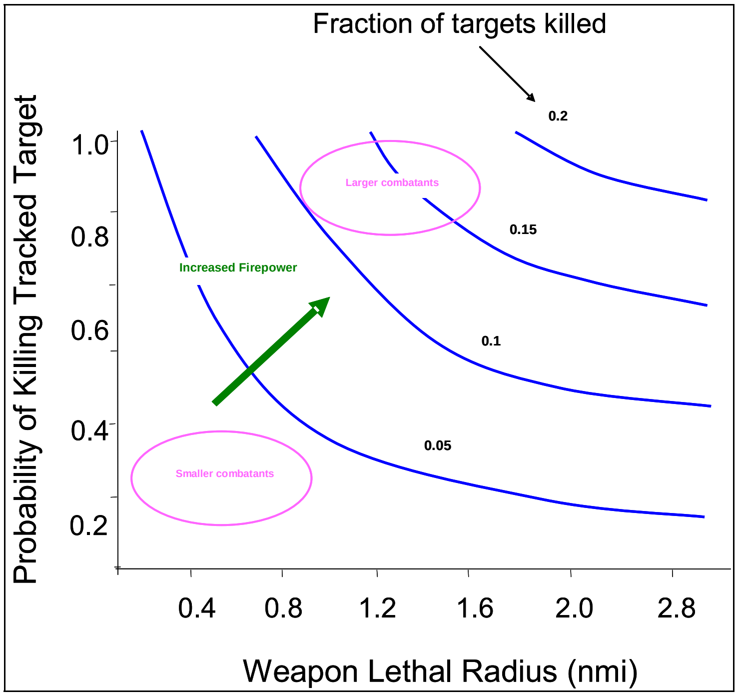

Figure 50. Constant Fight from the Sea Effectiveness Curves for Varying Probability of Killing Tracked Target and Weapon Lethal Radius in the Intervention/Asymmetric Setting

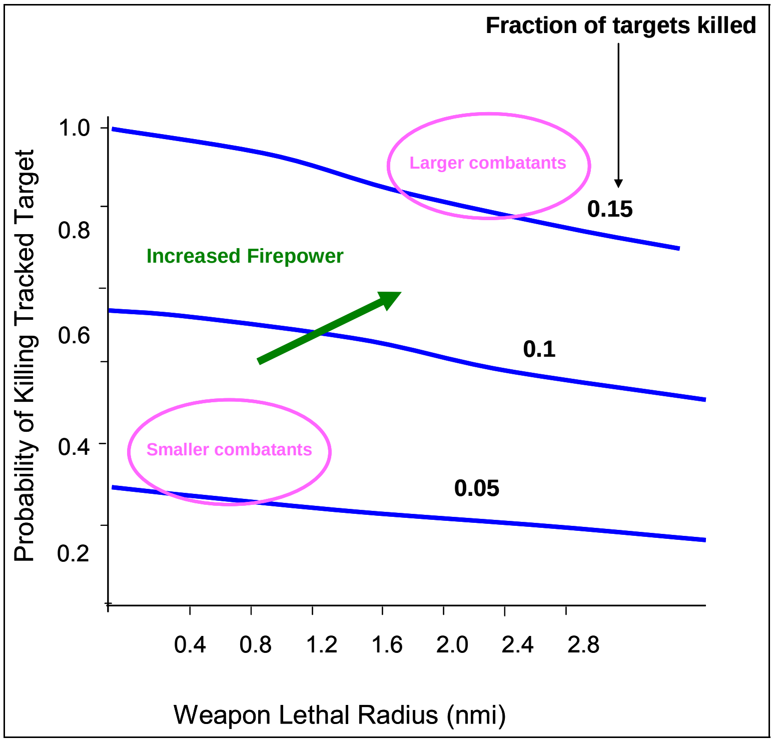

Figure 51. Constant Fight from the Sea Effectiveness Curves for Varying Probability of Killing Tracked Target and Weapon Lethal Radius in the Intervention/Symmetric Setting

b. Increased Defense

We consider the superior defense of large ships, composing the programmed fleet, in controlling the operational domain. Clearly, if the probability of kill given hit is low, we expect the operation to control the operational domain to succeed. As shown in Figure 52, we find that the large combatants composing the programmed fleet have an advantage in controlling the operational domain compared to the smaller combatants that make up the alternatives. The notional range of probability of kill given hit for large and small combatants is indicated by the gray area. Once hit, smaller combatants are virtually destroyed and are unable to complete the control operation.

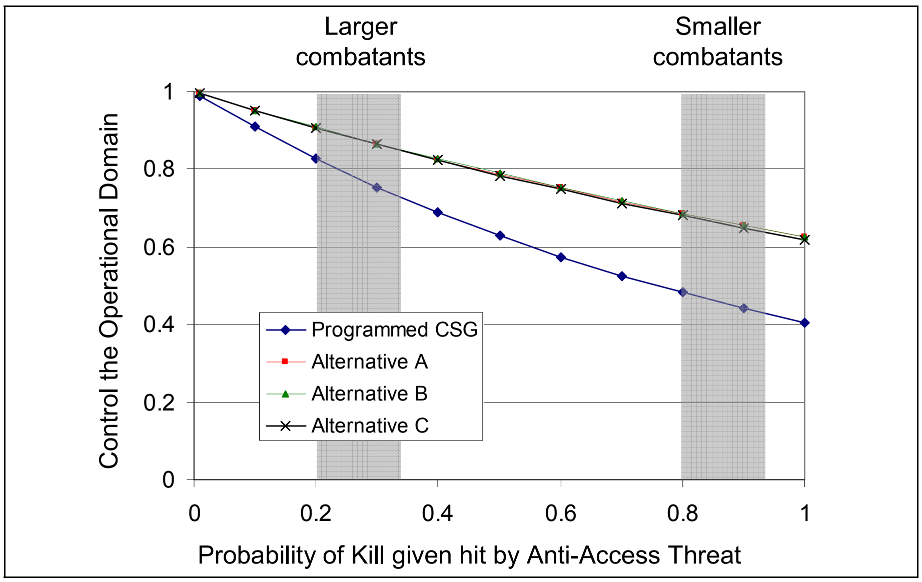

Figure 52. Control the Operational Domain Dependence on the Probability of Kill Given Hit

c. Non-Networked Naval Force

Our previous analyses explored the benefits of two types of networking: technical and relevancy benefits of networking. However, we cannot consider that networking will be fully exploited by the programmed and alternative fleets and, therefore, we must address the question: What happens if the fleets are not networked? As we have observed in our previous parametric analyses, networking significantly improves our ability to find and track enemy targets. More importantly, it reduces the enemy's ability to deceive. Shown in a previous section, Figure 53 presents constant agility curves for varying enemy deception and our surveillance quality. The variance in surveillance can diminish with technical benefits of networking whereas the variance in enemy deception decreases with the relevancy benefits of networking. By incorporating both networking benefits, a fleet significantly enhances its capability to be agile.

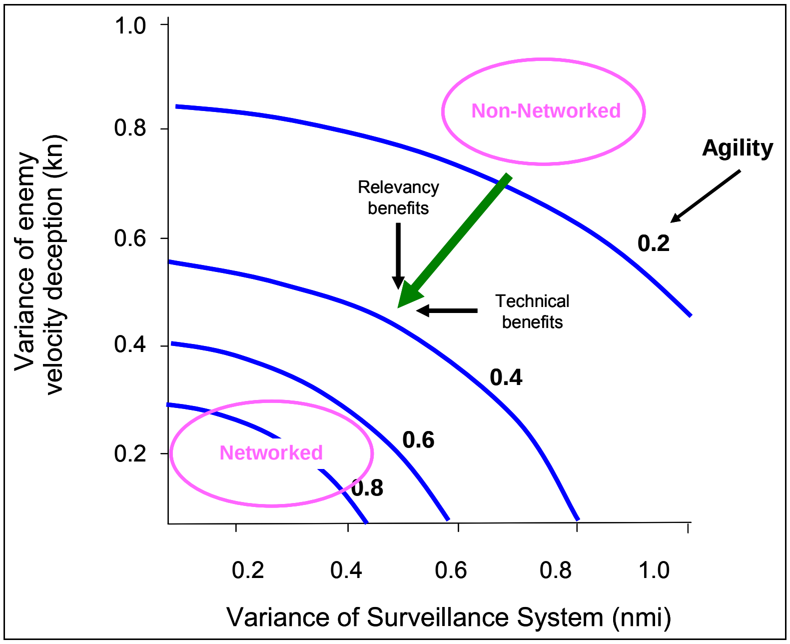

Figure 53. Constant Agility Curves for Varying Enemy Deception and Our Surveillance Quality

In a previous section, we plotted the fraction of targets killed as a function of the tracking and fleeing rates, which is shown in Figure 54. The tracking rate depends mainly on the quality of our surveillance system and could be improved by incorporating the technical benefits of networking. The enemy fleeing rate depends on the enemy's ability to break track and could be reduced by incorporating the relevancy benefits of networking. Although both benefits of networking improved the capability to fight from the sea, the relevancy benefits had a greater effect in increasing the fraction of targets killed.

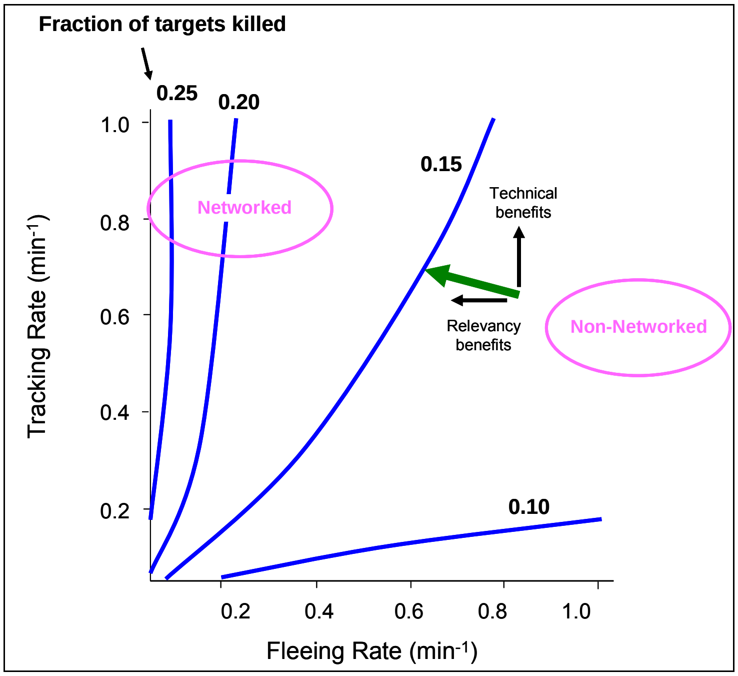

Figure 54. Constant Fight from the Sea Effectiveness Curves for Varying Enemy Fleeing and Tracking Rates

d. Results Without Networking

Although the surveillance capability of the networked fleet was considered inferior to the programmed fleet, the added benefits of networking overcame the diminished surveillance capability of each individual ship. However, if we do not consider these added benefits, we find that the alternatives are indeed inferior to the programmed fleet. For this next analysis, we assume the surveillance capability of the alternative fleets is 50 percent of the programmed fleet since the small combatants are less able to accommodate a sophisticated ISR system. Figures 55 and 56 present bar charts showing the capability to promptly bring forces where needed within the intervention/asymmetric and intervention/symmetric scenarios. The programmed fleet performs relatively better than the alternative fleets in both cases. Against the asymmetric enemy, it performs significantly better than the alternatives since the added increase in surveillance capability against this enemy helps considerably more than against a symmetric enemy. Figures 57 and 58 compare the capability to fight from the sea within the intervention/asymmetric and intervention/symmetric scenarios. Again, we find the programmed fleet performs significantly better than the alternatives against an asymmetric enemy.

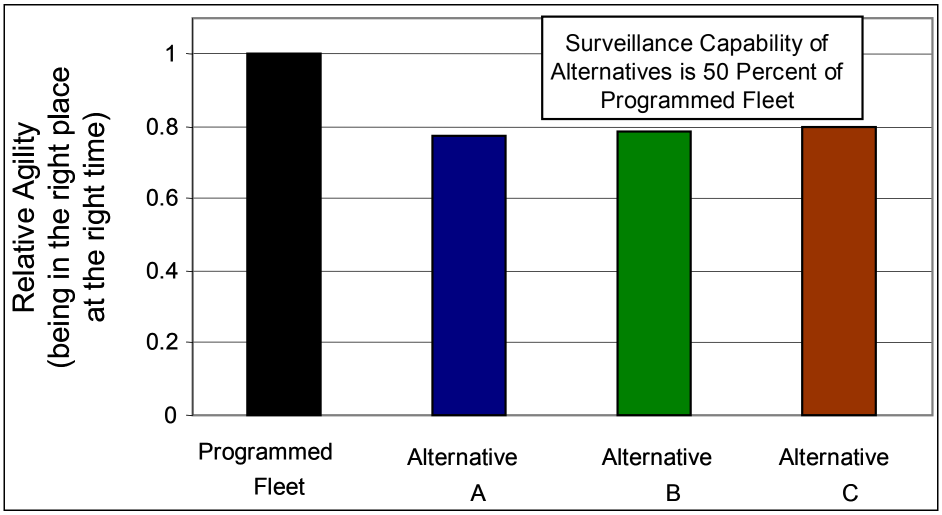

Figure 55. Comparing Programmed and Fleet Alternatives Ability to Promptly Bring Forces to Bear, No Networking, Asymmetric Enemy

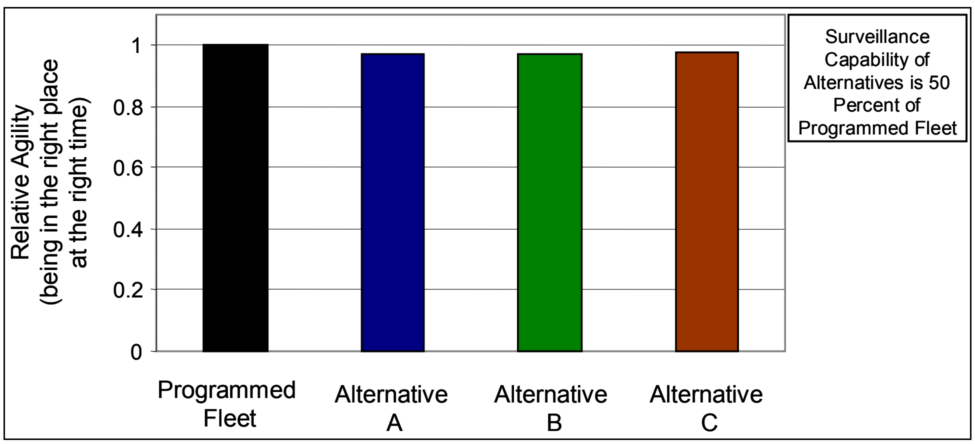

Figure 56. Comparing Programmed and Fleet Alternatives Ability to Promptly Bring Forces to Bear, No Networking, Symmetric Enemy

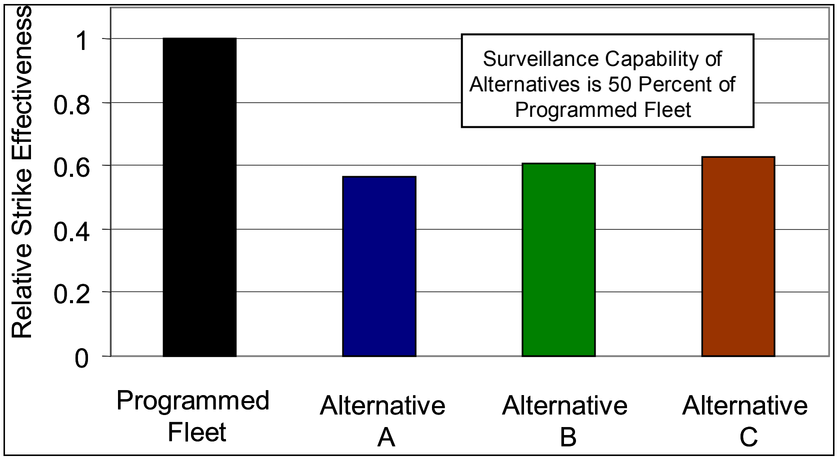

Figure 57. Comparing Programmed and Fleet Alternatives Ability to Fight from the Sea, No Networking, Asymmetric Enemy

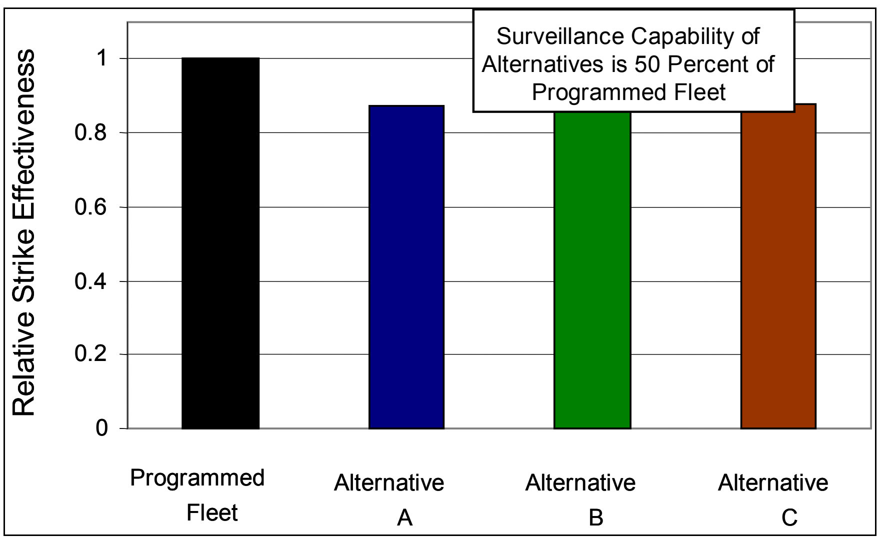

Figure 58. Comparing Programmed and Fleet Alternatives Ability to Fight from the Sea, No Networking, Symmetric Enemy

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V. COST ANALYSIS

This chapter describes how the costs for the alternative fleets developed in the previous chapter were estimated.

Cost Analysis

- **Construct alternative equal-cost fleets**
  - **Apply unit costs to fleet compositions**
  - **Select compositions to yield equal-cost alternatives**
  - **Analysis is limited to ships and aircraft assigned to major formations**
- **Take long-term view**
  - **All ships and aircraft are from new acquisition programs**
  - **Procurement plus 30-year O&S costs**
- **Alternative fleets**
  - **Programmed fleet**
    - **Current-design ships and aircraft (existing and programmed)**
  - **New alternatives**
    - **Replacement of some current-design by new-design ships**
- **Platforms formed into 12 CSGs, 12 ESGs, and 9 SSG/MDSAGs**

The purpose of this study is to determine the implications of future directions the Navy might take in major force construction. The analysis proceeds by constructing alternative equal-cost fleets and comparing their effectiveness. We calculated the costs of the alternatives by applying unit costs to the fleet compositions discussed in earlier chapters. This chapter describes how these unit costs were calculated. The fleet compositions were chosen to yield equal total costs. Analyzing all Naval forces was beyond the scope and purpose of the study. The analysis is limited to those ships and aircraft assigned to the formations (strike and actions groups) described below. Excluded are combat ships such as the SSBNs and SSGNs, the ships and aircraft of the CLF such as the cycling underway replenishment ships, sea- and land-based air (SH-3s and P-3s), and the entire training and support structure of the Navy.

The study takes a long-term view. All alternatives are composed of ships and aircraft produced by entirely new programs. Costs are the sum of procurement and 30-year O&S costs. The new ships and aircraft would transition into the force as existing ships and aircraft retire. There would thus be a future time at which the Navy would have replaced all its existing ships with those of the alternative fleets. The alternative fleets that would exist at this future time would have required the same total procurement costs, and operating the ships would have the same annual O&S costs. Development costs and salvage value are not included in the costing for reasons discussed later.

Although all systems are assumed to be procured from new programs, the “programmed” fleet is composed of ships and aircraft of "current design," i.e., designs whose basic hull construction is similar to that of existing or programmed platforms. The first unit costs of these current-design ships are based on the first unit costs of existing or programmed ships. The other alternative fleets are constructed by replacing some of the current-design ships and aircraft with those of new design. The costs of these ships are estimated from current analyses. For purposes of the effectiveness analysis discussed in other chapters, platforms in all alternatives are formed into 12 CSGs, 12 ESGs, and 9 SSGs or MDSAGs.

Succeeding charts will describe the major costing guidelines; the ship and aircraft platforms that compose the alternative fleets; how the unit procurement costs were estimated and the learning curves used to calculate total procurement costs; how the unit annual O&S costs were estimated; the costs of the module add-ons to the small combatants; the costs of the weapon, sensor, and UV add-ons to several of the X-ships; the final unit procurement and O&S costs; and a bar graph demonstrating that the alternative fleets are, in fact, approximately equal in cost.

Major Guidelines

- **Cost calculations**
  - **All procurement is from new programs**
  - **Include procurement and O&S costs**
  - **Development costs are small and not estimated**
  - **Salvage value is not estimated**
  - **Constant FY05 costs (no assumption of inflation, no discounting)**
- **Implications of equal-cost fleets**
  - **Cost streams are fairly constant over time, and equal**
  - **Alternatives involve current SCN and O&S budget levels**
  - **No detailed consideration of procurement and operating schedules**

Since all ships and aircraft are obtained from new programs, all are assumed to be produced at the top of their respective learning curves. The passage of time would degrade learning because of labor turnover in the shipyards. Moreover, it is likely that extensive modifications of major new weapons, sensors, and other engineering features would occur in new construction due to advances in technology and the threat.

Development costs are not included because they are a small part of total 30-year costs. Figures in the Future Years Defense Plan (FYDP) indicate that the Navy has spent an average of $3 billion annually on research, development, test, and evaluation (RDT&E) for ships and aircraft during the last 20 years, or 6 percent of the annual spending of $55 billion in all major appropriations on ship and aircraft programs (RDT&E, SCN, APN, and O&MN). (Ignoring development cost does, however, introduce a small error in the relative costs of the various fleets. New-design ships would likely require larger development costs than new versions of current-design ships in the programmed fleet.) Salvage costs are also not included, since ships approach retirement after 30 years of operations because their combat systems become obsolete, even if their maintenance costs remain steady. All costs are calculated in constant FY05 dollars, without consideration of either inflation or discounting, in order to focus on real resource use, rather than budgeting.

The fact that all the alternative fleets are constructed with the same *total* procurement and 30-year O&S costs has several implications for the *annual* cost streams. Since the Navy historically staggers its new ship procurement programs to avoid major peaks in the SCN (Shipbuilding and Conversion, Navy) budget (new ships are procured as old ones retire), equal total costs imply roughly constant and equal annual cost streams. Discounting the costs would, therefore, have no effect on the analysis; the costs would change, but remain equal across the alternatives.[1] Note that staggering the new procurement means that the O&S costs are staggered as well. In other words, the 30-year costing horizon does not have fixed start and end points. Ships procured in 2010 and 2015, for example, would retire in 2040 and 2045, respectively.

Second, since all alternatives have the same cost, and one of the alternatives is patterned after a segment of the current fleet (i.e., excluding the ships and aircraft mentioned earlier), the alternatives could be purchased with roughly current budget levels (SCN, APN, and O&MN). (The graph at the end of this chapter shows that the procurement and O&S costs of each alternative total approximately $740 billion over 30 years, or $25 billion annually, which is less than half of the average $52 billion the Navy has been spending annually for these costs over the last 20 years.) Finally, the assumption of smooth cost streams avoids the substantial complication of considering detailed procurement and operating schedules.

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1 Because discounting gives up-front development costs heavier weight, one might suppose that the alternatives with new-design ships and aircraft would have significantly higher present value. However, our development costs are not all "up-front." We are assuming that the new alternative fleets would replace the current fleet gradually, as the old ships and aircraft retire. Development costs would, therefore, be smoothed out over the 30-year period, just as operating costs are. So discounting would not change the relative costs of the alternatives. The alternatives with new-design ships and aircraft would, of course, cost more yearly, but since development (RDT&E) spending is historically only about 6 percent of total costs (see the text), even if the new ships and aircraft had 50 percent higher RDT&E costs, their total present-value costs would be only 3 percent higher (50 percent of 6 percent).

Ships and Aircraft

Current-Design Ships

- CVN-68
- DD(X)
- CG(X)
- LHD-1
- LPD-17
- LSD-49
- LCS
- AOE-6
- SSN-774

Current-Design Aircraft

- F-35 USN and USMC
- MV-22

New-Design Ships

Small Combatants

- VSC-100
- SSC-1000

X Ships

- X-WPS
- X-AVN
- X-CRS
- X-SPT
- T-AKX

UVs (on X-WPS, X-AVN, X-CRS)

- UAVs
- USVs
- UUVs

New-Design Aircraft

- Heliplane

The programmed fleet alternative consists of current-design ships and aircraft. The DD(X)s, CG(X)s and LCSs are included as current-design ships even though design work is still underway. The costs of those ships that carry aircraft (the CVN, CGX, SSC, LHD, and X-AVN) do not include the costs of the aircraft. These costs are listed on the chart separately. The new-design ships that replace some of the current-design ships in some of the alternatives are two small combatants (with modules) in addition to the LCS, five X ships, three types of UVs, and a new-design heliplane. The costs of the modules are included in the costs of the LCS, VSC, and SSC from which they would be operated, although the modules would be physically carried to action areas on the X-WPS and X-AVN ships. The costs of the UVs are included on the ships that carry them—a set on each X-WPS and X-AVN, and a set spread over four X-CRSs.

Estimating Procurement Costs

- **Methodology**
  - **Obtain first unit cost from recent sources**
  - **Apply learning curve and quantities to estimate cost of total buy**
- **Sources of first unit cost**
  - **Current-design ships (inc. submarine)** — **Proc. Annex, CBO, SAR**
  - **New-design ships**
    - **Small combatants** — **IDA study**
    - **X ships**
      - **Basic ship** — **CNA study**
      - **Weapons, launchers, radars, TRLs** — **CG(X) and DD(X)**
      - **UVs** — **IDA study**
- **Aircraft** — **JSF and V-22 SARs**

Total procurement costs of the ships and aircraft are calculated in several steps: obtaining first unit costs for the various platforms, applying cost improvement (learning) curves to obtain average costs (see next chart), and multiplying the average costs by the quantities of ships and aircraft bought (shown in an earlier chapter). The formulation of the learning curve used in the calculations is Average Cost = T1 x $Q^{\log(S,2)}$, where T1 is the first unit cost, Q is the quantity bought, S is the slope of the cost improvement (learning) curve, and log(S,2) is the logarithm of S to the base 2. (Cost improvement (learning) curves can also be used to generate marginal, as well as average costs.) For example, suppose the first unit cost is \$2 billion, the quantity is 20 ships, and the slope of the cost improvement (learning) curve is 90 percent. The average cost would be \$2B x $20^{\log(0.90,2)}$ = \$1.27B, and the total cost would be 20 x \$1.27B = \$25.4B. Logarithms to the base 2 have the convenient feature that doubling the buy multiplies the average cost by the slope. If the buy in the previous example were increased to 40 ships, average cost would be reduced to 90 percent of \$1.27B = \$1.14B.

The first unit procurement costs for most of the current-design ships (CVN-68, DD(X), LHD-1, LPD-17, LSD-49, AOE-6) were obtained from unclassified figures from the most recent Procurement Annex. Estimates for the CG(X) were obtained from a recent CBO study.[2] The costs for the SSN-774 were obtained from the Selected Acquisition Report (SAR) for this ship. (The SARs generally list average procurement unit costs, or APUCs. These average costs were backed up to first unit procurement costs using cost improvement (learning) curves, and the results escalated to FY05 dollars.) The figures for the small combatants and the modules they carry were obtained from the past IDA study of the littoral combat ship.[3] Costs of the X ships were calculated from three sources. The costs of the basic ships were obtained from a recent CNA study.[4] (The X-CRS was assumed to be one-fourth the size of the other X ships.) The costs of the weapons, radars, and TRLs stationed on the X-WPS were calculated using assumed percentages of procurement costs of the DD(X) and CG(X). The costs of the UVs stationed on the X-WPS, X-AVN, and X-CRS were obtained from the recent IDA T-AGOS 60 study.[5] UVs are given 15-year lifetimes and are bought twice in the 30-year costing horizon.

The first unit procurement costs and unit annual O&S costs of the F-35 (different figures for the Navy and Marine versions), were obtained from an extensive IDA analysis and the JSF SAR for December 31, 2003, unclassified. The costs of the MV-22 were obtained from the V-22 SAR of June 30, 2004, unclassified. The costs of the heliplane were estimated by the present study. This is a VTOL aircraft now being built by Carter Aviation for commercial application, with possibilities for a military version in the future. The costs are estimated by extrapolation from the costs of the V-22. The heliplane's speed is 40 percent higher (350 knots for the heliplane vice 250 knots for the MV-22) and its cargo capacity is 150 percent higher (25 tons for the heliplane vice 10 tons for the MN-22). The first unit cost of the heliplane was estimated at a middle position by setting it 100 percent higher than the costs of the MV-22 obtained from the V-22 SAR (i.e., doubling the unit cost of the MV-22).

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2 *Transforming the Navy's Surface Combatant Force,* CBO Report, March 2003, Appendix.

3 *Small Combatants: Implications for the Effectiveness and Cost of Navy Surface Forces (UJTL),* IDA Paper P-3716, September 2002, Secret.

4 *MPF(F) Analysis of Alternatives: Final Summary Report,* CNA Report CNR D0009814.A2/Final, April 2004, Unclassified.

5 *Assessment of the Environmental Battlespace Characterization Capabilities of the Navy's T-AGS 60 Class Ships,* IDA Paper P-3785, July 2003, Unclassified.

Learning Curve Applied to First Unit Procurement Cost

- **Ships (current and new design)**
  - **91 percent for first 400 units**
- **Aircraft**
  - **85 percent for first 400 units**
- **Small combatants**
  - **95 percent for first 100 units**

As mentioned earlier, since all platforms are from new programs, learning curves were applied to first unit costs starting at the top of the cost improvement (learning) curve. The cost improvement (learning) curve slopes for the major ships and aircraft are patterned after those for some historical procurement programs. (The lower slope for aircraft compared with ships means a faster fall-off of average cost with quantity; doubling the buy multiplies the average cost by 85 percent, rather than 91 percent.) Learning was limited to a given number of units to avoid the approach of average cost to zero as quantity increases without limit. (Since S is less than unity, log(S,2) is negative, and average cost $Q^{\log(S,2)}$ approaches zero as Q increases.) A limiting quantity of 400 is often used for large aircraft programs, and selected for ships as well. The total cost for 600 aircraft would, therefore, be 600 multiplied by the average cost of the first 400 aircraft: $600 \times T1 \times 400^{\log(0.85,2)}$. Because the small combatants are less complex than the major ships and aircraft, their production affords fewer possibilities for learning, so they are given a larger slope and a smaller cut-off.

The above procedure is modified for the X ships. Four of them—all except for the X-CRS—are assumed to have exactly the same HME (hull, mechanical, and electrical) and other basic shipboard equipment. Learning from the production of one of these ships can therefore be applied to the others, and a single cost improvement (learning) curve was used to capture the cost savings. For example, the number of X-WPS ships in one of the new-design alternatives was multiplied by the average cost calculated for the total number of the four ship types. The same treatment was not used for the Navy and Marine Corps versions of the F-35 aircraft, however. Separate cost improvement (learning) curves were used because of major differences between the two versions.

Although the cost improvement (learning) curve was applied to the cost of the new CVNs program, as well as to the cost of the other ships, an alternative assumption would have been to assume no learning. Carriers are procured in single units spaced several years apart, which allows the possibility of extensive changes in response to advances in technology and threat. In fact, the carriers of the CVN-68 *Nimitz* class funded in 1995, 2001, and 2007 cost $5.0, $5.3, and $5.6 billion in constant FY05 dollars, respectively. Using a constant $5.3 billion (the cost of the 2001 CVN in FY05 dollars) instead of a cost improvement (learning) curve for successive CVNs would have increased the cost of the programmed fleet (the only fleet in which the CVNs occur) by about $18 billion, or only 2.4 percent of the total cost of approximately $740 billion (shown later). The four fleets would still be approximately equal in cost.

Estimating O&S Costs

- **Sources of unit annual O&S cost**
  - **Existing ships—use VAMOSC**
  - **Remaining ships**
    - **Develop CER by relating VAMOSC O&S costs to ship complement**
    - **Apply to complement of new ships from NVR and IDA study**
  - **UVs on the small combatants**
    - **IDA T-AGS 60 study**
  - **Aircraft**
    - **IDA analysis and SARs**

O&S costs for most of the current-design ships that are existing are obtained directly from the September, 2004 version of the VAMOSC-Ships database (Visibility and Management of Operating and Support Costs-Ships). O&S cost for the *Virginia*-class submarine (SSN-774), which is not yet included in VAMOSC, was set equal to the VAMOSC cost for the *Sea Wolf* (SSN-21) on grounds that the complement (total manning) is virtually the same. The O&S costs for the remaining ships—the DD(X), CG(X), LPD-17, and the small combatants and X ships (basic ship)—were estimated by applying a Cost Estimating Relationship (CER) based on the complement and derived from historical data for 14 ship classes. The CER was derived by regressing average O&S cost from VAMOSC on total complement of the ships given in the Naval Vessel Register of October 7, 2004. The CER is Unit Annual O&S cost = 0.255 x $(\text{complement})^{0.827}$. The CER has extremely favorable statistical features: it explains 95 percent of the variability in O&S costs, and the coefficient of complement has an extremely high statistical significance of better than one percent. (These two statistics are closely related, since there is only one independent variable.[6])

6 The small combatants are outside the range of the 14 ships used to develop the CER. However, the CER predicts pretty well for the PC-1 patrol boat, the smallest ship used to estimate the CER. The CER predicts an annual O&S cost of $4.0 million, only 10 percent higher than the $3.6 million listed in VAMOSC. The PC-1 has a complement of 28, compared to 3 and 22 for the VSC-100 and SCC-100, the small combatants that were included in the alternative fleets.

The resulting equation was applied to the complements of the remaining ships obtained from a variety of sources: the Naval Ship Register, the Naval Ships Systems Command concept study for the small combatants, and an IDA estimate for the X ships. The latter ships are assumed to be manned by civilians plus a Navy crew for the combat systems. These complement levels were not reduced in anticipation of Smart Ship savings. The Smart Ship program uses automated bridge, engine room, and damage control systems, plus other initiatives, to reduce shipboard manning and maintenance costs. Trials of the concept aboard the *Yorktown* (CG-48) led to anticipated savings of 15 percent in maintenance workload, $1.75 million annually in shipboard manpower, and $2.76 million in life cycle costs, including shore manpower reductions and shipboard repair savings. If the Navy were to achieve these savings in all future ship procurements, future O&S costs would be less than those estimated by the complement-based CER. The reductions would likely be in proportion to size, however, so that the alternative fleets would remain equal in cost.

The unit O&S costs for the modules stationed on the small combatants were covered by choosing enough manning for the ships to operate the modules. Manning would constitute most of the support for the modules.) O&S costs of the UVs stationed on the X ships UV costs were taken from a past IDA study:[7]

The O&S costs of the F-35 (Navy and Marine versions) were obtained from an extensive IDA analysis and the JSF SAR, December 31, 2003, unclassified. The costs of the MV-22 were set equal to those of the V-22 from the SAR of June 30, 2004, unclassified. The costs of the heliplane were set at twice the cost of the V-22 for the reasons stated in the previous section on procurement costs.

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[7] *Assessment of the Environmental Battlespace Characterization Capabilities of the Navy's T-AGS 60 Class Ships,* IDA Paper P-3785, July 2003, Unclassified.

Cost of Module Add-Ons to Small Combatants (SSCs)

Ship	First Unit Procurement Cost			
	Number Bought per SSC	Combat Tons per Module (Tons)	Procurement Cost per Combat Ton ($ M)	Total ($ M)
VSC-100	6	23	0.75	104
SSC-1000	4	48	0.75	144
LCS	3	48	0.75	108

The small combatants operate modules of combat equipment. The first unit procurement cost of the modules were obtained by multiplying their number by the number of combat tons in each and a standard cost per combat ton ($0.60 million from the earlier LCS study escalated to FY05 dollars). These costs were added to the first unit cost of the basic ship, shown later. As mentioned earlier, O&S costs for the modules was assumed to be covered by choosing large enough complements of the small combatants to operate the modules.

Cost of Add-Ons to X-WPS, X-AVN, and X-CRS

System	First Unit Procurement Cost					Unit Annual O&S ($ M)
	Unit Cost ($ M)	Number per UV Set	Fixed Cost per Ship ($ M)	Expected Lifetime (Years)	Total Cost per Ship ($ M)	
Wpns, launchers, radar: X-WPS	4,940			30	4,940	
TRLs for fire support: X-WPS	1,090			30	1,090	
UV set for X-AVN, X-WPS, 4 X-CRS						
UAV (Fire Scout)	5.1	3	0.6	15	32	0.52
USV (Spartan Scout)	3.6	3		15	21	1.07
AUV/UUV Small (REMUS)	0.7	12		15	18	0.67
AUV/UUV Medium (BPAUV)	4.2	4		15	33	0.65
AUV/UUV Large (Sea Horse)	4.3	2		15	17	0.73
Total for UVs					122	3.6

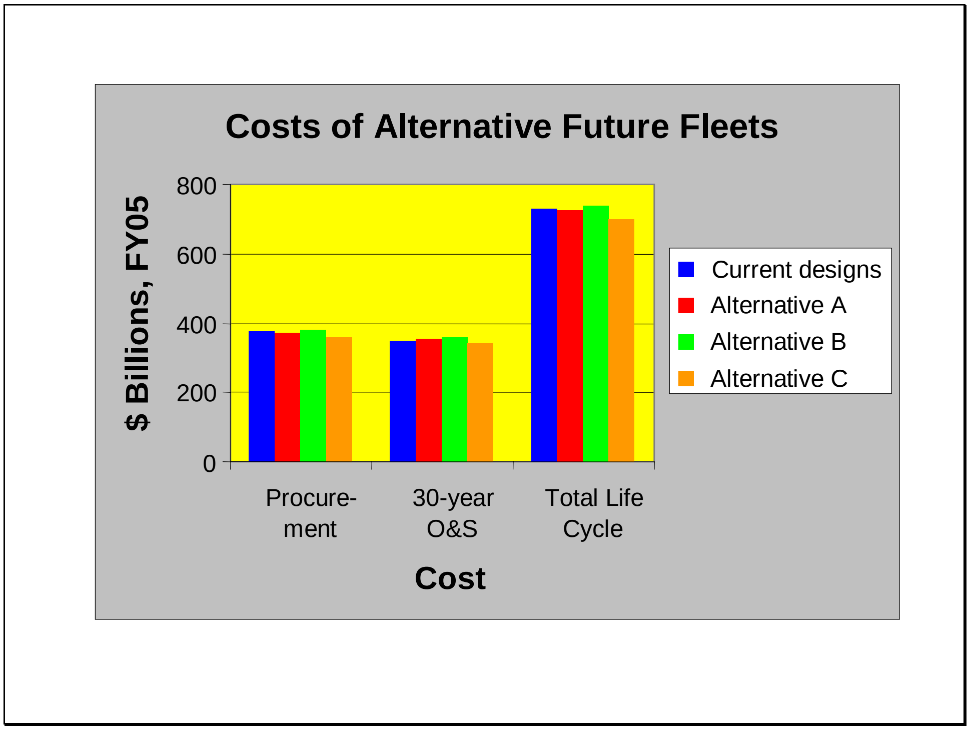
The first unit cost of the X ships was obtained by increasing the cost of the basic ship by the cost of the systems shown here. (The total costs, including those of the basic ships, are shown later.) The costs of the weapons, launchers, and radars installed on the X-WPS alone were estimated at 150 percent of the cost of one CG(X). The costs of TRLs, also installed on the X-WPS alone, were estimated at 60 percent of the cost of one DD(X). A set of 24 UVs was stationed on each X-WPS and X-AVN, and distributed over four X-CRSs. (The X-CRS is assumed to be much smaller than the other X ships, about one-fourth the size.) The first unit procurement costs of the UVs were calculated by multiplying the number per ship by the unit variable cost, adding a cost for modular payloads (estimated as the cost of the UV platform), adding a fixed cost for a maintenance van, and doubling the result to account for the assumed 15-year lifetime of the UVs. The $300,000 for a maintenance van assumed by the T-AGS 60 study for a single type of UV was doubled because of the large number of UVs assumed in the present study. The variable and fixed procurement costs, and the O&S cost, were taken from the previous study and updated to FY05 dollars.

Summary of Unit Costs
($M, FY05)

Craft	Procurement Cost: First Unit	Procurement Cost: Average for Programmed or Alt. Fleets	Unit Annual O&S Cost
Current Designs			
CVN-68	5,300	3,800	340
CG(X)	3,300	1,800	34
DD(X)	1,800	1,300	30
LHD-1	2,100	1,500	120
LPD-17	1,090	780	36
LSD-49	380	270	36
AOE-6	890	630	50
SSN-774	3,200	2,400	20
Small Combatants			
VSC-100	120	90	0.6
SSC-1000	340	150	3.3
LCS	690	400	6.5

Craft	Procurement Cost: First Unit	Procurement Cost: Average for Programmed or Alt. Fleets	Unit Annual O&S Cost
X Ships			
X-WPS	7,900	4,400	65
X-AVN	2,000	1,000	110
X-CRS	470	250	20
X-SPT	1,800	970	48
T-AKX	1,800	970	47
Aircraft			
F-35 USN	320	80	3.6
F-35 USMC	270	100	3.6
MV-22	320	80	4.3
heliplane	640	500	8.6

This chart summarizes the first unit procurement and unit annual O&S costs of all the platforms. As described earlier, the first unit costs were used, along with the number of platforms and learning curve assumptions, to generate total costs of the alternative fleets. The unit annual O&S costs were multiplied by the number of platforms and the 30 years of the horizon. The costs shown here include the modules for the small combatants and the UVs and other combat systems for the X ships. The first unit procurement costs are substantially higher than the figures often quoted elsewhere. For example, the SARs quote APUC for the number of systems currently programmed or planned. For that reason, the above tables also include the more familiar average procurement costs for the number of systems bought in the programmed fleet or in one or more of the alternative fleets.



The cost calculations derived in this chapter lead to approximately the same total procurement and total 30-year O&S costs. (The total life cycle costs are, therefore, approximately equal, as well.) As mentioned earlier, the fact that the fleets all have approximately the same cost is not accidental, since the ship platforms in the various alternatives were adjusted to achieve equal cost.

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VI. UNMANNED VEHICLES

In this chapter, we provide a set of UVs that are included in the alternative fleets. The information on them is taken from a previous IDA study.[1]

Outline

- **UV Set for Large Ships**
- **Unmanned Air Vehicles (UAVs)**
- **Unmanned Surface Vehicles (USVs)**
- **Unmanned Undersea Vehicles (UUVs) or Autonomous Undersea Vehicles (AUVs)**

In this chapter, we discuss unmanned vehicles UVs and develop a family of them for use on the large ships in the alternative fleets.

UAVs offer potential to dramatically extend the sensor reach of the surface combatants or submarines. The study identifies several candidate vehicles and UAV sensors.

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1 *Assessment of the Environmental Battlespace, Characterization Capabilities of the Navy's T-AGS 60, Class Ships*, IDA Paper P-3785, July 2003, Unclassified.

USVs can also extend the sensor reach of ships and submarines. A second consideration is the potential use of USVs for the deployment and recovery of small-to-mid-sized AUVs, which are otherwise limited in operating range. Surface combatants are easily capable of hosting one or more USVs, and this technology is considered very applicable as a means of providing the ships with enhanced capability.

UUVs or AUVs, like other unmanned vehicles, would extend the sensor reach of ships and submarines. Added benefits of employing AUVs are that they can be employed for covert sensing in denied areas, and they enable access to subsurface and ocean floor observations from remote locations. A wide range of AUVs could be employed, and several candidate vehicles are identified.

UV Set for Large Ships

- UAV
  - Fire Scout (Navy's VTUAV)
  - 3 per ship
  - Cost: Procurement $16M, Annual O&S $0.5M
- USV
  - Spartan Scout
  - 3 per ship
  - Cost: Procurement $10M, Annual O&S $1.1M
- UUV
  - Small (REMUS)
    - 12 per ship
    - Cost: Procurement $9M, Annual O&S $0.7M
  - Medium (BPAUV)
    - 4 per ship
    - Cost: Procurement $17M, Annual O&S $0.7M
  - Large (Sea Horse)
    - 2 per ship
    - Cost: Procurement $8M, Annual O&S $0.7M
- Procurement cost includes cost for modular payloads
- 15-year life for the UVs. Second set procured for second half of 30-year cost period
- 1 set for each of the X-AVN and X-WPS ships
- 1 set distributed over 4 of the X-CRS ships

The set of UV platforms on this chart are used in this study as representative of UAV, USV, and UUV capability platforms for the future fleet alternatives. This set will be included in each of the large ships, X-AVN and X-WPS, and one set spread over four X-CRS distributed aviation ships. Unit procurement and annual operations and support costs are included in the cost chapter of this study. The UV set is assumed to have a 15-year life, so a second set is bought at the 15-year point in the 30-year life-cycle cost analysis. The procurement cost includes cost of modular payloads for each UV. This cost is estimated to be approximately the cost of the UV alone.

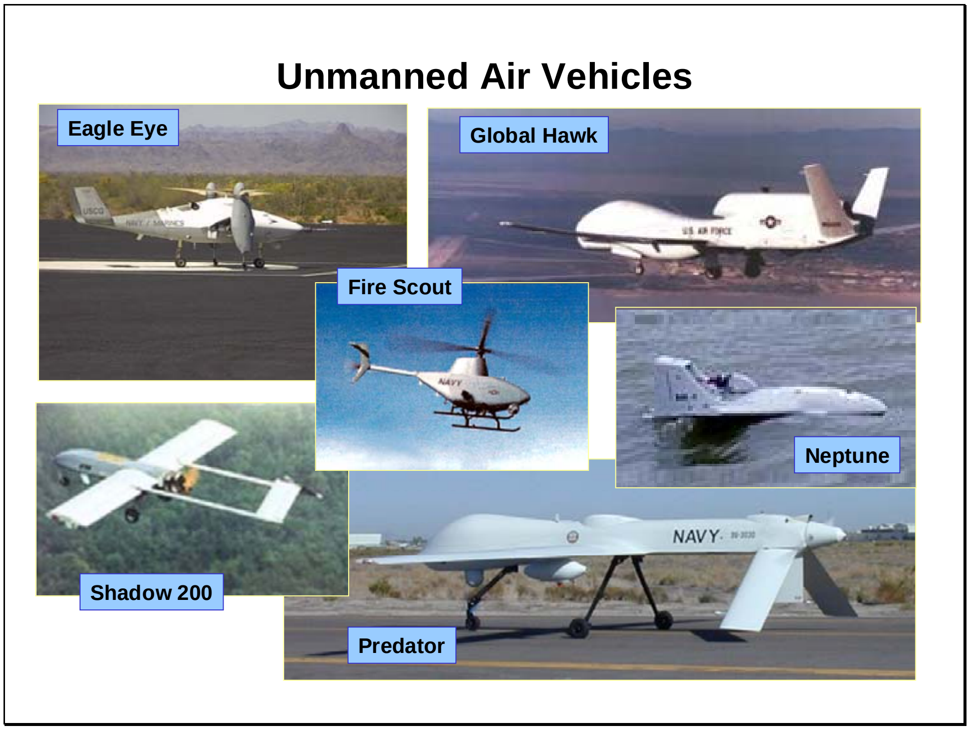
Details on each UV is contained in subsequent sections of this chapter.

Outline

- UV Set for Large Ships
- Unmanned Air Vehicles (UAVs)
- Unmanned Surface Vehicles (USVs)
- Autonomous Undersea Vehicles (AUVs)

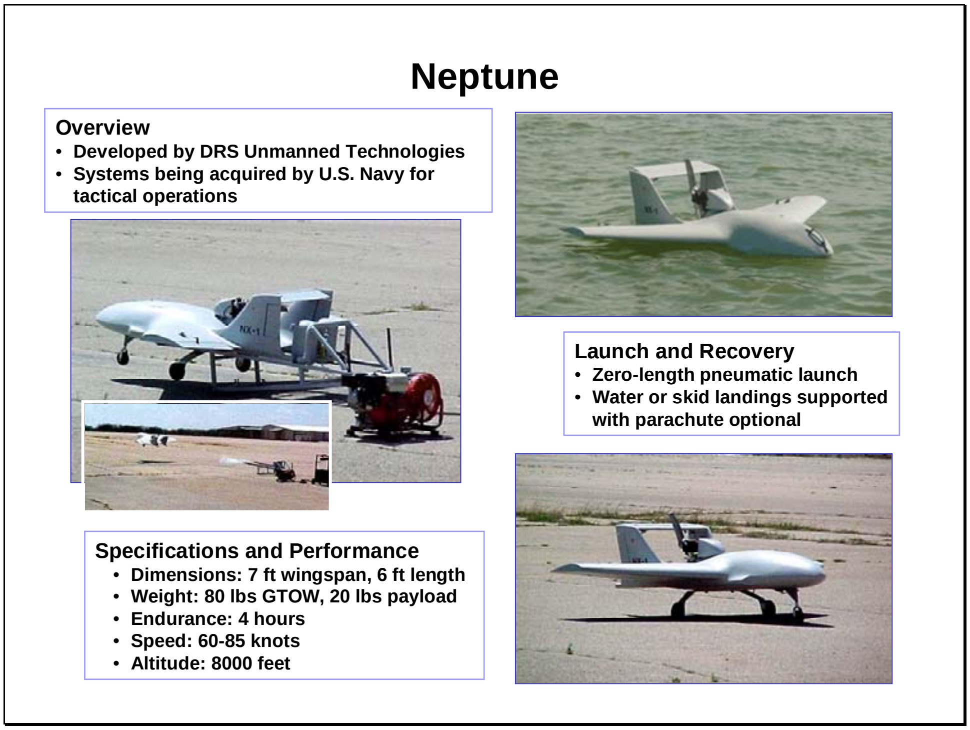
A. UNMANNED AIR VEHICLES (UAVS)

This section begins with an overview of UAVs with particular attention to three modern UAVs. A summary chart comparing the primary characteristics of the UAVs is included.



Since the 1950s, UAVs have been used for ISR and, in the past decade, the diversity of UAVs and UAV payloads has grown explosively. They now span a range in size from full-size aircraft to micro-UAVs, and many designs are available from fixed-wing to helicopter, tilt-rotor, and ducted fan.

Three modern UAVs were identified as being of particular interest, Neptune by DRS Unmanned Technologies, Bell Helicopter's Eagle Eye, and Fire Scout of the Northrup Grumman Ryan Aeronautical Center.



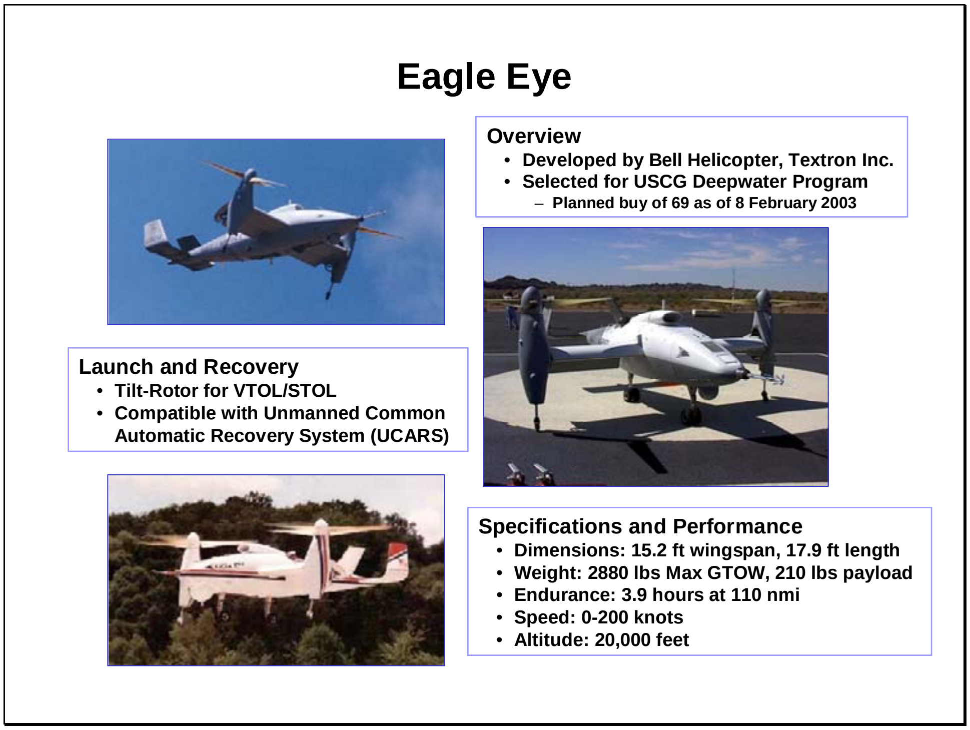
1. The Neptune UAV

The Neptune UAV was developed by DRS Unmanned Technologies as a maritime tactical asset for operations at a range of up to 40 nautical miles and was specifically designed to support day and night operations over land or water. The Neptune is the smallest of the UAVs considered, with low weight and a small on-deck footprint.

The Neptune is pneumatically launched from rails and can be stowed, ready for launch within minutes, on board the launcher. The Neptune is buoyant and protected against water intrusion for landings over water and can taxi after water landings. The Neptune is also equipped with skids for landings on smooth, hard surfaces and an optional parachute is available.

Communications with the Neptune are made over a secure digital data link with a range of about 40 nautical miles over open water. The system is capable of handoff from a rear launch site to a forward controller for extended-range operations.

Military payloads developed for the Neptune by DRS include a color-imaging camera, an infrared thermal imager, and ability to drop payloads up to 20 pounds. Several Neptune systems are being acquired by the U.S. Navy for tactical operations.

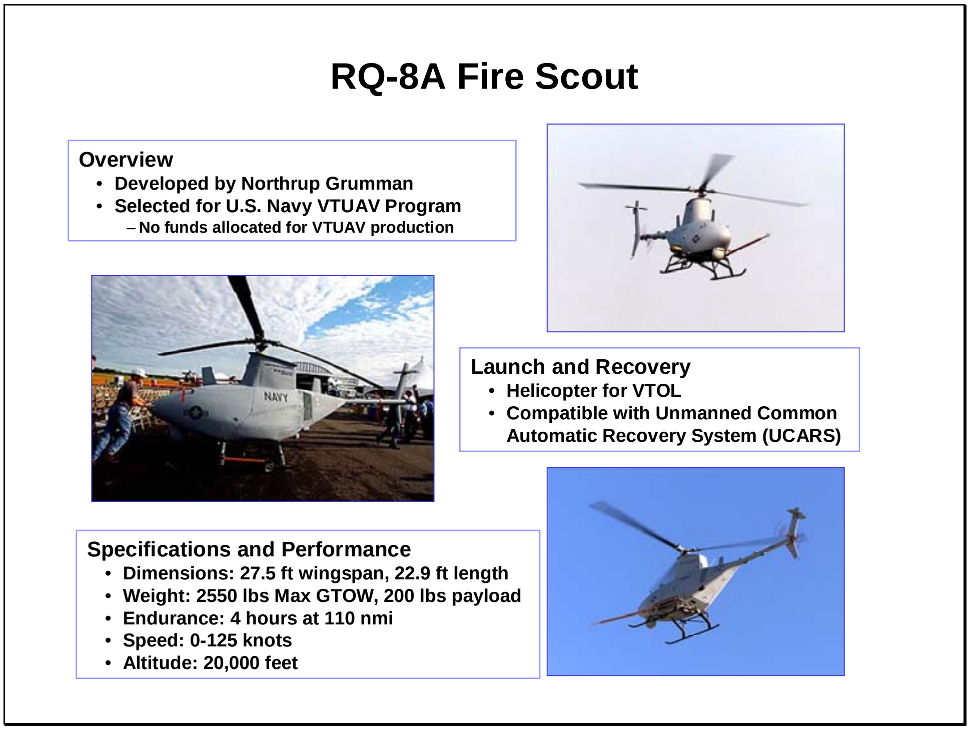


2. The Eagle Eye UAV

The Eagle Eye is a tilt-rotor UAV designed and built by Bell Helicopter of Textron Inc. The tilt-rotor design gives the Eagle Eye the flexibility of vertical takeoff and a top speed over 200 knots with rotors positioned forward. The Eagle Eye has been selected by the U.S. Coast Guard for the UAV portion of the Integrated Deepwater System program and will be deployed as part of the force package aboard the USCG's National Security Cutter and legacy aviation-capable cutters. As of 8 February 2003, the planned buy of Eagle Eye UAVs for the Deepwater program is 69 air vehicles.

The Eagle Eye will be compatible with the Navy's Unmanned Common Automatic Recovery System (UCARS), which enables the Eagle Eye to close with a ship, then automatically track and land on the ship in moderate-to-high winds and sea states. In addition to VTOL, the tilt-rotor design permits STOL, which increases the payload capacity of the Eagle Eye by at least 40 percent.

Communications with the Eagle Eye are made by S-band and UHF channels over digital data links. The Eagle Eye is compatible with the military Tactical Control Station (TCS) Q-70. The standard military and maritime payload developed for the Eagle Eye consists of electro-optical and infrared imaging systems.



3. The RQ-8A Fire Scout

The Fire Scout UAV is built by Northrup Grumman Ryan Aeronautical Center and is based on the Schweizer Model 333 manned helicopter. The Fire Scout was initially selected for the U.S. Navy's Vertical Takeoff UAV (VTUAV) to be based on aviation-capable cruisers and destroyers, and with Marine Expeditionary Units aboard large-deck amphibious ships. The decision for the VTUAV is now being reconsidered. The initial plan called for 23 systems, of 3 vehicles each, and Fire Scout entered low-rate initial production in May 2001. In February 2002, procurement of the Fire Scout was cancelled by the Navy and no funds have been allocated for its production.

Communications with the Fire Scout are provided over S-band and UHF digital data links. The avionics architecture of the Fire Scout is derived from Northrup Grumman's highly reliable Global Hawk UAV program. Like the Bell Eagle Eye, the Fire Scout will be compatible with UCARS and the TCS Q-70 control system.

The initial payload designed for the Fire Scout is an electro-optical and infrared imaging system combined with a laser designator for precision targeting support. Several other modular mission packages have been identified for additional mission areas.

UAV Comparison

Characteristic	DRS Neptune	Fire Scout (VTUAV)	Eagle Eye (USCG UAV)
Wingspan (ft)	7	27.5	15.2
Length (ft)	6	22.9 (folded)	17.9
Max GTOW (lbs)	80	2,550	2,880
Payload (lbs)	20	200	210
Propulsion	150 cc, 15HP, 2 stroke	Allison 250-C20W	P&W 200-55
Endurance at Range (hrs)	4	4	3.9
Radius (nmi)	40	110	110
Altitude (ft)	8,000	20,000	20,000
Speed (kts)	60-85	0-125	0-200
Launch	Pneumatic	Vertical	Vertical/STOL
Recovery	Skid, water landing, parachute	Vertical	Vertical/STOL
Downlink	40-nmi range	S-band/UHF	S-band/UHF

4. Comparison of Vehicle Characteristics

Of the three vehicles described, the Neptune UAV is the most distinct because of its low weight and very small footprint. However, the disadvantages of the Neptune are its limited payload capability, which would preclude some sensor types of potential interest, and its limited range, speed, and altitude compared with the other alternatives.

The Fire Scout and the Eagle Eye are more evenly matched and have more appropriate range and payload numbers. Since the Fire Scout was selected by the Navy as its VTUAV, we will use it as a representative UAV for the purposes of this study. The standard tactical payloads for UAVs could include electro-optical and infrared thermal imaging systems, a laser target designator, or synthetic aperture radar.

Outline

- UV Set for Large Ships
- Unmanned Air Vehicles (UAVs)
- Unmanned Surface Vehicles (USVs)
- Autonomous Undersea Vehicles (AUVs)

B. UNMANNED SURFACE VEHICLES (USVS)

This section describes a single USV program currently in development. The USV described has the potential to carry out near-surface meteorological and oceanographic measurements at the location of the USV and to serve as a launch and recovery platform for AUVs and possibly data buoy systems.

The USV considered is the Spartan Scout under development at the Naval Undersea Warfare Center (NUWC) Division, Newport, RI, as a FY02 new start Advanced Concept Technology Demonstration (ACTD). The objective of the ACTD is to “Demonstrate and assess the military utility of USVs for Assured Access and Force Protection in the Littorals and fill a void in capability that the Fleet is in critical need of today.” The concept is to integrate existing technologies in a new system to meet future Navy needs.

This particular USV platform is described to illustrate the concept of employment for such a system but should not be construed as the only such vehicle capable of performing this mission. It is used in this study as a representative USV.

Spartan Scout

- **Developed at NUWC as FY02 ACTD**
- **Based on existing Navy 7m RHIB, launched and operated from surface ships and shore facilities**
- **Modular design, configurable for**
  - **Mine Warfare**
  - **ISR/Force Protection**
  - **Precision Strike**
  - **ASW (not in FY02 ACTD)**
- **Performance characteristics:**

  Time on Station: up to 8 hours *[48 hrs]**

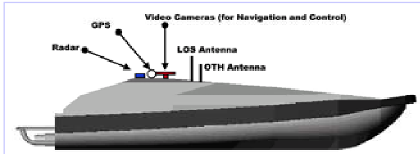
  Range: up to 150 nmi *[1000 nmi]**

  Payload: up to 2600 lbs *[5000 lbs]**

  Transit Speed: at least 26 kts *[50 kn]**

  **characteristics for possible 11m RHIB variant*

Spartan Scout in Narragansett Bay



Spartan Scout Core Configuration

- **Objective:** *"Demonstrate the Military Utility of USVs for Assured Access and Force Protection in the Littorals and fill a void in capability that the fleet is in critical need of today"*

The Spartan Scout is a 7-meter RHIB, but an 11-meter RHIB could also be used as a USV. The Navy uses manned versions of both RHIBs. Projected performance characteristics for both size USVs are shown.

The design of the Spartan Scout is modular and can be configured for individual warfare missions. The modules developed under the FY02 ACTD are specialized for mine warfare, precision strike, and ISR with force protection. The core system is propulsion, navigation, control elements, and core sensors and communications built on a standard Navy 7-meter RHIB, with the possibility to extend the program to 11-meter RHIB hulls for longer range and greater payload and endurance.

One method of employing the Spartan Scout would be to equip the vehicle with a dedicated sensors and weapons to support MIW, ASW, SUW, or precision strike.

As a delivery vehicle for AUVs, a USV could greatly extend the reach and responsiveness of AUV-based capabilities because of the range and speed of the surface vehicle. The payload capability of the USV would enable it to deliver several mid-to-small sized AUVs into the operating area. Further, with an appropriate communications package, the USV could remain in the operating area and serve as a communications node to relay collected data back to the host platform.

Outline

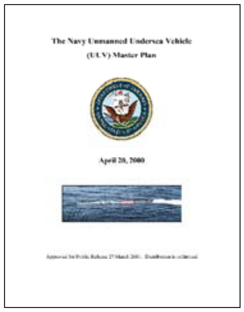
- UV Set for Large Ships
- Unmanned Air Vehicles (UAVs)
- Unmanned Surface Vehicles (USVs)
- Autonomous Undersea Vehicles (AUVs)

C. AUTONOMOUS UNDERSEA VEHICLES (AUVS)

This section begins by reviewing the U.S. Navy Unmanned Undersea Vehicle (UUV) Master Plan, which serves as a guide for Navy UUV development programs. One of the signature capabilities identified in the UUV Master Plan and targeted for development is related to environmental battlespace characterization.

The section then presents an overview of autonomous undersea vehicles and a similar semi-submersible vehicle and compares the primary characteristics of some AUVs selected for development within the naval community.

The Navy UUV Master Plan



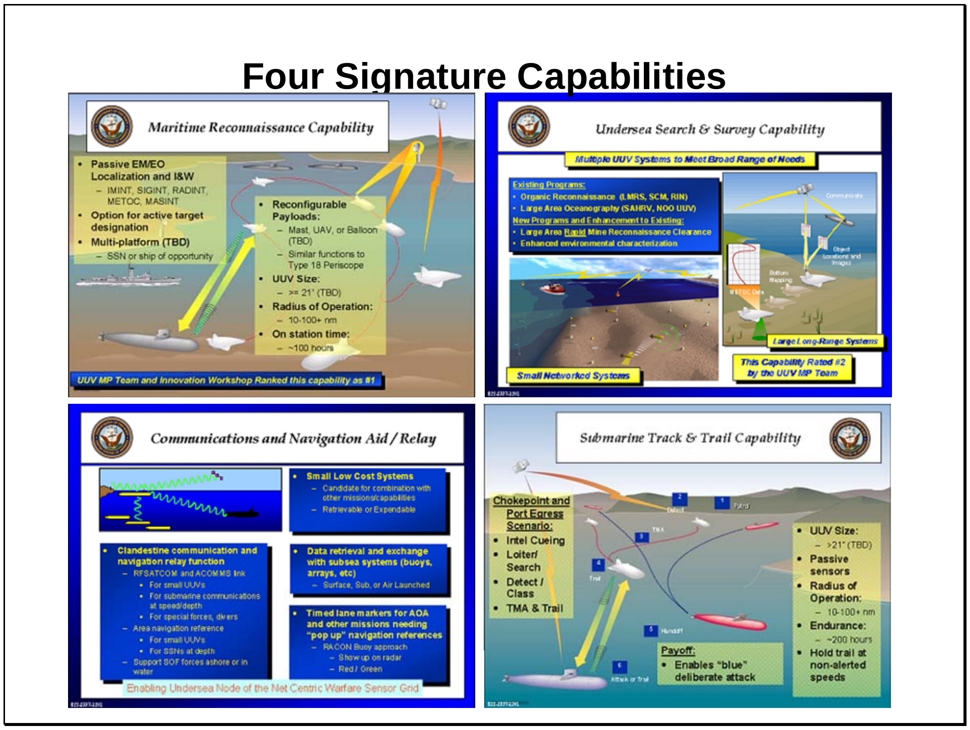
- **Lays out a long-term vision to establish priorities for near-term acquisition programs and foundation for long-term applications out to 50 years**
- **Generates and prioritizes emerging UUV missions**
  - Intelligence/Surveillance/Reconnainssance
  - Mine Countermeasures
  - Meteorology and Oceanography
  - Communication/Navigation Aid
  - Anti-Submarine Warfare
  - Autonomous Weapons Platform
  - Logistics Supply and Support
- **Defines Signature Capabilities for development to meet near-term and emerging needs**
- **Identifies technologies associated with Signature Capabilities and assesses acquisition risk**
- **Provides a Development Plan and Roadmap to realize the four Signature Capabilities**
- **Approved by DASN/MUW on 20 April 2000**

1. The Navy UUV Master Plan

AUVs are a subset of the larger class of UUVs which, in general use, also includes tethered and remotely operated vehicles. The Navy UUV Master Plan restricts its focus to UUVs that are largely autonomous or operate with minimal supervision and are untethered except for possible cabling for data links. Throughout this section we use the terms AUV and UUV synonymously to refer to the class of vehicles identified in the UUV Master Plan and extend the class to include semi-submersible vehicles developed primarily for ocean survey and undersea warfare superiority.

The objective of the Navy UUV Master Plan was to establish a long-term vision for the potential employment of AUVs out to the 50-year time horizon and to establish priorities for near-term acquisition and technology investment to lay the foundation for realizing that long-term vision.

The approach involved generating and prioritizing missions for which AUVs could potentially contribute. The resulting list includes warfare areas, intelligence, and communications, as well as collection of meteorological and oceanographic (METOC) data. The Master Plan then identifies four signature capabilities to address the high-priority mission area needs. Technological risk is assessed with regard to engineering issues that face the further development of AUVs. The Master Plan concludes with a development plan, programmatic roadmap, and recommendations for developing AUV capabilities within the Navy.



The four signature capabilities developed in the UUV Master Plan are Maritime Reconnaissance, Undersea Search and Survey, Communications and Navigation Aids, and Submarine Track and Trail.

The Maritime Reconnaissance Capability is the highest-priority capability identified in the Master Plan. It entails the covert collection of intelligence of every type in denied areas for purposes of localization and indications and warning. The autonomous vehicles will be capable of repositioning for collection purposes, avoiding obstacles and threats, and transmitting or returning with collected data.

The Communication and Navigation Aid Capability enables AUVs to act as clandestine relay stations and geo-located reference points. The communications element focuses on providing high-speed, high-bandwidth data links among surface forces, submarines, special forces, and other AUVs and fixed undersea or surface sensors.

The goal of the Submarine Track and Trail Capability is to patrol, detect, track, trail, and handoff adversary submarines during any stage of conflict and under any rules of engagement.

Undersea Search & Survey

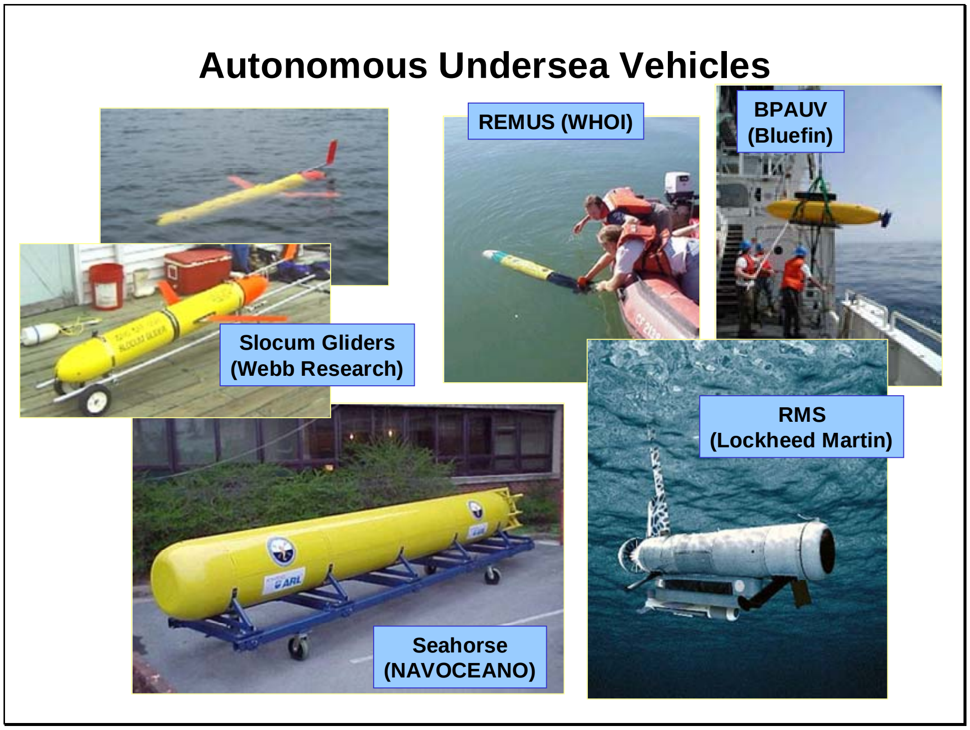
- **Signature Capability that addresses all aspects of environmental characterization from individual objects to large operating areas, from the littoral to the deep ocean**
  - **Object Sensing and Intervention (OSI)—finding and identifying mines, lost objects, and hazards to navigation and eliminating mine threats**
  - **Hydrographic and Oceanographic Survey—near real-time collection of physical, chemical, biological, and geological data in all ocean environments at required temporal and spatial sampling densities**
- **Achieving USS goals will require a family of UUV systems**
  - **Individual large vehicles for long-range and high-endurance missions to gather multi-disciplinary ocean survey data**
  - **Multiple mid-sized vehicles for simultaneous standoff USS missions**
  - **Very high numbers of small vehicles for massively parallel area coverage (SWARM concept) and very shallow water/surf zone operations**
  - **Extremely high endurance vehicles that drift or glide using energy extracted from the ocean environment**

The Undersea Search and Survey (USS) Capability is the second priority capability identified in the Master Plan. It covers both the mine counter-measures and METOC collection missions for AUVs.

The MCM mission is generalized to the more inclusive Object Sensing and Intervention (OSI) capability, including localization and identification of all objects and hazards to navigation on the ocean floor or in the water column. The OSI capability also extends to recovery, neutralization, or other intervention with objects in all ocean environments.

The METOC mission primarily involves ocean survey for bathymetry, bottom imaging, and bottom structure and composition but also covers the collection of information on meteorological data; ocean thermal and acoustic structure; ocean currents and tides; chemical, nuclear, and biological sampling; and the establishment of long-term observation stations.

The spectrum of requirements for the USS capability covers operating from long standoff distances, high rates for area search and clearance, long time on station capability, operations from the surf zone to the deep ocean, and payloads from very small, single-focus sensors to large, high capability packages of complex sensors. It is clear that these requirements cannot all be satisfied by any single vehicle. The UUV Master Plan advocates a family of complementary AUVs and AUV systems of diverse size and capability to achieve the goals for the USS Signature Capability.



2. Overview of Vehicles

To cover, in some measure, a diversity of vehicles and vehicle capabilities, five AUVs are considered for their potential contribution to environmental battlespace characterization. These AUVs fall into three size classes by hull diameter and weight. The most standard source of AUV propulsion is battery-powered motors, and each of the three size classes is represented by one battery-driven vehicle. In addition, because they offer dramatically different performance characteristics, vehicles representing two other propulsion sources, diesel engine and buoyancy, are also represented.

All five of the AUVs have either been developed with Navy support or are currently being adapted for Navy applications. Each of the five AUVs shown here is described in detail below. A number of other military AUV projects are under development, most notably the Long-Term Mine Reconnaissance System (LMRS). However, these five AUVs are representative of the types of UUVs and AUVs available in the near term. Also, each can carry a variety of weapons and sensors as needed to support their range of missions.

WHOI REMUS

- **Remote Environmental Monitoring Units (REMUS) developed at Woods Hole Oceanographic Institute (WHOI) and now offered as a commercial product through Hydroid Inc.**
- **Basis for Semi-Autonomous Hydrographic Reconnaissance Vehicle (SAHRV) cooperatively developed by NAVSEA and ONR**
- **REMUS/SAHRV Sensors: CTD, Side Scan Sonar, Doppler Velocity Log, Optical Backscatter Sensor**
- **Dimensions: 19 cm diameter, 160 cm length, 80 lbs dry weight**
- **Max Operating Depth: 100 m**

a. The REMUS Vehicle

The Remote Environmental Monitoring Units (REMUS) vehicle was initially developed by the Woods Hole Oceanographic Institute (WHOI) with support from the Office of Naval Research (ONR) and is currently offered as a commercial product through Hydroid, Inc. ONR and the Naval Sea Command are cooperatively developing the Semi-Autonomous Hydrographic Reconnaissance Vehicle (SAHRV), based on REMUS, to support naval special warfare.

The REMUS vehicle represents the smallest class of AUV considered, being easily operated and recovered by two people from a small boat. Another advantage of the REMUS' small size is that it can be deployed in greater numbers than other AUV platforms for a given shipboard footprint. The ease of employment is offset by a limited payload and endurance relative to the other AUVs considered.

The REMUS vehicle is powered by on-board batteries. A standard sensor package for the REMUS includes a conductivity-temperature-depth (CTD) sensor, side scan sonar (SSS), doppler velocity log, and an optical backscatter sensor.

Also of note, a larger AUV based on the REMUS and called the Semi-Autonomous Mapping System (SAMS) has been acquired by NAVOCEANO. The SAMS vehicle is rated for full-ocean depths, i.e., to 20,000 feet.

Bluefin BPAUV

- Battlespace Preparation Autonomous Underwater Vehicle (BPAUV) was developed and built by Bluefin Robotics for ONR
- Potential Sensors: CTD, Side Scan Sonar, Doppler Velocity Log, Acoustic Doppler Current Profiler, Optical Backscatter Sensor, Fluorometer, Synthetic Aperture Sonar, Multibeam Echo Sounder, Sub-Bottom Profiler, PAR Sensor
- Dimensions: 53 cm diameter, 305 cm length, 485 lbs dry weight
- Max Operating Depth: 300 m (a variant is rated to 3000 m depth)

b. The Battlespace Preparation AUV (BPAUV)

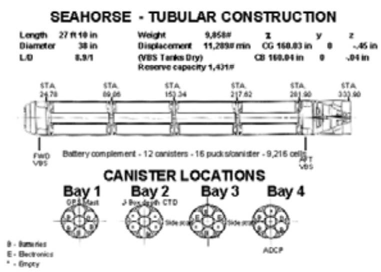
The Battlespace Preparation AUV (BPUAV) was developed by Bluefin Robotics with support from ONR and is very similar to Bluefin's commercial UUV 21 line of AUVs. The BPAUV is also propelled by battery power and has speed and endurance characteristics similar to the REMUS vehicle. The BPAUV represents an intermediate size class at several hundred pounds when dry. Although the BPAUV can be deployed and recovered from launches and small fishing boats, a hoist or crane is required because of its weight.

The standard sensor package for the BPAUV includes a CTD sensor, interferometric SSS, doppler velocity log, optical backscatter sensor, and a fluorometer for turbidity measurement. Other sensor systems that have been incorporated in the UUV 21 are acoustic doppler current profilers (ADCPs), synthetic aperture sonars (SASs), multibeam echo sounders, sub-bottom profilers, and sensors for photosynthetically active radiation (PAR).

One of the strengths of Bluefin's UUV 21 line is its modularity and flexibility. Although the standard length of the BPAUV is 305 centimeters, additional sections can be added to the hull of the UUV 21 to extend the length to 500 centimeters. In addition, the BPAUV is only rated to 300, meters depth but Bluefin produces a Thales UUV 21 variant rated to 3,000 meters depth.

Seahorse

- The Seahorse class AUVs were developed and built by ARL at Penn State for NAVOCEANO
- Demonstrated operations from the T-AGS 60 class ships
- Powered by 9317 D-cell alkaline batteries, by FY05 rechargeable
- Seahorse Sensors: CTD, Side Scan Sonar, Acoustic Doppler Current Profiler, Multibeam Echo Sounder, Sub-Bottom Profiler
- Dimensions: 38 inch diameter, 28 foot length, 10,500 lbs weight
- Max Operating Depth: 1000 feet



c. The Seahorse Vehicle

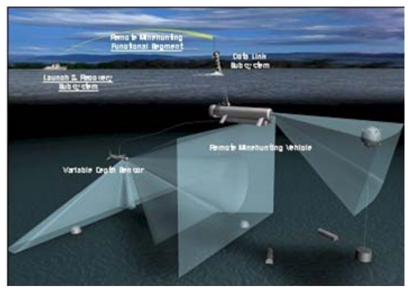
The Seahorse AUVs were built by Penn State's Applied Research Laboratory for NAVOCEANO and were partly inspired by the earlier Lazarus vehicle built by Draper Laboratories as a DARPA technical program then transitioned to NAVOCEANO.

The Seahorse vehicles are in the largest AUV size class, weighting several tons each and requiring special considerations for deployment and recovery. The larger volume of the vehicle makes higher endurance and longer ranges possible; however, the Seahorse's energy storage is alkaline batteries and the limited power available restricts the Seahorse's top speed to values comparable with the REMUS and the BPAUV. NAVOCEANO plans call for the development of a rechargeable battery system for the Seahorse by FY05 to alleviate this problem.

Standard sensors currently employed on the Seahorse include a CTD, a SSS, and an ADCP. The large size of the Seahorse and its modular payload design make incorporating almost any AUV sensor package, within the Seahorse's power budget, possible.

Remote Minehunting System (RMS)

- **AN/WLD-1 Remote Minehunting System (RMS) is built by Lockheed Martin for the U.S. Navy, to be deployed in FY05**
  - **First installation to be DDG-91, *USS Pinckney***
- **Semi-submersible vehicle with towed Variable Depth Sonar**
- **Powered by 307 hp Cummins diesel engine**
- **RMS Sensors: Obstacle-Avoidance Camera, Forward-Looking Sonar, AN/AQS-20 VDS with multiple sonars and EO Laser Imager (Multibeam Echo Sounder and Side Scan Sonar employed on earlier ORCA and DOLPHIN variants)**
- **Dimensions: 23 feet length, 12,850 lbs weight +980 lbs for VDS**



d. The Remote Minehunting System (RMS)

The RMS is an evolution of an earlier vehicle, started in 1981, the Deep Ocean Logging Platform with Hydrographic Instrumentation and Navigation (DOLPHIN) produced by International Submarine Engineering, Ltd., for the Canadian Hydrographic Service. In 1985, the Naval Research Laboratory (NRL) and NAVOCEANO ordered two vehicles denoted Oceanographic Remotely Controlled Automatons (ORCAs) equipped with multibeam echo sounders for bathymetric mapping. The current RMS is made by Lockheed Martin and specifically equipped for mine countermeasure operations.

The primary difference between the RMS or ORCA and the other vehicles considered in this section is the diesel engine of the RMS. Not relying on battery power, the RMS is capable of operations at much higher speeds and supporting instruments with larger power requirements. A consequence of the diesel engine is that the RMS is only semi-submersible and snorkels by means of a mast that extends above water level. Consequently, sensors are employed from near the surface or from tow bodies deployed from the RMS.

The RMS falls into the same size category as the Seahorse and requires special equipment for deployment and recovery.

Glider Vehicles

- Slocum gliders were developed and are built by Webb Research in two versions, Coastal Gliders and Deep Ocean Gliders
- Gliders rely on changing their buoyancy and orientation of wings for propulsion, moving forward with a saw-tooth depth profile
- Powered by batteries (Coastal) or ocean thermocline (Deep Ocean)
- Potential Sensors: CTD, Acoustic Doppler Current Profiler, Optical Backscatter Sensor, Fluorometer, Photosynthetically Active Radiation (PAR) Sensor, Bioluminescence Sensor
- Dimensions: 21.3 cm diameter, 1.8 m length, 52 kg dry weight
- Max Operating Depth: 200 m (Coastal) / 1500 m (Deep Ocean)

e. Glider Vehicles

Glider vehicles represent a third option for AUV propulsion. By changing their buoyancy, gliders control the rate at which they rise or sink in the water column. Control over the orientation of the vehicle's wings enable the glider to derive propulsion and steering from the vertical motion.

An energy source is still required to make the glider's buoyancy changes possible. Two versions of gliders have been developed: a battery-powered glider for coastal operations and a glider that derives its energy from the ocean's thermocline by means of an internal heat engine. The heat-engine glider, or deep ocean glider, requires a sufficient difference in surface and deep water temperatures to maintain its operations and thus is not capable of operating in shallow or arctic waters.

Because the glider's means of propulsion requires very low power, the endurance of gliders is at least an order of magnitude longer than the nearest competing AUV. Another consequence of the buoyancy-driven propulsion is that the speed of the AUV is severely limited and the trajectory of the AUV is more restricted than for other vehicles.

The gliders pictured here are Slocum gliders, produced by Webb Research with support from ONR. Another glider design, the SeaGlider, is built by the Applied Physics Laboratory at the University of Washington.

Slocum gliders are in the class of small AUVs with the REMUS vehicle. They can be deployed and recovered by one or two people, and no special equipment is required. Glider vehicles have been employed with an array of sensors including CTDs, ADCPs, optical backscatter sensors, fluorometers for turbidity measurement, PAR sensors, and sensors for bioluminescence. The sensor packages for gliders are somewhat restricted by size and endurance constraints. The long endurance of the gliders is due to the low power required for propulsion; sensors that require moderate power supplies are not possible on the deep ocean glider and will sap the batteries of the coastal glider affecting its endurance.

The long endurance and slow speed characteristics of the gliders and the saw-tooth depth profile of the glider's trajectory suggest that they will be used with a different concept of employment than the other AUVs described. The gliders may prove to be more appropriate platforms for long-term ocean survey and sampling than for rapid environmental assessment.

AUV Characteristics

Parameter	Slocum Glider (Coastal/Ocean)	REMUS/ SAHRV	BPAUV	Seahorse	RMS/ORCA
Diameter (inches)	8.4	7.5	21	38	39 (main hull)
Length (feet)	5.9	5.2	10	28	23
Displacement (pounds)	115	80	732	10,500	12,850
Range (nautical miles)	810 / 21,500	66	68	290	230
Speed (knots)	0.65	3	4	4	12
Rated Depth (feet)	656 / 4920	328	984	1000	RMS at 10 feet, tow body deeper
Endurance (hours)	30 days / 5 years	22/22.5	17/17.5	72/96	18/19
Swath Width at 30-meter Depth (feet)	0	164	656	197	728

f. Comparison of Vehicle Characteristics

The most significant operational characteristics distinguishing the AUVs considered in this section arise from differences in energy sources and propulsion. Both the high endurance of the Slocum gliders and the high speed of the RMS are due to their respective propulsion systems.

A second important distinguishing feature is the relative sizes of the AUVs, which will affect tradeoffs between higher sensor package capability for larger vehicles and greater ease of use and larger numbers of platforms available for smaller AUVs.

Only relatively minor changes can be made in the energy storage, propulsion, and size of each of the AUVs described without undertaking a redesign of the vehicle. However, other performance factors such as rated depth can be improved with relatively modest effort. For instance, the Thales variant of Bluefin’s UUV 21 could be adopted as a deep-ocean version of the BPAUV.

Also, the sensor systems employed on the vehicles can be changed to offer more or less capability as required for a particular application or mission. For instance, the swath widths presented in the table above reflect typical values for multibeam systems and side scan sonars employed by the vehicles. However, there is no reason, in principle, that the SSS of the BPAUV or the multibeam system of the RMS could not be applied to the Seahorse vehicle, thus resulting in significant improvement of the Seahorse’s swath width.

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Appendix A
AVERAGE NUMBER OF SHOOTER/PLATFORMS PER THEATER OF COMBAT

Appendix A
AVERAGE NUMBER OF SHOOTER/PLATFORMS PER THEATER OF COMBAT

For the capability to promptly bring forces to bear and strike from the sea, one major factor in the models is to determine the average distance between the shooter and target. In order to determine this distance, we consider a simple model as shown in Figure A-1. Within a circular area of radius *R*, we randomly distribute *n* points within this circular area. We would like to find the average closest distance between the shooter, located at distance ρ from the center of the circle, and a randomly distributed point within the circular area of radius *R*.

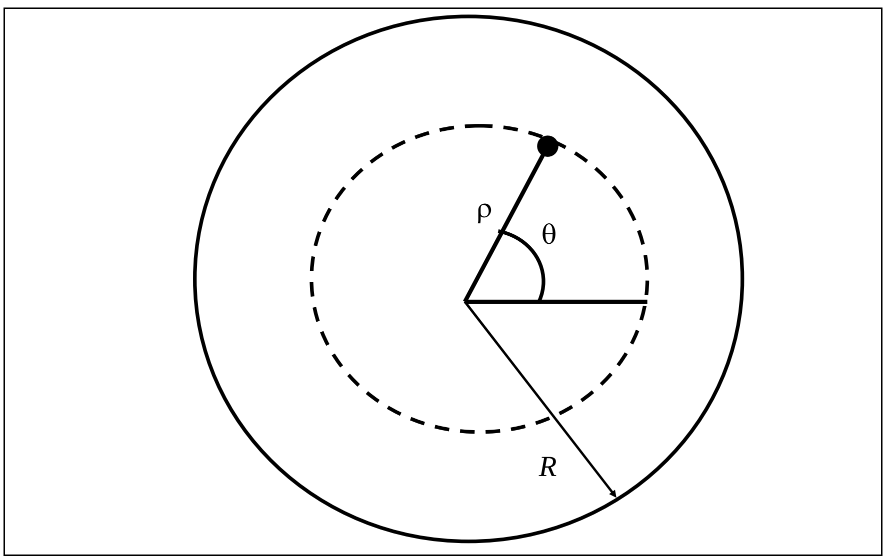

Figure A-1. Determining Average Distance Between Shooter and Target Within a Circular Area of Radius R

Let us consider the case of one random point within the circle of radius *R*. The probability that the point is located at a radial distance greater than ρ is given by,

$$\Pr(\rho^* > \rho) = \frac{1}{\pi R^2}\int_{\rho}^{R}\rho d\rho\int_{0}^{2\pi}d\theta = \frac{\rho^2}{R^2}\frac{\rho}{R}\bigg|_{\rho}^{R} = \frac{1}{R^2}(R^2 - \rho^2)$$

where θ is the angle between the *x*-axis and ρ. We now distribute *n* random points and find the probability *P* that at least one of the *n* random points is closer to the center than ρ is,

$$P = 1 - \left(1 - \frac{\rho^2}{R^2}\right)^n$$

We can then infer the probability density function *f*(ρ) as,

$$f(\rho) = n\left(1 - \frac{\rho^2}{R^2}\right)^{n-1} \frac{\rho d\rho d\theta}{\pi R^2}$$

We then calculate the average distance between target and shooter,

$$\overline{\rho} = \int_0^R \rho f(\rho) d\rho = \frac{2n}{R^2} \int_0^R \rho^2 \left(1 - \frac{\rho^2}{R^2}\right)^{n-1} d\rho$$

Letting $x = \frac{\rho}{R}$ and $d\rho = Rdx$, we have

$$\overline{\rho} = 2nR \int_0^1 x^2 \left(1 - x^2\right)^{n-1} dx$$

The average distance between the enemy target and our forces is then found to be:

$$\overline{\rho} = nRB(2;n) = nR \frac{\Gamma\left(\frac{3}{2}\right)\Gamma(n)}{\Gamma\left(\frac{3}{2} + 2\right)}$$

where *n* is the number of shooters in a given circular area of radius *R*. *B* is the Beta function defined as:

$$B(m,n) \equiv \frac{\Gamma(m)\Gamma(n)}{\Gamma(m+n)}$$

where Γ is the Gamma function defined as,

$$\Gamma(z) = \int_0^\infty t^{z-1} e^{-t} dt$$

The average distance between shooter and target is given in Figure A-2. We find that ρ decreases almost exponentially as the number of platforms is increased.

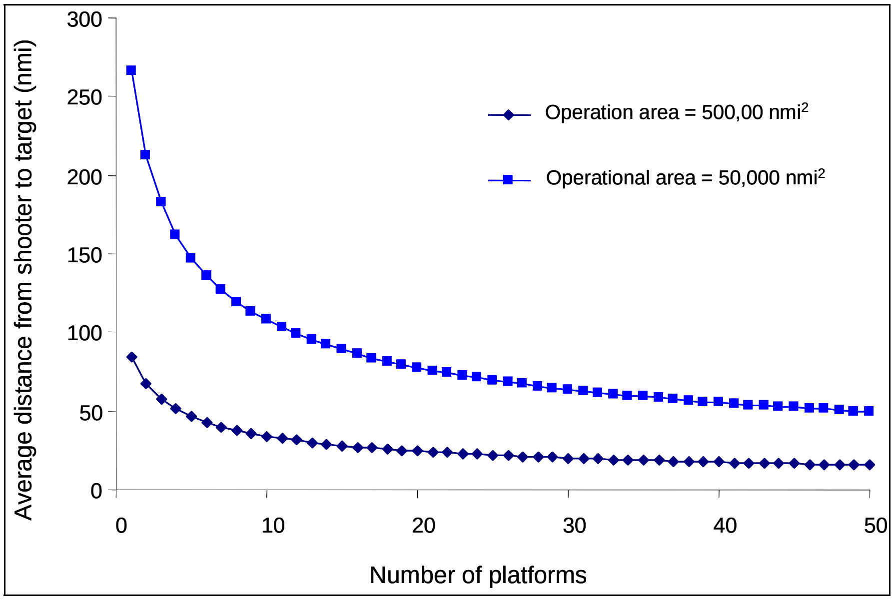

Figure A-2. Average Distance From Shooter to Target as a Function of the Number of Platforms.

GLOSSARY OF MATHEMATICAL SYMBOLS

d	Depth of Operating area
f	Fraction of targets killed
m	Number of surveilled areas
n	Number of platforms in operating area
p	Probability of killing fleeing target
r_0	Weapon lethal radius
t_0	Arrival time of power projection forces/weapon flight time
v	Average velocity of Blue naval forces
v_a	Velocity of Blue naval forces
v_{bx}	x-velocity component (perpendicular) of enemy forces
v_b	Total velocity of enemy forces
v_{escape}	Enemy fleeing velocity
v_{weapon}	Weapon speed
w	Removal platform sweep width
A	Operating area
F	Fraction of targets eliminated
I_0	Initial state of knowledge
L	Dimension of operating area along the shore
N_f	Number of fleeing targets
N_t	Number of tracked targets
N_u	Number of undetected targets
P	Probability of killing tracked target
R	Battlefield reality
S	Survivability of fleet
W	Power projection sweep width
α	Prob. of anti-access assets killing power projection forces/surveillance area
β_0	Initial density of removal forces
β	Density of removal forces as a function of time
λ_t	Rate at which targets transition from undetected to under track state
γ_u	Rate at which targets transition from fleeing to undetected state
ρ_0	Initial density of anti-access threats

ρ_0	Initial density of anti-access threats
$\rho_{distance}$	Average distance from shooter to target
μ	Enemy deception in intent
σ	Accuracy of surveillance system
σ_{io}	Standard deviation of individual observations
σ_{iw}	Standard deviation of indications and warnings
$\sigma_{network}$	Standard deviation of networked surveillance system
μ_f	Rate at which targets transition from the under track to fleeing state
ξ	Relative increase in accuracy
ζ	Perpendicular distance from operating location to starting point
τ	Time to engage enemy

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Appendix B
LIST OF FIGURES AND TABLES

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Appendix C
GLOSSARY

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GLOSSARY

AAW	anti-air warfare
ABMD	Anti-Ballistic Missile Defense
ACE	Aviation Combat Element
ACTD	Advanced Concept Technology Demonstration
ADCP	acoustic doppler current profiler
ADS	Advanced Deployable System
AEA	Airborne Electric Attack
AEW	airborne early warning
AGS	Advanced Gun System
AIP	air-independent propulsion
AoA	Analysis of Alternatives
AOR	Area of Responsibility
APN	Aircraft Procurement, Navy
APUC	average procurement unit cost
ARG	Amphibious Ready Group
ARL	Applied Research Laboratory
ASDS	Advanced SEAL Delivery System
ASW	anti-submarine warfare
AUV	Autonomous Underwater Vehicle
AVN	aviation ship
BMD	Ballistic Missile Defense
BPAUV	Battlespace Preparation Autonomous Underwater Vehicle
C2	command and control
C3	command, control, and communications
C4ISR	command, control, communications, computers, intelligence, surveillance, and reconnaissance
CCL	concentric canister launcher
CEC	Cooperative Engagement Capability
CER	Cost Estimating Relationship

CG	guided missile cruiser
CGX	new design cruiser
CID	combat identification
CIWS	close-in weapon systems
CLF	combat logistics force
CNA	Center for Naval Analyses
CNO	Chief of Naval Operations
CONOPS	concept of operations
COP	Common Operating Picture
CRRC	Combat Rubber Raiding Craft
CSAR	combat search and rescue
CSG	carrier strike group
CTD	conductivity-temperature-depth
CTP	Common Tactical Picture
CUP	common underwater picture
CV	aircraft carrier
CVBG	carrier battle group
CVN	nuclear-power aircraft carrier
DADS	Deployable Acoustic Detection System
DARPA	Defense Advanced Research Projects Agency
DDG	guided missile destroyer
DDS	dry deck shelter
DDX	new design destroyer
DOLPHIN	Deep Ocean Platform with Hydrographic Instrumentation and Navigation
EM	electro-magnetic
EOD	explosive ordnance disposal
ER	extended range
ERGM	Extended Range Gun Munition
ESF	Expeditionary Strike Force
ESG	expeditionary strike group
ESSM	Evolved Sea Sparrow Missile
EW	electronic warfare

FCS	fire control system
FDS	forward deployed site
FFRDC	Federally Funded Research and Development Center
FNCs	Future Naval Capabilities
FOB	forward operating base
FY	Fiscal Year
FYDP	Future Years Defense Plan
GCCS-M	Global Command and Control System—Maritime
HASC	House Armed Services Committee
HME	hull, mechanical, and electrical
ICAP III	Improved Capability EA-6B
IDA	Institute for Defense Analyses
IFF	Identification Friend or Foe
ILS	Integrated Logistics Support
IO	information operations
IR	infrared
ISR	intelligence, surveillance, and reconnaissance
IT-21	Information Technology 21
JDAM	Joint Direct Attack Munition
JOA	Joint Operating Area
JSF	Joint Strike Fighter
LAM	land attack missile
LCAC	loading craft, air cushion
LCS	Littoral Combat Ship
LCZ	Littoral Combat Zone
LHA	amphibious assault ship
LHD	amphibious assault ship, multi-purpose
LMRS	Long-Term Mine Reconnaissance System
LMSR	large medium-speed roll-on roll-off
LPA	Littoral Penetration Area

LPD	amphibious transport dock
LRLAP	Long Range Land Attack Projectile
LSD	landing ship, dock
MACM	Mine Acoustic Countermeasures
MCM	mine countermeasures
MCS	mine countermeasures support ship
MDSAG	Missile Defense Surface Action Group
MEMS	Micro Electro-Mechanical System
METOC	meteorological and oceanographic
MFR	multi-function radar
MFTA	Multi-Function Towed Array
MHC	mine hunter, coastal
MIW	Mine Warfare
MMA	Multi-Mission Aircraft
MNS	Mine Neutralization System
MPA	Maritime Patrol Aircraft
MPF(F)	Maritime Prepositioning Force Future
MPG	Maritime Prepositioning Group
MPS	Maritime Prepositioning Ships
MPSRons	Maritime Prepositioning Squadron
MSC	Military Sealift Command
MUOS	Mobile User Objective System
N/E	nanoelectronics
NAVSEA	Naval Sea Systems Command
NAVOEANO	Naval Oceanographic Office
NBC	nuclear, biological, and chemical
NFN	Naval Fires Network
NMCI	National Maritime Command Information
NMIC	National Maritime Intelligence Capability
NOC	Naval Operating Concept
NPS	Naval Postgraduate School
NRL	Naval Research Laboratory
NPS	Naval Postgraduate School

NUWC	Naval Undersea Warfare Center
NWDC	Navy Warfare Development Command
O&S	operating and support
O&MN	Operations and Maintenance, Navy
OFT	Office of Force Transformation
OMFTS	Operational Maneuver from the Sea
ONR	Office of Naval Research
ORCA	Oceanographic Remotely Controlled Automaton
OSD	Office of the Secretary of Defense
OSI	Object Sensing and Intervention
PAR	photosynthetically active radiation
PLA	Pervasive Littoral Awareness
PLS	Pervasive Littoral Sensing
PLVS	Peripheral Vertical Launch System
POL	petroleum, oil, and lubricant
RCS	radar cross section
RDT&E	research, development, test, and evaluation
REMUS	Remote Environmental Monitoring Units
RF	radio frequency
RHIB	Rigid-Hull Inflatable Boat
RMS	Remote Minehunting System
RO-RO	roll-on roll-off
SAG	surface action group
SAHRV	Semi-Autonomous Hydrographic Reconnaissance Vehicle
SAM	surface-to-air missile
SAMS	Semi-Autonomous Mapping System
SAP	special access program
SAR	special access required
SAR	Selected Acquisition Report
SAS	synthetic aperture sonar
SCN	Shipbuilding and Conversion, Navy

SDV	SEAL Delivery Vehicles
SEAD	suppression of enemy air defense
SES	Surface Effect Ship
SLBMS	submarine-launched ballistic missile
SOF	Special Operations Forces
SPT	support ship
SPTA	auxiliary support ship
SR/C	slowed rotor/compound
SS	diesel submarine
SS3	Sea State 3
SSBN	nuclear-powered ballistic missile submarine
SSG	surface strike group
SSGN	nuclear-powered cruise missile submarine
SSM	surface-to-surface missile
SSN	nuclear-powered attack submarine
SSS	side scan sonar
START	Strategic Arms Reduction Treaty
STOL	short takeoff and landing
STOM	Ship-to-Objective Maneuver
STOVL	short take-off, vertical landing
SUW	surface warfare
SWBS	Ship Work Breakout Schedule
TACTOM	Tactical Tomahawk
T-AOE	fast combat support ship
T-AE	ammunition ship
T-AO	oilers
TAMD	Theater Air and Missile Defense
TBM	theater ballistic missile
TBMD	theater ballistic missile defense
TCS	Tactical Control Station
TISS	Thermal Imaging Sensor System
TLAM	Tomahawk Land Attack Missile
TRL	trainable rocket launcher
TSSE	Total Ship Systems Engineering

UAV	unmanned air vehicles
UCARs	Unmanned Common Automatic Recovery System
UCAS	unmanned combat air system
UCAV	unmanned combat air vehicle
USS	Undersea Search and Survey
USV	unmanned surface vehicle
UUV	unmanned undersea vehicle
UV	unmanned vehicle
UWFCS	underwater fire control system
VAMOSC	Visibility and Management of Operating and Support Costs
VDS	Variable Depth Sonar
VLS	Vertical Launch System
VSTOL	vertical or short takeoff and landing
VTOL	vertical takeoff landing
VTUAV	vertical takeoff and landing unmanned aerial vehicle
WHOI	Woods Hole Oceanographic Institute
WPS	combat system ship

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14. ABSTRACT

The Congress directed the Secretary of Defense to provide two studies on the future fleet architectures by January 2005. One study was to be conducted by Federally Funded Research and Development Centers (FFRDCs), and the other by the Office of Force Transformation (OFT) within the Office of the Secretary of Defense (OSD). The two studies were to be conducted independently and not be constrained by current programs. The Center for Naval Analyses (CNA) was selected to conduct the FFRDC study. To assist in their study, the OFT requested IDA to conduct its own analyses and to provide inputs. After receiving and deliberating on these inputs, the OFT produced a report in January 2005 for the Congress. This IDA document is written as a stand-alone report. Some of the OFT report findings are drawn from analyses described in this document. Nonetheless, the results found here represent the views of IDA and not necessarily those of the OFT. The purpose of this report is to identify realistic alternatives to the programmed fleet and to assess their advantages and disadvantages. The emphasis in the alternatives identified is small, fast, numerous, and networked; and with high commonality in hull designs.

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