CSBA
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TAKING BACK THE SEAS

TRANSFORMING THE U.S. SURFACE FLEET FOR DECISION-CENTRIC WARFARE

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Cover: The *Arleigh Burke*-class guided-missile destroyer USS *John Paul Jones* launches an SM-6 during a live-fire test of the ship's Aegis Weapons System. U.S. Navy photo, June 19, 2014.

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Executive Summary

Naval surface warfare is undergoing a period of rapid technological and operational change. During the nearly 30 years since the end of the Cold War, navies encountered relatively permissive environments, and the threats they did face could largely be defeated by improved defensive systems. A new generation of challenges has emerged, however, including ubiquitous passive sensors, quiet submarines, supersonic and hypersonic anti-ship missiles (ASM), "smart" mines, and the increasing use of paramilitary forces in naval operations.[1] As a result, many fleets are revising their concepts and capabilities for traditional surface missions such as air defense, anti-submarine warfare (ASW), maritime and land strike, and mine warfare (MIW).

The U.S. Navy has been slow to address the changing threat environment. As a result, today's surface force lacks the size, resilience, and offensive capacity to effectively support the U.S. National Defense Strategy's approach of deterring aggression by degrading, delaying, or defeating enemy attacks. The surface fleet is weighted toward large combatants that are too expensive and manpower-intensive to achieve the numbers needed for distributed operations. They also rely on sensors that will likely be unavailable or create unacceptable vulnerabilities during combat against a great power like China. Perhaps of most concern is the fact that the current fleet is fiscally unsustainable due to the escalating costs to crew, operate, and maintain today's highly integrated manned surface combatants.

The surface fleet's shortfalls are especially problematic because the role of surface forces in Navy offensive operations will likely expand over the next few decades. Carrier air wings will be constrained in the number of weapons they can deliver because they will need to operate at least 1,000 nm from significant enemy missile threats, such as those on the Chinese or Russian coasts. Submarines, which have been considered the U.S. military's most survivable

1 See Office of the Secretary of Defense (OSD), *Military and Security Developments Involving the People's Republic of China 2019*, Annual Report to Congress (Washington, DC: DoD, 2019), available at https://media.defense.gov/2019/May/02/2002127082/-1/-1/1/2019_CHINA_MILITARY_POWER_REPORT.pdf; and John Costello and Joe McReynolds, *China's Strategic Support Force: A Force for a New Era* (Washington, DC: U.S. National Defense University, 2018), available at https://inss.ndu.edu/Media/News/Article/1651882/chinas-strategic-support-force-a-force-for-a-new-era/.

weapons delivery platforms, are retiring faster than they are being built and may be too vulnerable in waters close to China or Russia due to the fielding of seabed sonar networks.

Despite what is likely to be a constrained budget environment, the U.S. surface fleet could transition to an operationally effective and fiscally sustainable force by embracing a new approach to naval operations. Instead of focusing solely on attrition, surface forces should pursue forms of maneuver warfare in which they seek to impose multiple mutually insoluble dilemmas on adversaries. Maneuver warfare is more appropriate than attrition-centric warfare for the operating environment of today's U.S. surface fleet, in which adversaries like China can achieve local superiority in salvo size and fleet capacity. Furthermore, the goal of U.S. naval forces is primarily to deter conflict by convincing adversaries their aggression could be unsuccessful, not to seek attrition as a means of punishment only after the initiation of hostilities.

New Operational Concepts

In shifting from attrition to maneuver as the focus of naval operations, surface forces should implement operational concepts that center on making and enacting faster or better decisions while degrading the enemy's ability to do the same. The Navy and Marine Corps are moving tentatively toward decision-centric warfare with their new concepts for Distributed Maritime Operations (DMO) and Expeditionary Advance Based Operations (EABO). These concepts still, however, rely on attrition to defeat the enemy and are not well suited to a long-term competition. A decision-centric approach to warfare will require that surface forces take on the new mission of counter-ISRT (intelligence, surveillance, reconnaissance, and targeting) and pursue new tactics for the longstanding missions of ISRT, maritime strike or anti-surface warfare (ASUW), strike warfare (STW) against land targets, ASW, MIW, air and missile defense (AMD), and maritime security operations (MSO). In general, the surface fleet will need to pursue its missions in ways that reduce the ability of an adversary to quickly target surface combatants or understand the effects chains and tactics U.S. forces are executing.

Arguably the most important operational challenge to address will be command and control (C2) of distributed naval forces when decision-making superiority is an objective. U.S. forces may be unable to sustain high or moderate bandwidth communications over wide areas due to their proximity to adversary jammers and the long distances between U.S. units and theater commanders. Rather than expend scarce resources to build a new communications architecture to support desired C2 structures, communications requirements could be reduced through an alternative approach to command, control, and communications (C3) that adapts existing C2 structures to accommodate communications availability. This concept, which could be described as context-centric C3, relies on decision-support tools to help junior commanders develop and execute plans even when communications are lost with senior leaders.

New concepts for surface fleet missions such as ISRT, ASW, MIW, and ASUW will increasingly rely on unmanned systems to perform sensing operations because unmanned systems can achieve the proximity or distribution to use passive sensors effectively or employ active sensors at acceptable risk. Engagements will largely continue to be ordered by a human operator, although that operator may be on a nearby manned platform and the weapon launched by an unmanned vehicle. Unmanned systems would conduct almost all counter-ISRT missions; they can make risk-worthy decoys or employ active countermeasures without exposing a manned platform to detection and attack.

AMD will be the most difficult mission to change in support of a decision-centric approach to warfare. Surface combatants have traditionally relied on active monostatic radar to find and track threats with sufficient fidelity to enable engagements, which are conducted as far from the ship as possible. U.S. surface forces will need to pursue AMD at shorter ranges by using directed energy weapons and smaller interceptors that increase AMD capacity and improve surface force survivability. Surface combatants will also need to exploit new capabilities and techniques in passive and multistatic sensing for AMD in contested areas, although they could use monostatic radar to help protect bases or civilian and capital ships whose locations are likely already known to the enemy.

A New Surface Fleet Design

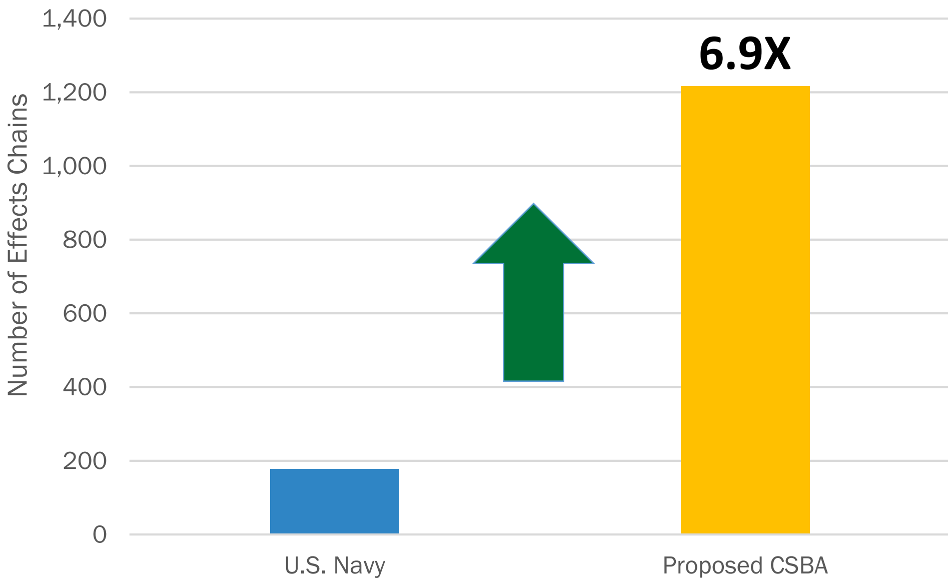
To support its new operational concepts and a decision-centric warfighting approach, the Navy should pursue three main objectives in surface fleet design:

1. Increase the complexity of U.S. surface force presentation to an adversary;
2. Grow the salvo size needed by an adversary for a successful, immediate attack; and
3. Increase the offensive capacity of U.S. surface forces.

Complexity can be measured in terms of the number of different effects chains a given force package or fleet can conduct. Combined with more offensive capacity, more possible effects chains would increase the ability of U.S. surface forces to decide and act quickly. Complexity and greater defensive capacity will also degrade the ability of an adversary to promptly identify and engage the most advantageous targets to defeat U.S. forces.

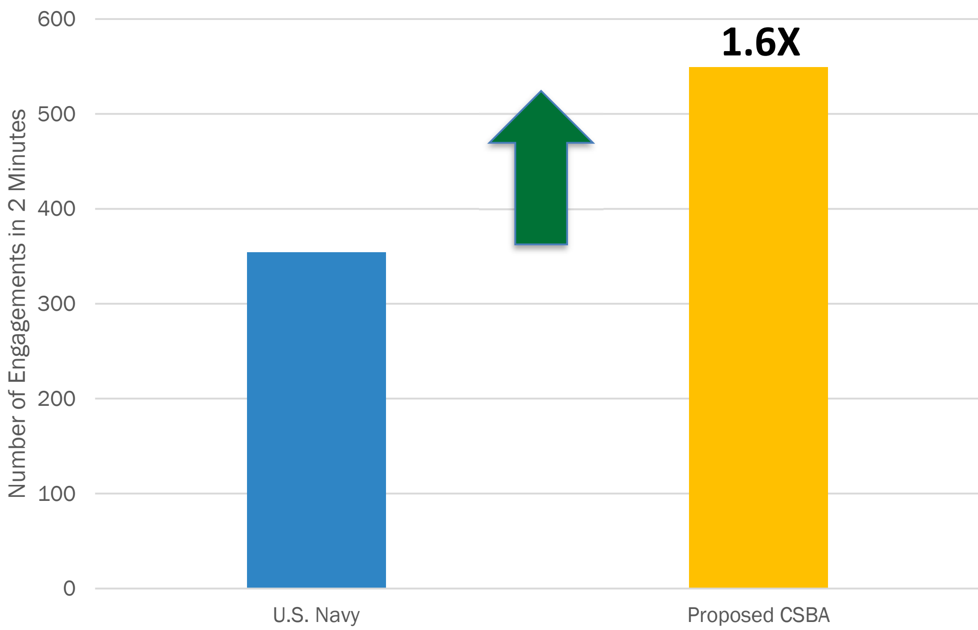
CSBA's proposed architecture improves the surface fleet's performance in these metrics compared to the Navy's planned force described in its most recent Long-Term Shipbuilding Plan, as shown in Figures 1 through 3. The deployed force packages proposed in CSBA's study are able to generate more independent effects chains, growing the complexity imposed on adversary decision-making. The proposed force posture also has more robust defenses using new AMD concepts and capabilities and Medium Unmanned Surface Vessels (MUSV) focused on decoy and counter-ISRT operations. Lastly, the CSBA fleet has more offensive capacity in terms of strike weapon cells compared to the Navy's current or planned surface force.

FIGURE 1: AGGREGATE NUMBER OF EFFECTS CHAINS OF DEPLOYED FORCE PACKAGES



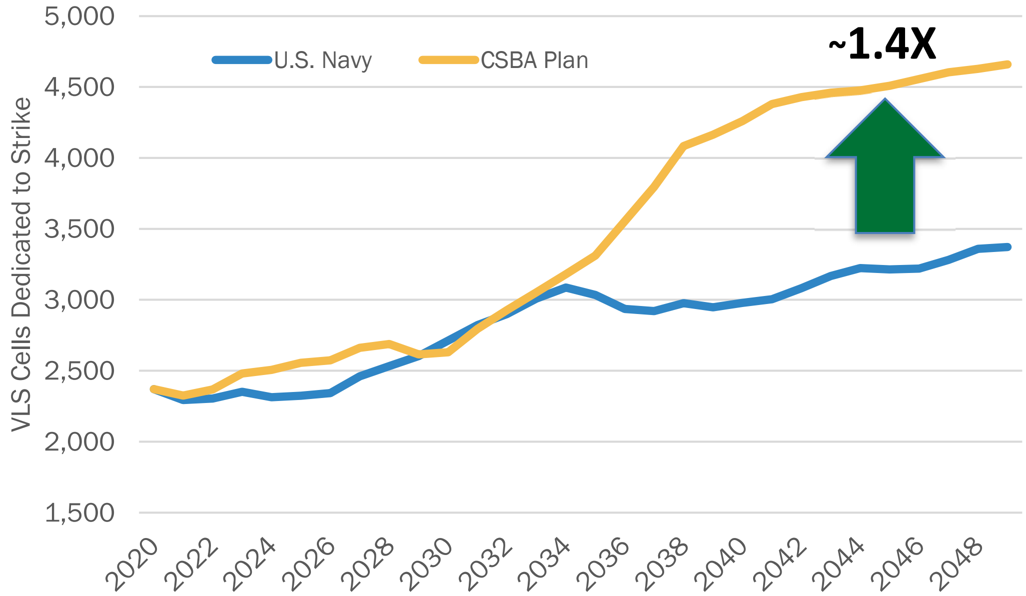
This estimate assigns ships C2/Multi-Function, Effectors, or Sensor/Counter-Sensor functions. It then assesses all possible effects chains within a force package, which are the combinations involving three or fewer ships, with C2/Multi-Function ships being able to take on all roles and Effectors or Sensors only taking on that role.

FIGURE 2: SURFACE ACTION GROUP DEFENSIVE CAPACITY



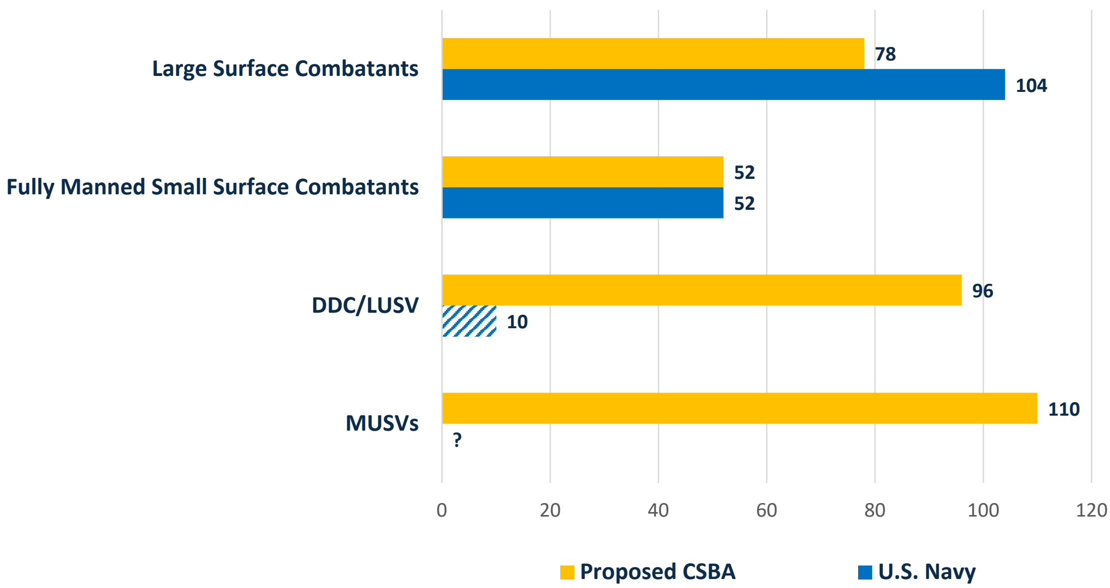
The U.S. Navy surface action group (SAG) consists of three guided missile destroyers (DDG). The proposed CSBA SAG consists of two DDGs, six DDCs (solely armed with offensive weapons), and five MUSVs that were not factored into defensive capacity.

FIGURE 3: SURFACE COMBATANT FLEET STRIKE CAPACITY



The estimate of Navy strike missile capacity in the figure assumes 25 percent of VLS cells in DDGs, CGs, and FFGs are allocated to strike. CSBA's proposed plan follows the same allocation as the Navy estimate, with the exception of DDCs. DDCs operating in non-CSG force packages allocate 100 percent of their magazines to strike, while DDCs operating in CSG force packages allocate 25 percent of their magazines to strike.

FIGURE 4: COMPOSITION OF THE NAVY AND PROPOSED CSBA SURFACE FLEETS



CSBA's proposed surface posture can be translated into a required fleet architecture by accounting for the readiness cycles of ships and the transit time to travel from homeports to operating areas. The resulting fleet, shown in Figure 4, consists of 336 manned and unmanned surface combatants. The proposed fleet includes fewer manned large surface combatants than the Navy's programmed force (78 instead of 104) and far more small surface combatants (258 instead of 52), which include optionally unmanned corvettes (DDC) and MUSVs. The surface combatant fleet would also incorporate additional sensors and vehicles, such as shipborne small unmanned vehicles and helicopters.

Navy leaders have stated that the Department of Defense (DoD) intends to rebalance the surface fleet toward a larger number of small surface combatants, but the Navy has not yet published a new fleet requirement.[2] Although there are similarities between CSBA's proposed fleet and the Navy's most recent shipbuilding plans, there are five major differences:

1. **Pursue DDG(X) instead of the Future Large Surface Combatant.** The Navy's plan to accelerate procurement of the Future Large Surface Combatant without first developing and maturing relevant technologies is risky and likely to result in a ship that will be delivered late, run over budget, and fall short of requirements. Moreover, the estimated $2.8 billion cost of the cruiser-like Future Large Surface Combatant continues to advance the Navy on a trajectory toward a smaller fleet of expensive ships. Instead of this approach, CSBA's plan first matures key technologies for automation, electric propulsion, and directed energy weapons, then procures a destroyer-sized DDG(X) in FY 2030 estimated to cost $2.25 billion.

2. **Pursue an optionally unmanned DDC instead of the Large Unmanned Surface Vehicle (LUSV).** Instead of procuring an optionally manned LUSV that may be difficult to employ throughout the spectrum of competition and conflict, CSBA's plan introduces a similarly designed DDC that is designed to be, conversely, optionally unmanned and would normally operate with small crews of around 15–24 personnel. DDCs primarily armed with offensive weapons would serve as offboard magazines for force packages.

3. **Field more MUSVs.** CSBA's plan includes a large force of 110 low-cost MUSVs to conduct passive and multistatic sensing, counter-ISR, and ASW in a truly distributed manner.

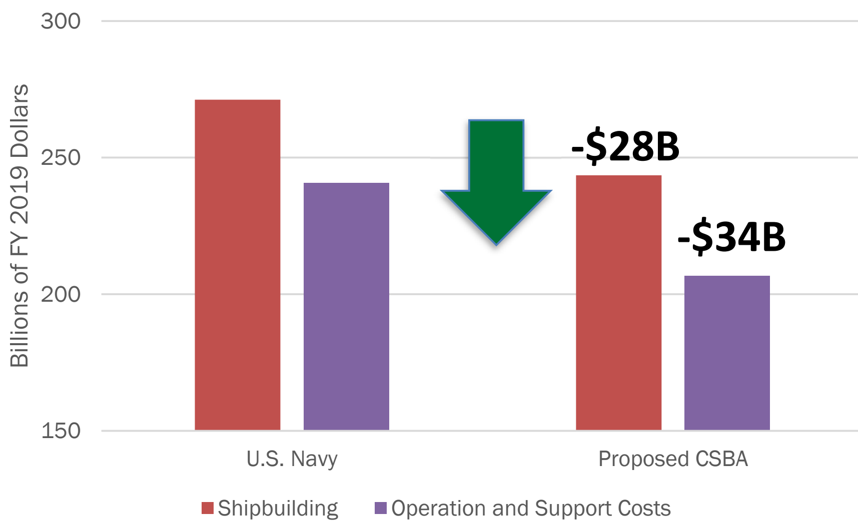
4. **Forego service life extensions for older cruiser and destroyers.** As large surface combatants focus on command and control and high-end air and missile defense, small surface combatants can replace them for a growing number of other missions. CSBA's proposed approach reduces operation and support costs by retiring older cruisers and destroyers as they reach the end of their service lives.

2 Megan Eckstein, "Navy: Next Force Structure Assessment Likely to Require More Small Combatants, Supply Ships," *USNI News*, March 27, 2019, available at https://news.usni.org/2019/03/27/navy-next-force-structure-assessment-likely-require-small-combatants-supply-ships.

5. **Invest in enablers.** In order to maximize lethality, the Navy must adopt a balanced approach to fleet design that funds valuable surface warfare enablers, even at the cost of combatant hulls. CSBA's plan generates savings that can be invested in key enablers such as munitions and other expendable payloads, broad-area ISRT and communications systems, and logistics platforms and equipment.

CSBA's proposed shipbuilding plan balances the need to implement a new surface fleet architecture with the imperative to manage expenses. It costs nearly $28 billion less than the Navy's FY 2020 plan with almost half the savings occurring during the first decade of the plan. Furthermore, CSBA's proposed plan requires approximately $34 billion less in operation and support funding than the Navy's plan, primarily as a result of retiring cruisers and destroyers at the end of their service lives and fielding few large combatants that use automation and employ smaller crews.

FIGURE 5: COMPARISON OF PROCUREMENT AND OPERATING COSTS BETWEEN THE NAVY'S PLANNED FORCE AND CSBA'S PROPOSED FLEET



Conclusion

The U.S. Navy's surface fleet is at a crossroads. Today's force lacks the size, resilience, and offensive capacity to contribute effectively to degrading, delaying, or denying aggression. These shortfalls are especially problematic in light of the fact that the surface fleet will play an increasingly important role in the U.S. Navy's ability to counter enemy attacks. The current fleet is also fiscally unsustainable due to growing operations and support costs for today's highly integrated and manpower-intensive surface combatants.

New technologies for unmanned systems, sensors, weapons, C3, and countermeasures could allow significant improvements in the surface fleet's ability to create complexity for an adversary and harden surface forces from attack while improving surface force's capacity for maritime or land strike. Freeing up the resources to fund new technologies and fielding platforms able to incorporate them will require dramatic changes to the Navy's current shipbuilding and capability development plans.

CSBA's proposed architecture of operational concepts, force packages, posture, readiness cycles, and platforms would improve the surface fleet's ability to support U.S. defense strategy as well as make it more sustainable. The proposed CSBA fleet is not the only answer, of course, but the Navy will need to pursue many of the same initiatives to break from its current trajectory of fewer, more expensive platforms. With U.S. carrier aviation constrained in range and capacity and challenged by rising sustainment costs, and with the submarine force shrinking, the surface fleet will have increased importance in deterrence, reassurance, and warfare. U.S. Navy leaders should make the hard choices needed to ensure the surface force can meet that challenge.

CHAPTER 1

Introduction

Naval surface warfare is undergoing a period of rapid technological and operational change. During the nearly 30 years since the end of the Cold War, navies encountered relatively permissive environments, and the threats they did face could largely be defeated by improved defensive systems. A new generation of challenges has emerged, however, including ubiquitous passive sensors, quiet submarines, supersonic and hypersonic ASM, smart mines, and the increasing use of paramilitary forces in naval operations.[3] As a result, many fleets are revising their concepts and capabilities for traditional surface missions such as air defense, ASW, maritime and land strike, and MIW.

The U.S. Navy is responding to the increasingly contested operating environment by implementing new approaches to distributed operations. Under these concepts, surface action groups (SAG) would be employed predominantly as independent elements of a naval force. This would shift the role of surface combatants from primarily serving as missile defense ships for aircraft carriers to serving as distributed sensor platforms, missile launchers, and hosts for unmanned vehicles.[4] In support of its new surface warfare concepts, the Navy is developing a new family of surface combatants, including a new guided missile frigate (FFG), a new large surface combatant, and several variants of unmanned surface vessels (USV).[5] During the next several decades, if the Navy's plans hold, these platforms would replace today's fleet of guided missile cruisers (CG) and destroyers (DDG), LCS, minesweepers (MCM), and patrol craft (PC).

The Navy will need to do more than simply recapitalize its current surface fleet to address the challenges posed by a new generation of anti-ship threats and fully exploit the potential

3 See OSD, *Military and Security Developments Involving the People's Republic of China 2019*; and Costello and McReynolds, *China's Strategic Support Force*.

4 Navy News Service, "CNO Visits Navy Warfare Development Command," *NavyLive*, April 13, 2017, available at https://www.navy.mil/submit/display.asp?story_id=99893.

5 Sydney J. Freedberg Jr., "Navy Says It Can Buy Frigate for Under $800M: Acquisition Reform Testbed," *Breaking Defense,* January 12, 2018; Megan Eckstein, "Navy Homing in on Requirement for Next Large Combatant; Industry Talks Start This Week," *USNI News*, January 15, 2019.

of smaller platforms like USVs and FFGs. Most importantly, it should evolve the operational concepts, tactics, and capabilities of surface combatants to give the United States new operational advantages and reduce the effectiveness of adversary capabilities and concepts. To reduce costs and better position the fleet for long-term competition, it will also need to change surface combatant design, the surface fleet's balance between large and small combatants, and the fleet's balance between manned and unmanned platforms.

This study will explore the environment in which surface warfare operations will be conducted between now and 2035 and what these changes imply for operational strategies, concepts, and capabilities, including:

- AMD;
- ASW;
- Strike against maritime and land targets;
- C2;
- MIW, including MCM operations; and
- ISRT and counter-ISRT operations.

Although this study will focus on the U.S. Navy, its lessons are applicable to other navies as well.

Dilemmas for Surface Warfare

Surface fleets have been the centerpiece of navies since their inception. Today, as in the past, frigates and destroyers provide a visible presence to signify a nation's interests and capabilities and can create an obvious impediment to a competitor seeking to deny maritime access or project power via the sea. With the introduction of long-range precision weapons like the RGM-84 Harpoon ASM and the BGM-109 Tomahawk land attack missile during the Cold War, surface naval forces were able to threaten targets at sea or ashore hundreds of miles away.[6]

The threat of ASMs also placed a defensive burden on surface naval forces. Large capital ships like U.S. aircraft carriers needed protection from increasingly lethal arsenals of long-range air-, surface-, and submarine-launched ASMs like the Soviet SS-N-19 Shipwreck. To address the ASM threat, U.S. surface combatants were equipped with phased-array radars such as the SPY-1 and semi-automated battle management tools such as the Aegis Combat System and

6 Navy History and Heritage Command, "Where are the Shooters? A History of the Tomahawk in Combat," *Surface Warfare Magazine*, Summer 2017.

increasingly pressed into service as missile defense ships.[7] Other navies, lacking a large fleet of aircraft carriers to protect, were able to diversify their surface forces to focus on a wider range of missions, like ASW and anti-ship operations. Although these missions remained important to the U.S. surface fleet, they were often subordinated to AMD.[8]

Today's U.S. surface fleet design reflects the Navy's continued emphasis on air defense. More than three-quarters of the current and planned U.S. surface force comprises Aegis-equipped large surface combatants carrying large SPY-1 or SPY-6 phased-array radars.[9] This emphasis would be appropriate if each surface combatant were expected to be used predominantly for AMD. In practice, however, the Navy's DDGs and CGs spend most of their time using their other capabilities for ASW, strike, and ISRT to support peacetime surveillance, deterrence, maritime security, and counter-terrorism operations. This use, in part, arises from day-to-day operational needs, but it also reflects the lack of small surface combatants to conduct these missions.[10] By deploying advanced air defense-oriented multi-mission combatants for almost every surface force operation, the Navy is suboptimizing the investment in these platforms and arguably consuming their limited service life unnecessarily.

The weighting of the U.S. Navy surface fleet toward CGs and DDGs is costly. Large surface combatants cost approximately $1.8 billion each.[11] More significantly, these highly integrated multi-mission platforms are difficult and expensive to maintain and upgrade. For example, the mid-life modernization of a CG or DDG costs more than $100 million and takes more than a year to complete.[12]

The U.S. Navy's reliance on CGs and DDGs also limits the fleet's operational flexibility. The multi-mission nature of CGs and DDGs could, in theory, create highly adaptable force packages that would be difficult for adversaries to assess and counter. In practice, the cost of buying and sustaining large surface combatants limits the number of ships the Navy can field, reducing the number of different ways a SAG could be employed and making each ship a lucrative target. Moreover, the reliance of the surface fleet on high-power active sensors such as SPY-1 and SPY-6 radars makes U.S. surface combatants vulnerable to the rapidly improving and proliferating passive sensors being fielded by America's great power competitors.

7 See Thomas G. Mahnken, *The Cruise Missile Challenge (*Washington, DC: Center for Strategic and Budgetary Assessments, 2005), pp. 9–13, available at https://csbaonline.org/uploads/documents/2005.03.10-Cruise-Missile.pdf; and U.S. Navy, "Aegis Weapons System," *Fact File*, U.S. Navy, January 10, 2019, available at https://www.navy.mil/navydata/fact_display.asp?cid=2100&tid=200&ct=2.

8 Bryan McGrath, *NATO at Sea: Trends in Allied Naval Power* (Washington, DC: American Enterprise Institute, September 18, 2013).

9 Office of the Chief of Naval Operations (CNO), *Report to Congress on the Annual Long-Range Plan for Construction of Naval Vessels for Fiscal Year 2020* (Washington, DC: U.S. Navy, 2019), p. 13.

10 The Navy has 30 small surface combatants and a requirement for 52. Ibid., p. 11.

11 U.S. Navy, *Department of Defense Fiscal Year (FY) 2020 President's Budget Estimate Submission*, volume 1, *Shipbuilding and Conversion, Navy* (Washington, DC: DoD, March 2019), p. 123.

12 Sam LaGrone, "Navy Altered Destroyer Upgrades Due to Budget Pressure, Demand for Ships," *USNI News*, June 3, 2014.

Effective adversary strategies

Potential U.S. adversaries are developing operational approaches that exploit the limitations of today's U.S. surface fleet design and create multiple dilemmas for U.S. commanders. For example, the Chinese and Russian militaries have deployed long-range sensor and weapons networks that can find and engage naval forces hundreds of miles from their coasts using a combination of ground, maritime, airborne, and space-based sensors and long-range ASMs.[13] China and Russia are fielding ASMs with ranges similar to that of the U.S. Navy's planned maritime strike version of the Tomahawk, which could attack ships more than 900 nm away.[14] The physical signatures of U.S. surface combatants and their reliance on organic radar increases their susceptibility to detection, while the cost, multi-mission utility, and relatively small number of U.S. surface warships makes each of them a high-value target.

The Chinese and Russian militaries complement their long-range sensor and weapons networks with paramilitary forces.[15] Although Russian paramilitary operations are generally ashore in Eastern Europe, China's "gray zone" operations in the East and South China Seas impede the use of international waters and prevent access to disputed maritime features and islands. These activities, backed by conventional military forces, raise the risk to U.S. forces that lack a robust defensive capacity.

An inadequate U.S. response

Chinese and Russian battle networks and gray zone operations undermine the ability of U.S. forces to operate within contested environments to defend U.S. allies and ensure free access to the global commons.[16] For example, the most recent U.S. National Defense Strategy (NDS) calls for DoD to "prioritize ground, air, sea, and space forces that can deploy, survive, operate, maneuver, and regenerate in all domains while under attack."[17]

The U.S. surface fleet could better support the NDS by fielding smaller, more proportional force packages that are able to operate at acceptable risk in contested areas and equipping them to counter enemy aggression. To its credit, the Navy is attempting to improve the air defense capacity of individual surface combatants by pursuing directed energy weapons,

13 OSD, *Military and Security Developments Involving the People's Republic of China 2019*; and Roger McDermott, "Russia's High-Precision Strike Capabilities and 'Pre-Nuclear' Deterrence," *Eurasian Daily Monitor*, Jamestown Foundation, October 2, 2018, available at https://jamestown.org/program/russias-high-precision-strike-capabilities-and-pre-nuclear-deterrence/.

14 Sydney J. Freedberg Jr., "Tomahawk Vs. LRASM: Raytheon Gets $119M for Anti-Ship Missile," *Breaking Defense*, January 10, 2018.

15 Lyle J. Morris et al., *Gaining Competitive Advantage in the Gray Zone* (Santa Monica, CA: Rand Corporation, 2019), pp. 13–43, available at https://www.rand.org/pubs/research_reports/RR2942.html.

16 Donald J. Trump. *National Security Strategy of the United States* (Washington, DC: U.S. Government Printing Office, 2017), pp. 27–30, available at https://www.whitehouse.gov/wp-content/uploads/2017/12/NSS-Final-12-18-2017-0905.pdf.

17 OSD, *Summary of the 2018 National Defense Strategy of the United States of America* (Washington, DC: DoD, 2018), p. 6, available at https://www.defense.gov/Portals/1/Documents/pubs/2018-National-Defense-Strategy-Summary.pdf.

improved interceptors, and new electronic warfare (EW) systems.[18] In concert with these initiatives, the Navy is implementing a new Distributed Maritime Operations (DMO) concept that could increase the survivability of a surface naval force and its ability to maneuver and integrate effects across an operating theater.[19]

The Navy's efforts, however, are incomplete and not focused on a coherent set of objectives. For example, the surface force is not pursuing a comprehensive approach to increase surface combatant offensive capacity, which both depends on additional missile platforms like the Navy's proposed Large USV (LUSV) as well as on more efficient concepts for air defense to make more vertical launch system (VLS) cells available for offensive missions.

A more fundamental flaw in the Navy's plans for improved air defense is the continued need for monostatic active radar, or a radar that both transmits and acts as its own receiver. Powerful radars such as the SPY-1 and SPY-6 are detectable at long ranges by passive RF sensors, which can quickly classify and geolocate the emitter. The risk created by the use of monostatic radar may be acceptable to defend a high-priority target like an aircraft carrier or air base—especially if it is already under attack. But for an individual surface combatant or a SAG, the risk created by active sensors may not be worth the capability gain.

The Navy's concept for Electromagnetic Maneuver Warfare (EMW) is intended to help reduce the ability of adversaries to find and track U.S. surface forces in the electromagnetic spectrum (EMS) while allowing U.S. combatants to communicate, conduct defensive operations, and engage the enemy.[20] As with the Navy's efforts to increase surface fleet offensive or defensive capacity, however, the implementation of EMW falls short. For example, passive sensors and low probability of intercept and detection (LPI/LPD) radars are often shorter range and less precise than their active or high-power counterparts, requiring platforms that can act as relays or that are expendable and can operate closer to the enemy. The Navy is not yet fielding these systems. Decoys could also degrade adversary sensing in the EMS but are not yet part of U.S. surface forces.

The surface fleet will also need to change its sensing and engagement approaches undersea. The Navy's reliance on passive sonar for most ASW operations provides an advantage to the adversary, which can deploy relatively inexpensive noisemakers, decoys, and acoustic jammers to increase the background noise level and degrade passive sonar. Passive sonar, particularly if it is degraded by active countermeasures, will not be able to detect submarines more than a few dozen miles away, allowing a submarine to approach well within ASM range. Powerful active sonars could be a way to overcome this approach, but almost all U.S. surface fleet

18 Thomas Rowden, "Sea Control First," *Proceedings Magazine* 143, no. 1, January 2017, available at https://www.usni.org/magazines/proceedings/2017-01/commentary-sea-control-first.

19 "CNO Visits Navy Warfare Development Command," *Navy News Service,* April 13, 2017, available at https://www.navy.mil/submit/display.asp?story_id=99893.

20 Mark Coffman, "Advancing Electromagnetic Maneuver Warfare," *NEXT* 3, no. 2, Navy Warfare Development Command, Summer/Fall 2015, available at https://www.nwdc.navy.mil/NeXT%20Assets/current/NeXTw2016.aspx.

active sonars are bow-mounted and limited in their reach by the sonic layer that lies 100–200 feet below the surface.[21] And even if a submarine is detected 100 nm or more away, surface combatants would need to rely on vulnerable, land-based P-8A Poseidon patrol aircraft to engage them due to the short range and endurance of shipboard helicopters.[22]

The U.S. Navy's adoption of distributed operations will not by itself reduce the surface fleet's vulnerability or increase its lethality. Concepts for distributed operations are often portrayed by Navy leaders as a way to complicate adversary targeting and create more opportunities for surface forces to attack the enemy.[23] Proliferation and improvements to commercial and military ground-based, acoustic, airborne, and satellite sensors will, however, likely overcome any complexity imposed by simply distributing today's fleet. Unless the U.S. surface force changes its approaches to surveillance, targeting, counter-ISRT, and engagement of air, surface, and undersea threats, it will have insufficient operational flexibility or weapons capacity to take advantage of distribution.

A More Coherent Way Ahead

The Navy will need to develop a more coherent approach to guide improvements to surface fleet survivability and lethality and implement it through potentially dramatic changes in surface force structure and capabilities. To that end, the Navy should adopt a new set of metrics that rely on directly measurable parameters or conservative assumptions that reflect the ability of surface forces to deter or defeat aggression. This study will use three main metrics to assess the value of various surface force improvements:

- **Complexity of U.S. surface force presentation.** This study enumerates the different ways in which a given surface force, including decoys, could be composed into effects chains of sensors, C2 elements, and effectors, assuming the adversary can find and classify each component of the force but not immediately discern between a decoy and real system. This metric reflects the level of difficulty imposed by U.S. distribution and counter-ISRT operations on an enemy's orientation and targeting process.

- **Salvo size needed by the adversary for a successful, immediate attack.** Assuming a conservative probability of success for enemy weapons, adversaries such as China, Russia, or Iran have enough ASMs to attack each U.S. surface combatant in their region with enough weapons to overcome the ship's defenses. U.S. surface force efforts to improve air defense capacity, degrade enemy ISRT, shift to passive sensing, and conduct

21 Vance Villareal, *Relationship Between The Sonic Layer Depth and Mixed Layer Depth Identified from U.S. Navy Sea Glider Data* (Monterey, CA: Naval Postgraduate School, 2014), pp. 5–43, available at https://apps.dtic.mil/dtic/tr/fulltext/u2/a620640.pdf.

22 "MH-60R Sea Hawk Helicopter," *Fact File*, U.S. Navy, February 6, 2019, available at https://www.navy.mil/navydata/fact_display.asp?cid=1200&tid=500&ct=1.

23 Thomas Rowden, Peter Gumataotao, and Peter Fanta, "Distributed Lethality," *Proceedings Magazine* 141, no. 1, January 2015; and "CNO Visits Navy Warfare Development Command."

distributed operations could all increase the number of weapons an adversary would need to launch to defeat a given surface force. If these U.S. efforts were integrated to be mutually reinforcing, they could further increase the salvo size required by an enemy. The salvo size needed for a single attack is a useful proxy for the level of effort an adversary will need to expend to better understand the targeting picture and eventually defeat U.S. forces in detail.

- **Offensive capacity of U.S. surface forces.** Simply imposing a large salvo cost on a potential aggressor will be insufficient to deter an act of aggression if the adversary perceives no threat to its own forces. A great power competitor like China or Russia could accept the cost of defeating U.S. forces and move on to its nearby objective unopposed. Therefore, U.S. surface force improvements should also be evaluated on their ability to reserve offensive capacity, even if that capacity is used as surface combatants withdraw to regroup and reload.

Potential surface force improvements

Viewing potential surface force improvements through the lenses of complexity, enemy salvo size, and offensive capacity provides a way to prioritize initiatives the Navy could pursue between now and 2035 as well as evaluate the impact of those initiatives on relevant surface fleet capabilities. Examples of improvements this study will propose include:

- Shifting toward shorter-range air defense tactics and systems to improve air defense capacity, combined with EMW operations to increase the uncertainty and number of potential targets presented to an attacker;
- Employing unmanned systems and vessels to find enemy submarines and aircraft-delivered ASW weapons to suppress submarine operations;
- Increasing the use of multi-mission weapons and USVs to maximize the surface fleet's capacity for offensive operations;
- Relying almost exclusively on passive and multi-static sensing and targeting to reduce the vulnerability of U.S. surface combatants to detection by the passive sensors that great powers employ to exploit their home field advantage; and
- Disaggregating surface fleet operations by incorporating a larger portion of smaller, less multi-functional ships and unmanned platforms to improve the ability of the force to adapt, incorporate new technology and systems, and impose complexity on adversaries.

Chapter 2 of this study will detail the changing strategic environment facing U.S. surface forces and the approach to U.S. strategy and force posture that is emerging in response. Chapters 3 and 4 will describe the new operational concepts and capabilities for future surface combatants that the Navy should pursue during the next 15 years. Chapters 5 and 6 propose a future family of surface combatants and an approach to implement a new fleet architecture.

CHAPTER 2

Surface Warfare Challenges, Strategy, and Opportunities

Navies will need to dramatically change how they conduct surface warfare in the face of increasingly contested operational environments and well-designed adversary strategies. Today's self-contained multi-mission surface combatants and their tactics resulted from nearly two decades of unfettered military access since the end of the Cold War. During that time, the lack of capable opponents allowed U.S. and allied surface forces to focus on efficiency over effectiveness by fielding shrinking fleets of warships designed to address the range of possible missions needed during a deployment.

Fleet architectures centered on monolithic multi-mission ships are now becoming a liability. Improving adversary sensing and precision attack capabilities make today's surface combatants more vulnerable, and smaller surface fleets make the force less resilient and reduce the commanders' flexibility in composing surface formations in ways that confuse or deceive an enemy. Moreover, the focus of surface forces on self-contained, multi-mission platforms limits the fleet's technological and operational adaptability because of the cost and difficulty involved in making changes to highly integrated warships.

The U.S. Navy will need to develop new operational concepts and a more affordable and flexible surface fleet architecture to compete effectively with China and Russia. This chapter will detail challenges posed to U.S. and allied surface fleets by the return of great power competition, tightening fiscal constraints, and today's fleet design. It will conclude with an interpretation of the role surface forces play in current U.S. defense strategy. Subsequent chapters will describe how the U.S. surface fleet can regain an advantage in surface warfare through new operational concepts and capabilities.

The Return of Great Power Competition

More than a quarter century after the Soviet Union's dissolution, the United States finds itself in a new kind of great power competition. In contrast to the bipolar contest between the United States and the Soviet Union that characterized the Cold War-era, this era is better characterized as a tripolar competition, at least in the short run, between the United States, China, and Russia.[24] China's efforts are focused in the East and South China Seas, where it has attempted to expand its territorial claims and influence at the expense of U.S. treaty allies Japan and the Republic of the Philippines, respectively.[25] A resurgent and active Russia seeks to recapture its great power status and regional standing, which includes restoring a sphere of influence near its territory to form a buffer of friendly or neutral states between Russia and potential adversaries, such as members of the North Atlantic Treaty Organization (NATO) alliance.

Power projection versus counter-intervention

For the first time in more than a generation, the U.S. military's ability to project power around the world is not assured. China and Russia have established battle networks capable of tracking and engaging U.S. forces at range.[26] Degrading and denying U.S. power projection is an essential element of Chinese and Russian efforts to reshape regional balances in their favor. By raising the level of escalation needed for the United States to intervene on behalf of an ally suffering Chinese or Russian aggression, these adversaries aim to erode the credibility of U.S. security assurances as part of so-called "counter-intervention" strategies. This may not only undermine the leadership of the United States, but also make neighboring nations more likely to accede to Chinese or Russian demands.

China

China's People's Liberation Army (PLA) has established a comprehensive network of counter-intervention capabilities, as shown in Figure 6, including long-range land attack and anti-ship missiles; land, air, sea, and space-based ISRT systems; resilient C3 networks; cyber and EW weapons; and anti-satellite capabilities. Within this umbrella, China could project power to blockade or attack Taiwan, seize the Senkaku Islands, or occupy features such as Scarborough

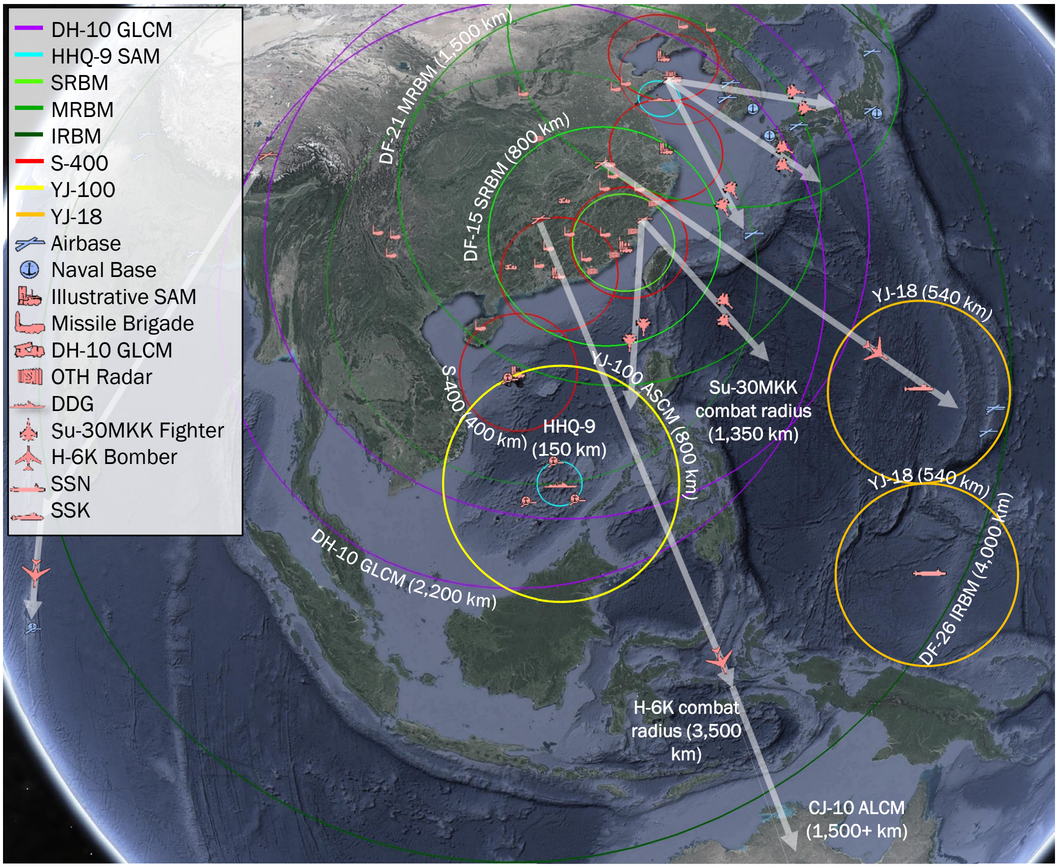
24 For how to address China and Russia, see Evan Braden Montgomery, *Reinforcing the Front Line: U.S. Defense Strategy and the Rise of China* (Washington, DC: Center for Strategic and Budgetary Assessments, 2017); and Eric S. Edelman and Whitney Morgan McNamara, *U.S. Strategy for Maintaining a Europe Whole and Free* (Washington, DC: Center for Strategic and Budgetary Assessments, 2017).

25 Mark Valencia, "South China Sea: America Needs a Better Strategy," *Straits Times*, June 30, 2017. For further assessments and a timeline of Chinese expansionism in the South China Sea, see Ross Babbage, *Countering China's Adventurism in the South China Sea: Strategy Options for the United States and Its Allies*, revised edition (Washington, DC: Center for Strategic and Budgetary Assessments, 2017).

26 See Barry D. Watts, *Six Decades of Guided Munitions and Battle Networks: Progress and Prospects* (Washington, DC: Center for Strategic and Budgetary Assessments, 2007), pp. 3–4.

Shoal.[27] In addition, the PLA Air Force and Navy could attack U.S. and allied forces, bases, and communications and logistical nodes throughout the Indo-Pacific. The Chinese government has expanded its sensor and weapons network during the last decade by occupying disputed islands, building new ones on existing reefs, and militarizing islands seized in the past.[28] These islands and artificial features, some of which fall in the Exclusive Economic Zones of the Philippines and Indonesia, now regularly host PLA troops and aircraft that can threaten freedom of navigation throughout the South China Sea.

FIGURE 6: CHINA'S COUNTER-INTERVENTION CAPABILITIES



Data to build this chart was derived from IHS Jane's in January 2016 and December 2018.

The Chinese government uses a combination of civilian fishing vessels, coast guard ships, and maritime law enforcement troops to protect its island-building efforts and enforce its excessive

27 "Commentary: Respecting China's Core Interests is the 'Bottom Line' for Businesses," *Xinhua*, January 12, 2018.

28 Thomas Gibbons-Neff, "New Satellite Images Show Reinforced Chinese Surface-to-Air Missile Sites Near Disputed Islands," *Washington Post*, February 23, 2017.

maritime claims in a campaign of operations often characterized as gray zone warfare.[29] In addition to preventing access around islands and features to which the Chinese government has staked a claim, these paramilitary units harass and impede the maritime forces of its neighbors and the United States.[30] China's Maritime Militia provides the PLA with access to thousands of ships of varying types, many of whom have ostensibly commercial reasons for operating in the vicinity of military targets throughout the Indo-Pacific and beyond.

Russia

Russia's advanced air defenses, EW systems, strike aircraft, precision fires, and heavy infantry vehicles give it military superiority over its immediate neighbors, enabling the Russian military to rapidly invade neighbors such as the Baltic states, Georgia, Romania, or Bulgaria. The Russian military's counter-intervention capabilities can range NATO's eastern front-line states and extend into central Europe, allowing aircraft and missiles based in Russia to degrade a potential NATO response. And similar to China, Russia's counter-intervention capabilities raise the cost and disruption of an attempt to eject Russian forces after their initial aggression, making it less likely the United States and international community would undertake such an action. Russia also has interests in the Eastern Mediterranean and the Black Sea, which have seen a dramatic increase in Russian naval and air activity.[31] To support and protect these operations, the Russian military has expanded its facilities in Syria and the Crimean Peninsula, including the deployment of capabilities to extend the reach of its sensor and weapons networks.

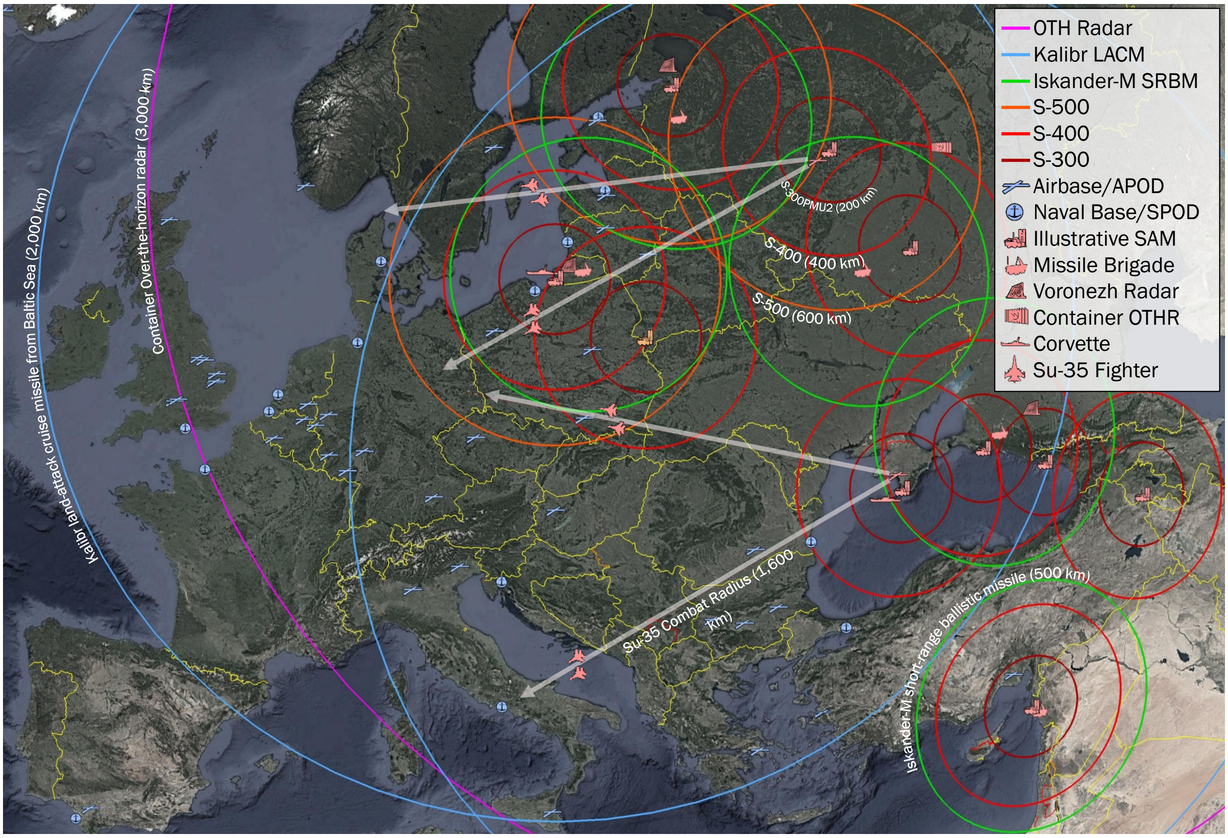
Russian and Chinese military capabilities are proliferating to nations such as Iran, North Korea, and others. Advanced land attack ballistic missiles, anti-ship cruise and ballistic missiles, and long-range anti-air networks are providing these states with more dangerous capabilities than those fielded by North Vietnam and other Soviet proxies during the Cold War. Armed with counter-intervention systems of their own, these strategically located regional powers could threaten the interests of the United States, its allies, and its partners.

29 As Hal Brands noted, "Gray zone conflict is best understood as activity that is coercive and aggressive in nature, but that is deliberately designed to remain below the threshold of conventional military conflict and open interstate war. Gray zone approaches are mostly the province of revisionist powers—those actors that seek to modify some aspect of the existing international environment—and the goal is to reap gains, whether territorial or otherwise, that are normally associated with victory in war. Yet gray zone approaches are meant to achieve those gains without escalating to overt warfare, without crossing established red-lines, and thus without exposing the practitioner to the penalties and risks that such escalation might bring. Gray zone challenges are thus inherently ambiguous in nature. . . . They represent that coercion that is, to varying degrees, disguised; they eat away at the status quo one nibble at a time." Hal Brands, "Paradoxes of the Gray Zone," *E-Notes*, Foreign Policy Research Institute, February 5, 2016, available at http://www.fpri.org/article/2016/02/paradoxes-gray-zone/.

30 Harry Kazianas, "China's Expanding Cabbage Strategy," *The Diplomat*, October 29, 2013, available at http://thediplomat.com/2013/10/chinas-expanding-cabbage-strategy/; and Nicholas Fedyk, "Russian 'New Generation' Warfare: Theory, Practice, and Lessons for U.S. Strategists," *Small Wars Journal*, August 25, 2016.

31 Andrea Macias, "A Detailed Look at How Russia Annexed Crimea," *Business Insider*, March 24, 2015.

FIGURE 7: RUSSIA'S COUNTER-INTERVENTION CAPABILITIES



Data to build this chart was derived from IHS Jane's in January 2016 and December 2018.

Key Operational Challenges for U.S. Naval Forces

Today's surface combatants would be challenged to carry enough defensive weapons to protect themselves in areas near China or Russia without giving up the offensive capacity needed to slow or stop aggression. Considering Chinese and Russian reconnaissance-strike networks and deployed forces as described above, the most immediate challenges for the surface fleet will be conducting AMD and ASW. Attacks from land, air, or sea are all likely to manifest themselves as ASM or UAV attacks, and submarines could threaten U.S. surface combatants with torpedoes or mines. Challenges posed by enemy air and subsurface threats for the U.S. surface fleet and their implications for surface force concepts and capabilities are detailed below.

Air and missile threats

The most significant threat facing the U.S. surface fleet is the large number of ASMs that China, Russia, and regional powers could fire from ground launchers, ships, or aircraft. The ASM threat is exacerbated by its increasing range. Today, most enemy ASMs have maximum ranges of around 500 nm, but current and emerging land attack cruise missiles (LACM) could be modified to have anti-ship capabilities as the U.S. Navy is doing with the Maritime Strike Tomahawk (MST). This could extend the range of ASMs to 900 nm or more.[32] The numbers and sophistication of air and missile threats demand that an increasing portion of U.S. surface combatant VLS magazines be devoted to defensive weapons, reducing the offensive weapons needed to degrade, delay, or deny enemy aggression.

The balance between surface combatants' proximity to targets and the need to defend surface forces from missile attack can be viewed in terms of a salvo competition.[33] In this competition, surface forces operating closer to an adversary's territory will have to defend against larger potential weapons salvos because shorter-range ASMs are less expensive and likely to be more numerous than longer-range strike weapons. Furthermore, enemy weapons platforms like submarines, ships, and aircraft are able to launch more attacks closer to shore because they can rely on protection from mainland-based defenses and more easily reload.

Figure 8 shows the approximate weapons payload that the PLA could deliver at various ranges and the number of launchers and aircraft able to deliver this payload. Although not all of these weapons are configured for anti-ship missions, most ballistic missiles have an anti-ship variant, and it is reasonable the PLA could develop an anti-ship modification to the DH-10 LACM, similar to that planned for the U.S. Navy Tomahawk cruise missile.

Figure 8 suggests that beyond about 1,000 nm from the Chinese mainland, U.S. naval forces would be at risk from the PLA Air Force (PLAAF) bombers and fighter-bombers carrying ASMs and PLA Rocket Force (PLARF) DF-26 intermediate-range ballistic missiles (IRBM). Assuming each weapon is configured with a 1,000-lb warhead, a U.S. naval force located about 1,000 nm from China could face over 4,500 weapons over the course of a single day.[34] However, factoring in missile launcher capacity and aircraft hardpoint constraints reduces the number of weapons that U.S. forces may need to defeat to about 530 weapons in a single

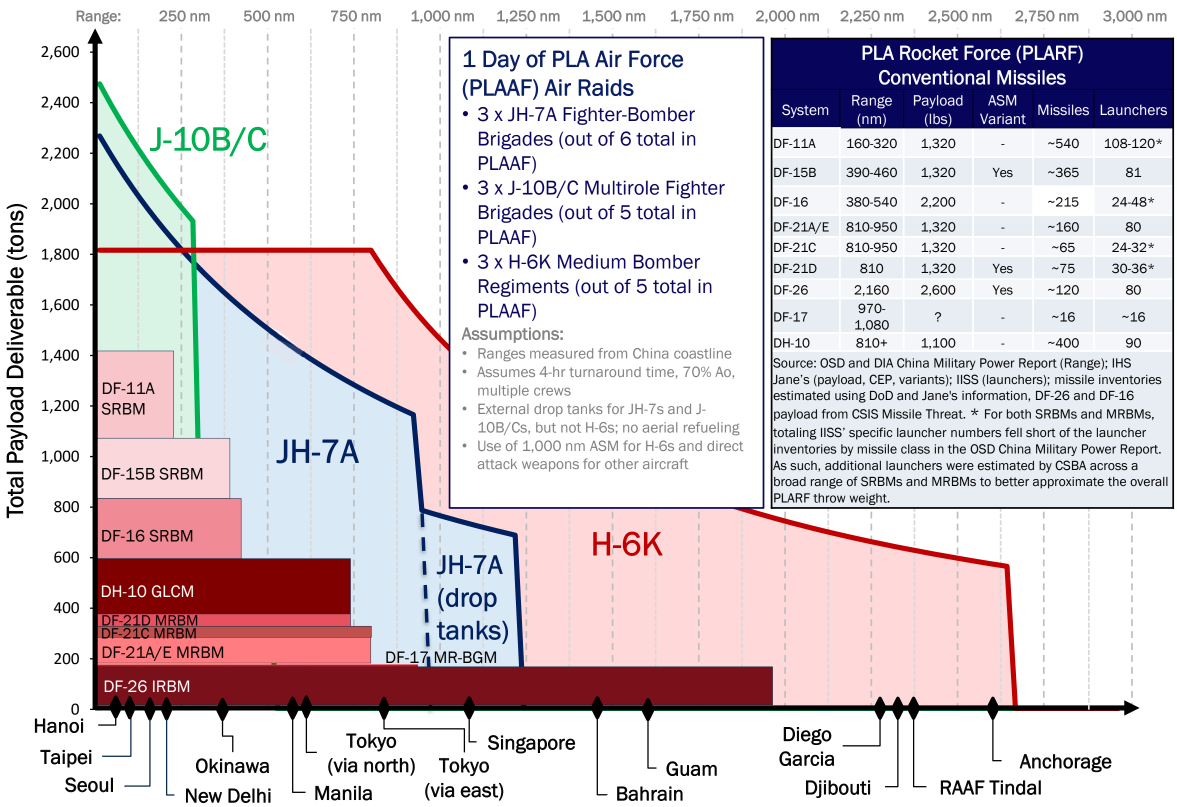
32 The U.S. Tomahawk land attack cruise missile has a range of more than 900 nm, and the Maritime Strike Tomahawk can be expected to have a similar range. The Tomahawk is a 25-year-old weapon, and it is likely the Chinese DH-10 and Russian Kalibr missiles share similar characteristics. ASM versions of these missiles could be expected to have ranges of more than 1,000 nm. See "Tomahawk Cruise Missile," *Fact File*, U.S. Navy, updated April 26, 2018, available at http://www.navy.mil/navydata/fact_display.asp?cid=2200&tid=1300&ct=2; Jeffrey Lin and P.W. Singer, "China Shows Off Its Deadly New Cruise Missiles," *Popular Mechanics,* March 10, 2015, available at https://www.popsci.com/china-shows-its-deadly-new-cruise-missiles; and Sebastien Roblin, "Kalibr: Russia Has Its Own 'Tomahawk' Cruise Missile," *The National Interest,* April 7, 2017, available at http://nationalinterest.org/blog/the-buzz/kalibr-russia-has-its-very-own-tomahawk-missile-20073.

33 The dynamics and implications of the salvo competition are described in Mark Gunzinger and Bryan Clark, *Sustaining America's Precision Strike Advantage* (Washington, DC: Center for Strategic and Budgetary Assessments, 2015); and Mark Gunzinger and Bryan Clark, *Winning the Salvo Competition: Rebalancing America's Air and Missile Defenses* (Washington, DC: Center for Strategic and Budgetary Assessments, 2016).

34 This includes approximately 160 tons from DF-26 IRBMs, 770 tons from JH-7A fighter-bombers, and 1,450 tons from H-6 bombers, for a total of 2,380 tons of ordnance with an equivalent strike potential of 4,760 1,000-lb weapons.

incoming salvo.[35] This threat will likely grow in range and scale with the PLA's fielding of new, longer-range aircraft like the H-20 bomber and the incorporation of longer-range weapons on existing surface combatants and aircraft.

FIGURE 8: PLA CRUISE AND BALLISTIC MISSILE THROW WEIGHT, INCLUDING THE POTENTIAL ASM PAYLOAD OF SOME PLAAF AIRCRAFT



PLA Rocket Force (PLARF) Conventional Missiles					
System	Range (nm)	Payload (lbs)	ASM Variant	Missiles	Launchers
DF-11A	160-320	1,320	-	~540	108-120*
DF-15B	390-460	1,320	Yes	~365	81
DF-16	380-540	2,200	-	~215	24-48*
DF-21A/E	810-950	1,320	-	~160	80
DF-21C	810-950	1,320	-	~65	24-32*
DF-21D	810	1,320	Yes	~75	30-36*
DF-26	2,160	2,600	Yes	~120	80
DF-17	970-1,080	?	-	~16	~16
DH-10	810+	1,100	-	~400	90

Source: OSD and DIA China Military Power Report (Range); IHS Jane's (payload, CEP, variants); IISS (launchers); missile inventories estimated using DoD and Jane's information, DF-26 and DF-16 payload from CSIS Missile Threat. * For both SRBMs and MRBMs, totaling IISS' specific launcher numbers fell short of the launcher inventories by missile class in the OSD China Military Power Report. As such, additional launchers were estimated by CSBA across a broad range of SRBMs and MRBMs to better approximate the overall PLARF throw weight.

Undersea threats

Chinese and Russian efforts to counter U.S. power projection also extend underwater. China is modernizing its undersea force, to include both diesel and nuclear submarines. Although relatively noisy compared to U.S. submarines, the PLA Navy has more submarines than the U.S. Navy and can focus its efforts in the Western Pacific and Indian Oceans.[36] Although Russia's

35 Using the data in Figure 8, there are about 80 launchers for DF-26 IRBMs capable of delivering one weapon each. Moreover, assuming a 70 percent aircraft availability rate and a 1,000 nm combat radius, a force of 70 JH-7s could deliver approximately 196 weapons; assuming a 70 percent aircraft availability rate and a 1,000 nm combat radius, a force of 60 H-6s could deliver approximately 252 weapons. Therefore, approximately 528 weapons could be delivered simultaneously by these assets against targets at 1,000 nm.

36 ONI, *The PLA Navy: New Capabilities and Missions for the 21st Century* (Washington, DC: ONI, April 9, 2015), pp. 13–25, available at http://www.oni.navy.mil/Portals/12/Intel%20agencies/China_Media/2015_PLA_NAVY_PUB_Print.pdf?ver=2015-12-02-081247-687.

submarine fleet is smaller than the U.S. Navy's, its latest class of nuclear submarines is reportedly as quiet as some of the newest U.S. submarines, and previous generations are on par with older U.S. submarines.[37]

Surface forces will be challenged to detect and engage submarines before they approach within ASM range. Surface combatant hull-mounted sonars are constrained from detecting submarines below about 100–300 feet by the surface sound layer, and passive towed array sonars will be limited by the quieting and countermeasures used by modern Chinese and Russian submarines.[38] The surface fleet's ASW challenge will be compounded by the increasing range of ASMs simply by expanding the area over which the fleet must search. Moreover, even if enemy submarines are detected before they can attack, surface combatants can only engage them with ASW rockets (ASROC) or helicopter-borne torpedoes, neither of which can reach more than 100 nm away.[39]

The U.S. Navy would normally rely on its own submarines or maritime patrol aircraft (MPA) to conduct ASW at long ranges from surface forces, but these platforms may not be able to operate near adversary territory. The Chinese and Russian militaries are establishing undersea sensor networks like the U.S. Sound Surveillance System (SOSUS) and incorporating low frequency active (LFA) sonar on ASW corvettes and frigates to find U.S. submarines. And even if PLA ASW attacks are unsuccessful, they could have the effect of compelling U.S. submarines to break off their operations and leave the area.[40] Similarly, U.S. land-based MPA such as the P-8A Poseidon may be unable to conduct ASW within hundreds of miles of China's or Russia's coasts due to enemy air defenses or fighters. As a result, the U.S. surface fleet will need new concepts and capabilities for conducting ASW at longer ranges and over wider areas to defeat enemy submarines before they reach ASM range.

The surface fleet will also need new capabilities and concepts for mine warfare. Mining, which has not been considered a high-priority mission in recent years, may be an attractive option to address the threat of Chinese or Russian submarines and constrain the movement of enemy surface combatants. More urgently, however, naval forces will need to address the threat posed by enemy mines, especially those deployed by strategically located regional powers like

37 Kathleen H. Hicks, Andrew Metrick, Lisa Sawyer Samp, and Kathleen Weinberger, *Undersea Warfare in Northern Europe* (Washington, DC: Center for Strategic and International Studies, 2016), pp. 10–12.

38 Villareal, *Relationship Between the Sonic Layer Depth and Mixed Layer Depth Identified from U.S. Navy Sea Glider Data*, pp. 5–43.

39 Stephen Valerio, *Probability of Kill for an ASROC Torpedo Launch*, M.S. Thesis (Monterey, CA: U.S. Naval Postgraduate School, 2009); "Vertical Launch ASW Rocket," *Fact File*, U.S. Navy, December 6, 2013, available at https://www.navy.mil/navydata/fact_display.asp?cid=2200&tid=1500&ct=2. The MH-60R ASW helicopter has a range of 380 nm; assuming an ASW engagement 100 nm away would leave about an hour on station to localize a possible submarine and attack it. See "MH-60R Seahawk Multimission Helicopter," *Fact File*, U.S. Navy, February 6, 2019, available at https://www.navy.mil/navydata/fact_display.asp?cid=1200&tid=500&ct=1.

40 Lyle Goldstein and Shannon Knight, "Wired for Sound in the Near Seas," *Proceedings*, April 2014, available at http://www.usni.org/magazines/proceedings/2014-04/wired-sound-near-seas; and Hicks, Metrick, Samp, and Weinberger, *Undersea Warfare in Northern Europe*, pp. 10–12.

Iran. The Navy has placed a higher priority on MCM since 2010 with the introduction of the LCS, but development and fielding of LCS MCM mission packages is almost a decade behind schedule.[41]

Changes in U.S. Strategy

The operational challenges faced by U.S. naval forces largely derive from the home field advantage of America's adversaries. By establishing regional military superiority and delaying the arrival of U.S. and allied forces, China and Russia could quickly execute an invasion or seizure and present the international community with a *fait accompli*. U.S. forces attempting to reverse the results of such an operation would need to deploy under the threat of adversary precision weapons, rather than safely mobilizing in adjacent countries as U.S. and allied forces did to prepare for Operation Desert Storm. The resulting great power conflict would likely be bloody and costly, and it could escalate to a nuclear confrontation. These factors would likely reduce diplomatic or military support for the operation among U.S. allies and partners.[42]

America's adversaries and allies understand U.S. forces would be challenged to reverse the results of an attack or invasion. This could embolden great power competitors and regional powers to be more assertive, as well as make allies more likely to give in to coercion. To sustain the effectiveness of American deterrence and reassurance, the 2018 U.S. NDS shifted the U.S. military's operational approach from responding to acts of aggression to denying and delaying them altogether.[43]

The emphasis on denying aggression in the NDS has significant implications for force posture, capabilities, and metrics. To enable prompt responses to aggression, the strategy reorganizes deployed U.S. military forces into a Contact layer that remains forward to engage with allies and adversaries and a Blunt layer that augments the Contact layer in the event of a conflict. Surge forces based in the continental United States would reinforce the Contact and Blunt layers. To increase an adversary's uncertainty regarding the U.S. force it could face, the strategy complements its posture model with Dynamic Force Employment, which varies the timing, location, and nature of U.S. deployments.

In many situations, naval forces will be the primary military instrument to deter aggressors and reassure allies. Although they have a finite weapons capacity, naval forces can operate

41 See Scott Truver, "Taking Mines Seriously," *Naval War College Review* 65, no. 2, Spring 2012, available at https://digital-commons.usnwc.edu/nwc-review/vol65/iss2/5; and "Littoral Combat Ships: Mine Countermeasures Mission Package," *Fact File*, U.S. Navy, updated December 6, 2016, available at http://www.navy.mil/navydata/fact_display.asp?cid=2100&tid=425&ct=2.

42 Elbridge Colby, "Implementation Of The National Defense Strategy," testimony before the Senate Armed Services Committee, January 29, 2019, available at https://www.armed-services.senate.gov/imo/media/doc/Colby_01-29-19.pdf; and Eric Edelman and Gary Roughead, *Providing for the Common Defense: The Assessment and Recommendations of the National Defense Strategy Commission* (Washington, DC: U.S. Institute of Peace, 2018), available at https://www.usip.org/sites/default/files/2018-11/providing-for-the-common-defense.pdf.

43 OSD, *Summary of the 2018 National Defense Strategy of the United States of America*, p. 7.

persistently in international waters near a potential area of conflict. They also operate with less chance of provoking the enemy and less impact on the local population than forces based on allied territory. Ships self-deploy, enabling the level of force to be scaled commensurate with the situation. Once in an operating area, however, they may require access to fuel and supplies from the region.[44]

U.S. surface forces are likely to play different roles in the Contact and Blunt layers. In the Contact layer, surface combatants will need to conduct offensive operations rapidly against enemy surface, air, and amphibious forces. To maximize the speed and capacity of offensive operations, U.S. surface combatants will need to employ strike missiles, ASMs, and anti-air interceptors fired from VLS magazines or deck-mounted launchers. At the same time, surface combatants will need to protect themselves against large salvos of enemy ASMs, constraining the capacity that ships in the Contact layer can devote to offensive weapons. In the Blunt layer, surface combatants will likely need to defend aircraft carriers, amphibious forces, and bases ashore, and their weapons magazines will be devoted predominantly to air defense interceptors.

Institutional Challenges for U.S. Forces

The Navy will face significant headwinds in its efforts to overcome the operational challenges China and Russia are imposing on the United States. Budget constraints, technological proliferation, and the U.S. military's focus on imposing attrition will hinder the ability of the Navy to gain an advantage in what is likely to be a long-term competition. Changes to surface force concepts and capabilities will need to be affordable, sustainable, and designed for an era in which military success is increasingly achieved through superior decision-making, rather than killing more of the enemy.

Constrained funding

Improvements to the surface force are unlikely to benefit from further increases to defense spending. In fact, some Congressional leaders oppose further defense budget growth, in part out of concern for rising costs to service U.S. federal debt and fund non-discretionary Medicare and Social Security benefits.[45] Within the defense budget, the Navy is unlikely to receive a greater percentage of DoD spending based on historical trends in which budget shares among the U.S. military departments have varied only modestly.

The Navy's ability to improve surface force capability and capacity will be further hindered by the growing cost to operate and maintain the fleet and compensate each servicemember.

44 See Geoffrey Till, *Seapower: A Guide for the Twenty-First Century* (Portland, OR: Frank Cass, 2004), pp. 162–192; and Milan Vego, *Maritime Strategy and Sea Control: Theory and Practice* (New York: Routledge, 2016), pp. 18–27.

45 Joe Gould, "Lawmakers Push and Pull Over $750B Defense Policy Bill NDAA Top Line at HASC Markup," *Defense News,* June 13, 2019.

Operations and maintenance expenditures have risen steadily as a percentage of Navy budgets since the 1960s, crowding out funding for R&D and procurement.[46] Compensation costs for each U.S. servicemember also increased dramatically after 2000 with the introduction of larger annual pay increases and new benefits such as Tricare-for-Life and the Post 9/11 GI Bill.[47] Recruiting highly skilled operators could require further growth in compensation, especially in an increasingly competitive employment environment where a decreasing number of young people are eligible for military service.[48] In part due to increases in the cost to buy, operate, maintain, and crew each multi-mission platform and unit, U.S. military force structure and end strength both shrank during the last two decades, despite large and steadily increasing defense budgets.[49]

A level technological playing field

Technologies the U.S. military used to win the Cold War have now proliferated to great power and regional competitors. Stealth aircraft, guided weapons, precision navigation systems, and wide-area communication networks have been fielded by the Russian, Chinese, and other militaries.[50] To pursue a decision-centric approach to warfare, DoD will need to exploit emerging computing and information technologies such as AI and autonomous systems. These technologies are being advanced primarily through commercial investment, which now greatly exceeds government and DoD spending on research and development. The U.S. military, however, will be hindered in incorporating commercial technologies due to the highly integrated nature of the multi-mission platforms that make up most of the U.S. force.

The wrong approach for long-term competition

The 2017 U.S. National Security Strategy and 2018 NDS posit that the emerging great power competition between the United States, China, and Russia will persist over the long term.[51] The goal in such a competition would be to establish and sustain economic, political, and

46 David A. Arthur, "The Increasing Costs of the Department of Defense," Congressional Budget Office presentation, November 9, 2018, slides 3–5, available at https://www.cbo.gov/system/files/2018-11/54688-presentation.pdf.

47 Mark Cancian, "The Impact of Rising Compensation Costs on Force Structure," *Joint Force Quarterly*, 2015, available at https://ndupress.ndu.edu/JFQ/Joint-Force-Quarterly-79/Article/621134/the-impact-of-rising-compensation-costs-on-force-structure/.

48 John Grady, "Panel: Pentagon Facing Future Recruiting Challenge Due to Lack of Candidates," *USNI News*, October 12, 2017.

49 Steve Kosiak, *Is the U.S. Military Getting Smaller and Older?* (Washington, DC: Center for a New American Security, 2017), p. 1.

50 Defense Intelligence Agency (DIA), *Russia Military Power: Building a Military to Support Great Power Aspirations* (Washington, DC: DIA, 2017), p. 23, available at https://www.dia.mil/Portals/27/Documents/News/Military%20Power%20Publications/Russia%20Military%20Power%20Report%202017.pdf?ver=2017-06-28-144235-937; OSD, *Military and Security Developments Involving the People's Republic of China 2019*.

51 OSD, *Summary of the 2018 National Defense Strategy of the United States of America*, p. 2.

military advantages, but competitors should not necessarily expect prompt capitulation by their opponents or a rapid overturning of the status quo.[52]

Today's multi-mission units and attrition-centric U.S. concepts such as Distributed Maritime Operations (DMO) may not be well-suited for a long-term competition. Implied in attrition-based warfare is the expectation that a military force can establish superiority when needed in order to attrite enemy forces. In a long-term competition against adversaries like China and Russia, U.S. and allied forces may be unable to reliably achieve the superiority needed to win a confrontation through attrition alone. Moreover, as evidenced by the increased use of gray zone warfare by the Chinese and Russian governments, America's adversaries may avoid initiating a conflict in which U.S. forces could employ high-intensity precision strike warfare.

Opportunities to Regain an Advantage

The operational and institutional challenges facing the U.S. surface fleet are formidable, but not insurmountable. Rather than pursuing incremental improvements to a force designed to impose attrition, the Navy could adopt maneuver warfare concepts, which seek to overwhelm adversaries' decision-making with multiple dilemmas and high operational tempo.[53] Specifically, a maneuver warfare approach focused on achieving superior decision-making could deter conflict by creating uncertainty for an aggressor as to its probability of success or the level of risk that U.S. forces pose to an aggressor's centers of gravity. Such an approach could challenge the PLA's concept of System Destruction Warfare, in which PLA forces would attempt to disintegrate what the PLA considers a relatively fixed U.S. system of system (SoS) architecture. Instead, U.S. surface forces could generate numerous fluid effects chains that would be difficult for adversaries like China to assess and counter.

A warfighting concept centered on maneuver and decision-making could benefit from a surface fleet that is more disaggregated and able to conduct numerous high-risk operations or impose greater complexity on an enemy's sensing and orientation processes. Such an approach could be a more effective at deterring and defeating aggression than solely relying on the threat of a large-scale attrition campaign. It could also improve the fleet's ability to adapt. By fielding more platforms that perform fewer functions and require less integration, the Navy would be able to more easily incorporate new components into each successive generation.

These elements will be explored in the following chapters, which will describe new concepts for surface warfare missions, the capabilities needed to implement those concepts, and how an evolution of the U.S. Navy surface fleet architecture could be implemented during the next decade.

52 Hal Brands, "The Lost Art of Long-Term Competition," *The Washington Quarterly* 41, no. 4, pp. 31–51, available at https://doi.org/10.1080/0163660X.2018.1556559.

53 Robert Leonhard, *The Art of Maneuver: Maneuver Warfare Theory and AirLand Battle (*New York, NY: Ballantine Books, 1991), pp. 21–23.

CHAPTER 3

New Operational Concepts for the Surface Fleet

The militaries of U.S. competitors such as China, Russia, and Iran have fielded a comprehensive set of operational challenges designed to reduce the ability of U.S. naval forces to defend U.S. allies and interests against aggression. Overcoming these challenges using current operational concepts and capabilities will likely be infeasible for the planned U.S. surface fleet due to the institutional head winds facing the Navy. New concepts for theater-wide naval operations and surface fleet missions will be needed to enable naval forces to sustainably contribute to U.S. strategy and deter conflict.

Emerging Naval Operational Concepts

The emerging generation of operational concepts being pursued by the Navy and Marine Corps, described below, are designed to complicate enemy targeting and enable naval forces to concentrate fires on enemy forces. Although they begin to shift the Navy's warfighting emphasis toward superior decision-making, the continued reliance of these concepts on attrition to defeat the enemy will limit their ability to overcome the dense sensor coverage and precision weapons capacity of potential U.S. adversaries. The Navy and Marine Corps will need to advance these concepts further to defeat the home field advantage enjoyed by militaries like those of China, Russia, or Iran.

Distributed Maritime Operations (DMO)

The most prominent new naval operational concept is DMO, which evolved from the concept of Distributed Lethality proposed by surface fleet leaders in 2015. The central idea of Distributed Lethality was that each surface combatant, amphibious warship, and logistics ship should have an offensive capability. Expanding the number and distribution of U.S. surface threats would complicate an enemy's targeting and give U.S. forces more opportunities to take the initiative by engaging the enemy first.[54] The Distributed Lethality concept, however, has several shortfalls. Adding weapons to new platforms lacking organic sensors would make them dependent on receiving targeting information in a potentially highly contested electromagnetic environment. Platforms without robust defenses might likewise not survive long enough to effectively employ their offensive weapons. Finally, under Distributed Lethality, the Navy would deploy too few platforms to sufficiently complicate enemy decision-making or grow the number of weapons needed for an attack beyond what the enemy is willing to expend.

DMO seeks to address the limitations of Distributed Lethality by integrating naval forces across domains throughout a theater to provide targeting and coordinate fires. Unlike Distributed Lethality, naval forces employing DMO would only place offensive weapons on combatant ships; warship defenses would be improved by deploying decoys to draw enemy fire and incorporating directed energy weapons (such as lasers and high-powered microwave [HPM]) onto surface combatants. By combining distribution, decoys, and better defenses, DMO would increase the size of an attack needed for an adversary to defeat U.S. naval forces, thereby deterring aggression. It might also require the adversary to take more time to determine the most advantageous way to conduct a smaller attack, thereby delaying aggression.[55]

Another major difference between the two concepts is span of control. Whereas Distributed Lethality focused on the tactical level, DMO orchestrates operations at the theater level. The wider scope of DMO activities includes ways to provide third-party or remote sensor information to fires platforms, improve defenses through mutual support or employing offensive fires against imminent threats, and coordinate offensive fires to defeat well-protected targets.

The Navy, particularly the surface Navy, has failed to implement DMO in the fleet's platforms and mission systems. If surface forces are going to operate in a distributed manner, their air defense focus could shift from protection of other ships or bases to self-defense. Surface combatants could therefore adopt air defense tactics that engage enemy missiles at closer ranges, such as using directed energy weapons or small, inexpensive short-range interceptors in place of large, expensive long-range interceptor missiles. If the fleet is going to operate in distributed formations but coordinate sensing and fires between them, individual platforms do not need to be capable of conducting multiple missions. Some multi-mission surface combatants could be replaced by a group of smaller, less-expensive manned and unmanned platforms. The Navy is not pursuing these facets of a DMO strategy, which will be addressed by this study's concepts and fleet architecture.

54 Distributed Lethality and related concepts are designed to make more ships able to conduct anti-ship and strike operations and to expand the multi-mission capability of ships that already have offensive capabilities. See Thomas Rowden, Peter Gumataotao, and Peter Fanta, "Distributed Lethality," *Proceedings*, January 2015, available at http://www.usni.org/magazines/proceedings/2015-01/distributed-lethality;

55 "CNO Visits Navy Warfare Development Command"; and Christopher H. Popa et al., *Distributed Maritime Operations and Unmanned Systems Tactical Employment* (Monterey, CA: Naval Postgraduate School, 2018), available at https://apps.dtic.mil/docs/citations/AD1060065.

A significant operational weakness of DMO is the need for robust, theater-wide communication networks to coordinate offensive, defensive, and counter-ISRT effects from a more distributed force. Navy leaders insist the communication requirements for distributed operations are manageable because individual manned or unmanned units will be highly autonomous, individual commanders will rely on mission command to govern their actions in the absence of higher direction, and the communications needed to pass targeting information or coordinate fires will be minimal.[56]

The confidence of senior Navy leaders in the viability of DMO in a contested communications environment is likely misplaced. DMO assumes that theater-level commanders are able to develop a plan that can accommodate improvisation after communications are lost. Junior commanders, however, are unlikely to have the time and planning resources to either continue with an existing plan by predicting the actions being taken by other friendly forces or formulating and executing a new plan that exploits the complexity demanded by the DMO concept. Given the lack of planning tools, junior commanders will likely fall back to the previous plan, resulting in a growing lack of coordination as the operation progresses. Alternatively, if commanders improvise a new plan, they will have to fall back on habit or doctrine, resulting in less-complex and more-predictable operations that an adversary will more easily counter. Some approaches to mitigate these vulnerabilities are addressed by this study's proposed concept of Context-Centric C3 described below.

Electromagnetic Maneuver Warfare (EMW)

The Navy intends to mitigate the impacts of a contested EMS using its EMW concept.[57] EMW seeks to gain control of the EMS by carefully managing the electromagnetic (EM) emissions of U.S. naval forces, exploiting the emissions of enemy forces or noncombatants, and integrating kinetic and non-kinetic fires to improve defensive capacity and offensive proportionality. Naval forces can manage their emissions using systems such as Real-Time Spectrum Operations (RTSO) to reduce an enemy's ability to detect, identify, or target friendly units, as well as employ decoys or deceptive emissions to create additional contacts for an adversary to investigate. U.S. surface forces can, however, also use the EM emissions of adversaries to find and classify potential enemy targets, which may compel adversaries to reduce their own emissions with a concurrent reduction in detection range and precision.

Although the Navy is fielding RTSO systems on all combatants, the surface fleet has not developed the tactics or the systems needed to employ passive or multistatic targeting that would enable U.S. warships to take advantage of spectrum monitoring by turning off their radars. For example, using passive sensors for detection and targeting will require platforms able to more

56 Scott Swift, "Master the Art of Command and Control," *USNI Proceedings,* February 2018, available at https://www.usni.org/magazines/proceedings/2018/february/master-art-command-and-control.

57 John Joyce, "Navy Expands Electromagnetic Maneuver Warfare for 'Victory at Sea'," *Navy News Service,* November 2, 2017, available at https://www.navy.mil/submit/display.asp?story_id=103165.

closely approach enemy forces and integrate detections from multiple aspects. The surface force may need to deploy smaller unmanned surface and air vehicles in greater numbers than it is currently planning in order to create such a passive sensor network.[58]

EM capabilities including EW systems and directed energy weapons are becoming an increasingly important element of offensive and defensive fires; their essentially infinite magazine provides greater capacity than munitions or missiles. The ability of EW or HPM and laser systems to defeat enemy platforms or electronics with less physical damage also provides more proportional options to commanders than traditional weapons.[59] To improve its exploitation of EM capabilities, the Navy accelerated introduction of its all-digital multi-function wideband SLQ-32(V)6 Block 3 EW system and is installing a 60 kW laser on USS *Preble* in 2021.[60] The surface fleet, however, has not made the tactical changes necessary to take advantage of directed energy weapons in air defense. As line-of-sight weapons, the only way for lasers or HPM to take the place of interceptor missiles is to conduct air defense at shorter ranges than preferred by today's tactics.

Littoral Operations in a Contested Environment (LOCE) and Expeditionary Advance Base Operations (EABO)

The Navy and Marine Corps are implementing new concepts for operations on and near shore. The littoral environment is exceptionally challenging for naval forces because ships are constrained in their ability to maneuver close to shore, and are exposed to more numerous and diverse threats than in open ocean. The LOCE concept proposes ways for naval forces to conduct offensive actions from Littoral Combat Groups that combine amphibious ships, surface combatants, and Carrier Strike Groups. These units would defend themselves against littoral threats using distribution and maneuver in multiple domains, managed by new C2 structures and processes.[61]

In concert with DMO and LOCE, EABO seeks to enable Marines to conduct mobile and distributed operations in austere conditions ashore for the purpose of providing fires, ISRT, EW, and ground support to an overall naval force. Like individual ships or SAGs, Expeditionary Advanced Bases (EAB) would form part of an integrated naval force within the

58 Mark Johnson, "Real-Time Spectrum Operations (RTSO)," presentation to National Spectrum Management Association, May 15, 2019, available at https://nsma.org/wp-content/uploads/2019/05/real-time-spectrum-operations.pdf.

59 Sydney J. Freedberg Jr., "Navy Forges New EW Strategy: Electromagnetic Maneuver Warfare," *Breaking Defense*, October 10, 2014.

60 Sam LaGrone, "Navy Ready to 'Burn the Boats' with 2021 Laser Installation on a Destroyer," *USNI News*, March 20, 2019; and Sam LaGrone, "Northrop Grumman Awarded $27.6M Contract to Build First Two SEWIP Block III Ship Sets," *USNI News,* January 15, 2019.

61 "Littoral Operations In A Contested Environment," *Marine Concepts and Programs*, U.S. Marine Corps, available at https://www.candp.marines.mil/Concepts/Subordinate-Operating-Concepts/Littoral-Operations-in-a-Contested-Environment/.

arc of adversary long-range precision fires to support U.S. allies and partners.[62] This would create a larger number of dispersed targets for an adversary to address and multi-axis threats to enemy forces. Although Marine units at EABs will only have small numbers of ASMs or air defense interceptors, they would require adversary ships and aircraft to shift capacity from offensive weapons to defenses. This could reduce the ability or capacity of an adversary to project power across areas defended by Marine forces, such as the Philippines or Southwest Islands of Japan.[63]

The surface fleet has not yet developed the operational concepts or capabilities to support or leverage EABO as part of theater-wide maritime operations. The current amphibious fleet consists of a small number of large warships that have minimal self-defense capabilities. Marines distributed over an island chain and conducting EABO may need to be sustained, relocated, or defended by a combination of amphibious and logistics ships protected by surface combatants, or directly by surface combatants and unmanned vessels operated as part of an integrated naval fleet.

New Approaches to Surface Fleet Missions

The new operational concepts being pursued by the Navy and Marine Corps will require different approaches for surface forces to conduct their missions. The urgency of implementing these changes is intensified by the worsening threat environment and the growing inability of other naval warfare communities to support the NDS objective of deterrence by denial. U.S. carrier air wings (CVW) lack the range to deliver significant weapons salvos or air patrols from areas where carrier strike groups can defend themselves.[64] Improving Chinese and Russian ASW capabilities will increase the risk to U.S. submarines of being counter-detected if they were to conduct torpedo or missile attacks close to adversary territory. As a result, the U.S. surface fleet will increasingly need to perform offensive missions inside contested areas.

Future surface forces will need to conduct ISRT, counter-ISRT, maritime strike or ASUW, STW against land targets, ASW, AMD, and MSO.[65] Although surface combatants have performed these missions in the past, their modes of execution will evolve in two signifi-

62 David H. Berger, *Commandant's Planning Guidance: 38th Commandant of the Marine Corps* (Arlington, VA: Headquarters, U.S. Marine Corps, 2019), p. 11, available at https://www.hqmc.marines.mil/Portals/142/Docs/%2038th%20Commandant%27s%20Planning%20Guidance_2019.pdf?ver=2019-07-16-200152-700.

63 This effect, also known as "virtual attrition," is described in John Stillion and Bryan Clark, *What it Takes to Win: Succeeding in 21st Century Battle Network Competitions* (Washington, DC: Center for Strategic and Budgetary Assessments, 2015).

64 This challenge is explained further in Bryan Clark et al., *Regaining the High Ground at Sea: Transforming the U.S. Carrier Air Wing for Great Power Competition* (Washington, DC: Center for Strategic and Budgetary Assessments, 2019).

65 There are other significant missions that surface fleet forces will need to conduct (such as the deployment of small units of marines or special forces or collecting intelligence), but in general these other missions should not be primary drivers of the size or composition of the surface warfare force.

cant ways. First, the capabilities required to conduct these missions will increasingly rely on unmanned systems to enable new sensing and engagement tactics. Second, surface fleet missions will take place across multiple domains. This section describes new concepts the surface fleet will need to employ by the 2030s against great power and regional adversaries.[66]

Context-centric C3

U.S. surface forces will likely operate in a contested and congested EMS during future conflicts. To overcome this challenge, DoD is investing significant resources in the development of resilient and adaptable communications architectures, including new low earth orbit (LEO) satellite constellations, UAV relays, and jam-resistant radios.[67]

Despite these investments, U.S. forces may be unable to sustain high or moderate bandwidth communications over wide areas due to their proximity to adversary jammers and the long distances between U.S. units and theater commanders. Rather than expend scarce resources to build a new communications architecture to support desired C2 structures, communications requirements could be reduced through an alternative approach to C3 that adapts existing C2 structures to accommodate communications availability. This concept, which could be described as context-centric C3, relies on decision-support tools to help junior commanders develop and execute plans even when communications are lost with senior leaders.

Under context-centric C3, junior commanders would employ automated decision aids to support operational planning and execution. Several of these tools are under development today and could be fielded by 2030.[68] When they are unable to receive orders from senior leaders, decision aids would help junior commanders develop courses of action to pursue objectives using the units in communication at that time. In a degraded or denied communications environment, planning tools would help coordinate a commander's plan with those of friendly forces that are out of radio contact by predicting the actions of other forces given the guidance of senior leaders and sensor data on friendly and adversary units.

ISRT and Counter-ISRT

Although ISRT is a longstanding surface warfare mission, its conduct will need to evolve dramatically during the next two decades to reduce the air and missile threat to surface forces. Today, surface combatants employ active monostatic radars like the SPY-1 to find and identify air or surface contacts or rely on inorganic sensors such as satellites and aircraft to locate

66 Additional information on anticipated threats can be found in Chapter 2.

67 Theresa Hitchens, "DARPA Blackjack: Who'll Get Prized Satellite Tech, Air Force Or SDA?" *Breaking Defense*, April 22, 2019; Cheryl Pellerin, "DARPA Brings Game-Changing Technology and Its Creators to Pentagon," *DoD News,* May 11, 2016.

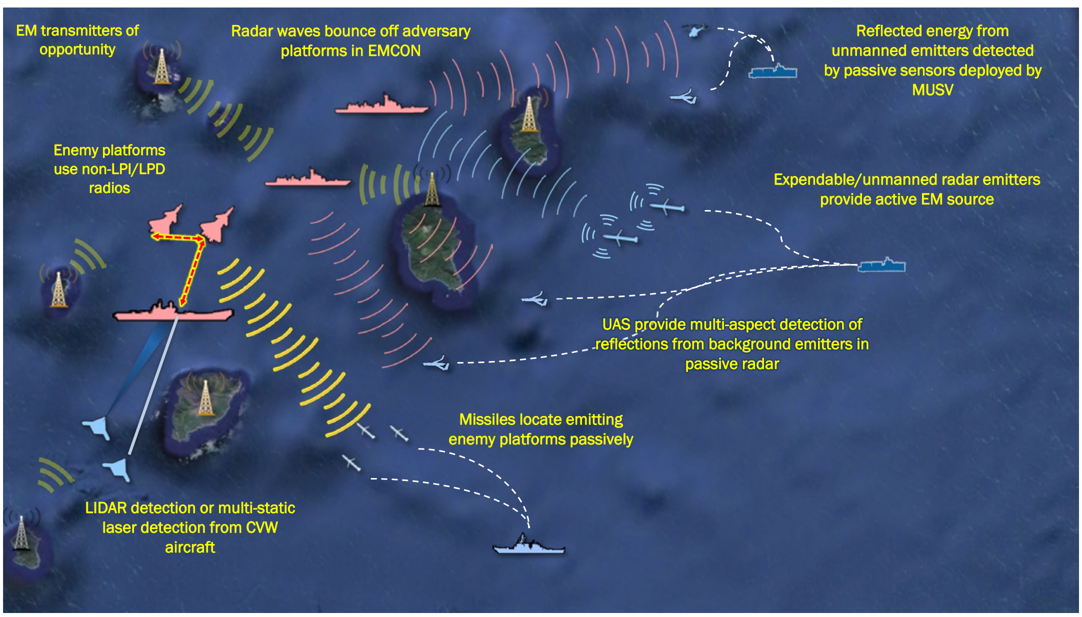
68 Jimmy Jones, "Resilient Synchronized Planning and Assessment for the Contested Environment (RSPACE)," DARPA, available at https://www.darpa.mil/program/resilient-synchronized-planning-and-assessment-for-the-contested-environment.

targets over the radar horizon. These techniques are effective when surface combatants are defending aircraft carriers or allies far from an adversary's territory; counter-detection of surface combatant radar is less consequential and communications with external sensors are unlikely to be degraded in these areas. As surface combatants increasingly become the Navy's strike arm, the risks associated with counter-detection will grow in significance, as will those of losing communications with offboard sensors.

Surface forces will need to rely more on sensing techniques that do not expose manned surface combatants to counter-detection, such as geolocation of enemy radios and radars; LPI/LPD radars; monostatic radars that emulate civilian radars; and multistatic radar using friendly illuminators or emitters of opportunity like mobile phone or radio transmitters. These techniques often require multiple, geographically separated receivers and may have shorter ranges than monostatic radar. This is partly because U.S. forces may not control the radiated power of EM sources for passive radar and geolocation, nor the background EM energy used to hide LPI/LPD sensor transmissions. As a result, the U.S. surface fleet will need more numerous sensors that can operate closer to enemy units. Moreover, given potential adversary efforts to lower their signatures and adopt LPI/LPD waveforms, this approach will also require more sensitive sensors and improved onboard processing to rapidly refine and fuse sensor data.

As shown in Figure 9, the U.S. surface force could use small unmanned systems to illuminate targets and provide multiple sensor nodes for passive radar and geolocation without exposing manned U.S. surface combatants to counter-detection and attack. Candidate unmanned systems for this mission include small glider USVs, MUSVs, and small and medium UAS or stratospheric balloons that could be launched from manned combatants or USVs.

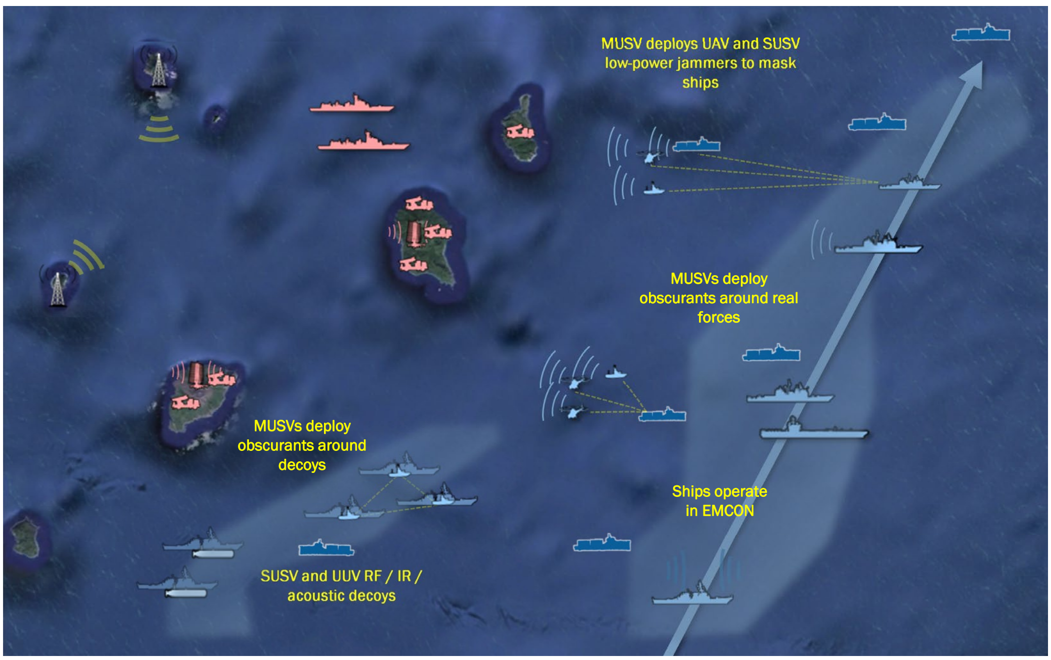
FIGURE 9: EMPLOYING PASSIVE AND MULTI-STATIC SENSING CAPABILITIES



The U.S. surface fleet will also need to counter the ISRT activities of enemy forces. In doing so, U.S. surface forces should not expect to completely avoid or prevent detection due to the growing ubiquity of military, commercial, and civilian space, airborne, and shipboard sensors. The focus of surface fleet counter-ISRT should instead be preventing an adversary from classifying surface units as warships or identifying them as specific U.S. platforms.

With the focus shifted to classification and identification, a way to assess the effectiveness of counter-ISRT operations is the salvo size U.S. air defenses must defeat. Conversely, the salvo size that an adversary must launch to ensure all actual U.S. surface warships are defeated could serve the same purpose. If U.S. surface fleet counter-ISRT operations are effective, the enemy will have difficulty identifying the right contacts to attack among a large collection of decoys, noncombatants, USVs, and U.S. surface combatants. To ensure each surface combatant is engaged, an adversary would need to attack all the potential targets or take additional time to better clarify the target picture. Given that an adversary will always have a fixed number of weapons for an attack, creating more potential targets and obscuring which are real would dilute attacks over a larger number of aimpoints, thus shrinking the salvo size an individual ship or SAG would need to defeat. This approach is shown in Figure 10.

FIGURE 10: EMPLOYING COUNTER-ISRT EFFORTS DRIVE UP REQUIRED SALVO SIZE TO TARGET NAVAL FORCES



To reduce the ability of enemy sensors to discriminate between real and decoy targets, surface forces should focus their counter-ISRT efforts on the widest-area and longest-range sensors first and drive adversaries to use sensors with smaller fields of view to lengthen the time needed to better understand the target picture. The widest-area and often most accurate sensors for identification and classification are signals intelligence (SIGINT) satellites and shore stations because RF emissions from radars and radios are relatively easy to detect at long range and often particular to a platform's type and country of origin. If U.S. surface forces operate in complete emissions controls, they could be discovered by an accidental emission or by spotters. A smart enemy may assume a target emitting easy-to-detect U.S. radar and radio signals is likely a decoy and that the less-detectable target is likely to be a real ship or system. Therefore, surface forces and decoys should emit a similar set of limited RF signals to compel an enemy to use other sensors with smaller fields of view such as imaging satellites or radar that will take more time to conduct a search.

Shore-based over-the-horizon HF radar and satellite synthetic aperture radar (SAR) is likely to be the other type of wide-area sensor used by potential adversaries against U.S. surface forces, which can discern U.S. warships by observing their operations or obtaining precise measurements of ship design, respectively. Jammers could be used against these radars to obscure the return from actual U.S. forces and should be deployed on decoys to provide false returns that approximate a real ship or aircraft. Because neither return will be good, the enemy will likely need to confirm targets using visual, IR, or acoustic sensors.

Decoys for visual sensors will be difficult and costly, but IR decoys could create emissions that are close enough to that of an actual platform to require further investigation, particularly if combined with IR signature reduction features, camouflage, or obscurants. These technologies have advanced considerably since the Cold War, when U.S. forces last seriously considered the need for visual countermeasures. Laser dazzlers, which are already being deployed on some warships, should be more widely fielded to obscure, temporarily blind, or permanently damage the focal plane array of electro-optical and infrared (EO/IR) satellites, which are capable of classifying and identifying U.S. warships through image recognition.

Although acoustic sensors are relatively short range, they could gain more utility in future conflicts as adversaries install seabed arrays like the SOSUS system. To prevent acoustic sensors from becoming a classification and identification tool, U.S. surface forces should make modest efforts to reduce identifiable noise sources from surface combatants or employ acoustic jammers to mask ships and ensure decoys have acoustic noise generators that approximate the sound of combatants.

For more protracted operations, counter-ISRT operations would include selectively destroying or disabling elements of the enemy ISRT architecture. The counter-ISRT concepts described above would become less effective over time as the adversary improved its ability to penetrate camouflage and discern real from decoy targets. U.S. surface forces would need to begin permanently or temporarily disabling sensors on islands, ships, and aircraft to reduce their likelihood of being consistently tracked. This would include nontraditional ISRT capabilities such as the sensors and communications of paramilitary forces (like those of the People's Maritime Militia). These capabilities and other sensors could be nullified by jamming, or U.S. forces may require maritime exclusion zones and rules of engagement under which enemy sensor platforms can be destroyed or disabled.

Communications, ISRT, and counter-ISRT operations will need to be integrated and managed to prevent inadvertent counter-detection and conflicts that could reduce the effectiveness of EM operations. Surface combatants will need to adopt an integrated approach to EMS operations supported by C2 aids. The Navy's RTSO approach is one way this integration is being pursued in terms of spectrum management; DoD's Joint Electromagnetic Spectrum Operations Concept and Electromagnetic Battle Management program are also pursuing processes and tools to integrate and coordinate ISRT and counter-ISRT operations.

Air and Missile Defense

Distribution, passive or third-party ISRT, and coordinated counter-ISRT should increase the number of potential U.S. surface targets Chinese and Russian forces would need to engage during a conflict. To survive in highly contested areas long enough to counter aggression with maritime or land strikes, U.S. surface forces will need to complement distribution and counter-ISRT with greater air defense capacity, making each potential target harder for an enemy to defeat and geometrically increasing the number of enemy weapons needed to sweep U.S. surface forces from the area. Air defense capacity will also be important for surface combatants defending shore facilities and ships that lack their own robust AMD capabilities like logistics vessels, amphibious warships, or aircraft carriers.

A medium-range air defense approach

As recommended in previous CSBA studies, the Navy should increase its air and missile defense capacity by shifting to an AMD approach that engages enemy missiles at shorter ranges than today.[69] Current surface fleet air defense tactics preferentially use large and expensive long-range interceptors such as SM-2 or SM-6 to engage incoming ASMs and only use medium-range air defenses for back-up.[70] Medium-range (10–30 nm) interceptor SAMs such as the Evolved Sea Sparrow Missile (ESSM) are smaller and less expensive than longer-range interceptors such as the SM-2 or SM-6, allowing each ship to carry more. ESSM is also being fielded in a fully active Block II configuration, eliminating the need for an illuminator radar or communication link to guide it.[71] A medium-range AMD concept would enable U.S. forces to use gun-based defenses such as the hyper-velocity projectile (HVP) and directed energy weapons or EW instead of interceptors—rather than only using these systems as a back-up after interceptors fail. Energy-based defenses such as lasers or HPM and electronic warfare systems such as the SLQ-32 operate in a straight line and cannot reach a target over

69 For additional information on this subject, see Bryan Clark et al., *Restoring American Seapower: A New Fleet Architecture for the United States Navy* (Washington, DC: Center for Strategic and Budgetary Assessments, 2017); and Bryan Clark, *Commanding the Seas: The U.S. Navy and the Future of Surface Warfare*, revised edition (Washington, DC: Center for Strategic and Budgetary Assessments, 2017).

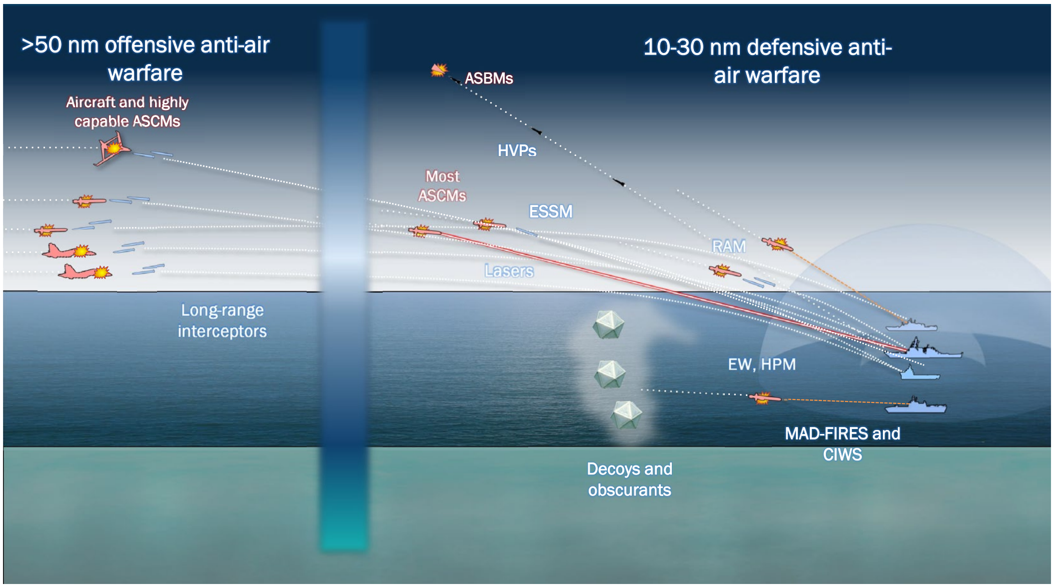
70 Sam LaGrone, "USS Mason Fired 3 Missiles to Defend from Yemen Cruise Missiles Attack," *USNI News*, October 11, 2016.

71 Megan Eckstein, "Evolved Seasparrow Missile Block 2 Successfully Intercepts Aerial Target in First Live Fire Test," *USNI News,* July 6, 2018.

the horizon, limiting their range to 10 nm at a minimum—or more if the target is at a higher altitude.

An increased reliance on medium-range interceptors, guns, and energy-based systems would retain short-range air defenses such as the Close-In Weapons System (CIWS), Rolling Airframe Missile (RAM), or DARPA's Multi-Azimuth Defense Fast Intercept Round Engagement System (MAD-FIRES) for self-defense.[72] The proposed approach is depicted in Figure 11.

FIGURE 11: NEW SURFACE FLEET AIR DEFENSE APPROACH

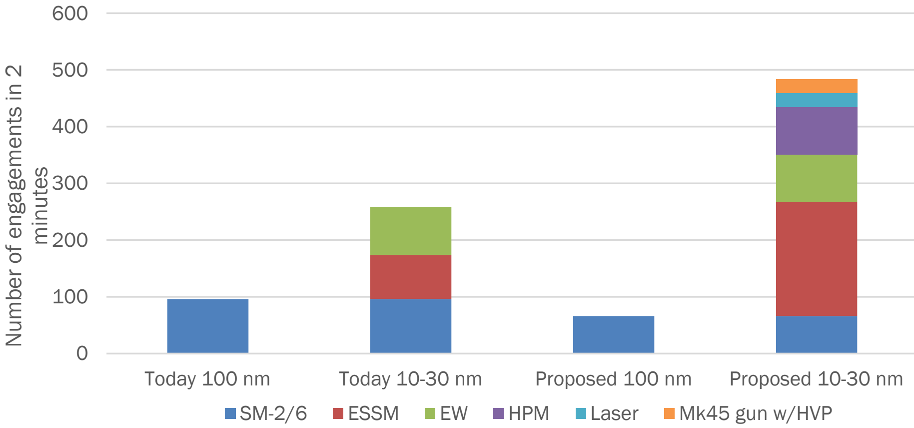


Anti-air warfare (AAW) should be differentiated into long-range offensive AAW against aircraft and the most sophisticated anti-ship missiles vs. medium-range air defense against most ASMs

Shifting more VLS capacity to medium-range interceptors and relying to a greater degree on energy-based defenses would allow U.S. surface combatants to engage more ASMs in a single salvo than today's approach. Figure 12 shows the impact of this change, which could double air defense capacity.

72 MAD-FIRES is a system under development at DARPA. See Alexander M. G. Walan, "Multi-Azimuth Defense Fast Intercept Round Engagement System (MAD-FIRES)," DARPA, available at https://www.darpa.mil/program/multi-azimuth-defense-fast-intercept-round-engagement-system.

FIGURE 12: SHORTER-RANGE AIR DEFENSE CONCEPTS DOUBLE CAPACITY



Shorter-range defenses and directed energy weapons could increase surface force air defense capacity. These charts show defensive capacity for a SAG of three DDG-51 destroyers. This chart assumes a VLS cell loadout of 10 percent SM-3, 20 percent SM-6, 20 percent SM-2, 10 percent ESSM (with 4 ESSMs per cell), 25 percent Tomahawk, 5 percent ASROC; interceptors like SM-2 and SM-6 are assumed to have a SSPK of 0.7, while directed energy weapons, HVP, and EW systems are assumed to have a SSPK of 0.4.

Naval forces could devote larger and more expensive long-range interceptors such as the SM-6 to defeating sophisticated supersonic or hypersonic ASMs and enemy launch platforms such as ships and aircraft. These threats should be fewer in number and more expensive compared to less-challenging subsonic ASMs, making the cost of using an SM-6 interceptor more justifiable.[73] The Navy's planned SM-6 Block IB, expected to be fielded in the mid-2020s, will be capable of longer ranges and greater speeds than the current SM-6 Block IA.[74] By deploying SM-6 Block 1B on more manned and unmanned vessels, surface forces could shape enemy tactics by compelling aircraft to launch at longer ranges, providing more opportunities to engage ASMs. Surface combatants will, however, need to use a network of disaggregated sensors for over-the-horizon targeting to allow SM-6 and potential future longer-range missiles to be effective at their maximum ranges.

An alternative approach to engage enemy aircraft and ASMs at long range would be to position USVs or ground-based surface-to-air missile launchers carrying medium-range interceptors between defended forces and enemy territory or force concentrations. Using organic sensors or external targeting information, medium-range air defense systems could attack enemy aircraft before they can launch ASMs, or they could engage ASMs after launch but before they begin more complex and sophisticated maneuvers. This approach would require knowing the likely location of launch platforms or path of ASMs, which could be difficult.

Integrated combat systems with automated decision aids, such as the Aegis Combat System, could, with some modification, be used to coordinate energy- and gun-based defenses with

73 Clark, *Commanding the Seas*; Gunzinger and Clark, *Winning the Salvo Competition*; and Clark et al., *Restoring American Seapower*, particularly pp. 17–41.

74 Jason Sherman, "Navy Looking to Increase Range, Speed of SM-6 with Larger Rocket Motor," *Inside the Navy*, July 23, 2018.

medium- and long-range interceptors on a specific surface combatant. Aegis could also integrate data from offboard sensors using the Cooperative Engagement Capability (CEC) datalink, allowing the use of passive or multistatic sensing from USVs, UAS, or aircraft like the E-2D. The Aegis Combat System and associated C2 systems such as COMBATS-21 will need to be modified to coordinate new gun-based air defenses such as HVP or MAD-FIRES, as well as coordinate AMD operations by USVs and shore-based launchers with those from manned surface combatants.[75]

New AMD detection and tracking schemes

Beyond capacity, the other significant AMD challenge facing U.S. surface combatants is detecting and tracking air and missile threats. Today, U.S. surface forces rely primarily on active monostatic radars such as the current SPY-1 or planned SPY-6 radars. As noted in Chapter 1, these sensors are readily identifiable and would allow adversaries to find U.S. surface combatants more easily and discern them from decoys and noncombatant ships. Instead, U.S. surface forces should employ passive sensors where possible to support AMD operations. Passive long-wave and mid-wave IR sensors can detect and, in some cases, track aircraft and missiles. Passive RF sensors such as those in the SLQ-32 Surface Electronic Warfare Improvement Program (SEWIP) system can detect aircraft and missiles that are emitting RF energy via their radars or radios and provide engagement-quality tracks to air defenses.

New and emerging ASMs, however, travel at high supersonic or hypersonic speeds and may not have an active seeker or communication links, which could prevent effective tracking using passive RF or IR sensors. Against these threats, U.S. surface combatants may need to use radars to obtain engagement-quality tracks. To reduce the counter-detection risks of using a monostatic radar, surface forces should use the minimum possible level of power and narrow beams to track a target after its approximate range and bearing are determined using onboard passive search sensors or offboard sensors like satellites. When operating farther from threats, such as when protecting a nuclear aircraft carrier (CVN) or a land base, surface combatants may be able to use a monostatic radar for both search and track of air and missile threats without significantly increasing their vulnerability to attack.

Surface forces could also employ offboard radars to achieve greater precision and speed than with passive sensors without increasing the risk to manned ships. The Navy Integrated Fire Control-Counter Air (NIFC-CA) program has demonstrated the ability to use the E-2D Advanced Hawkeye Airborne Early Warning and Control (AEW&C) aircraft to detect threats and pass tracks to other aircraft and surface ships using CEC.[76] However, E-2Ds will likely be operating from aircraft carriers and may not be available to provide AEW support to distrib-

75 David Larter, "The Future of the US Surface Fleet: One Combat System to Rule Them All," *Defense News,* January 14, 2019.

76 Tom Rowden, "Navy and Marines Demonstrate Integrated Fire Control," *Surface Warfare Magazine*, no. 52, Fall 2016, available at https://www.public.navy.mil/surfor/Pages/Navy-and-Marines-Demonstrate-Integrated-Fire-Control.aspx.

uted SAGs or other non-CSG surface ships. Additionally, the E-2D's operation of its active radar may make it vulnerable to detection and attack by enemy forces. The Navy and Marine Corps also tested the use of F-35Bs as an elevated sensor, which relayed data back to a test ship through the Multi-Function Advanced Data Link.[77] This supplementary capability should be matured, but like the E-2D, it is questionable whether F-35s will be able to provide persistent surveillance for distributed SAGs.

A more effective approach for offboard radar would be to use unmanned aircraft. The surface force could embark potential future UAS like the Marine Air-Ground Task Force (MAGTF) Expeditionary Unmanned Aerial System (MUX), potential future expendable or attritable UAS, and constellations of stratospheric balloons to serve as networked, active and passive aerial search RF and EO/IR sensors. Many of these sensors could be ship-launched, while others could be land-launched.

Surface forces could employ multistatic sensing to detect and track air and missile threats without exposing manned ships or aircraft to counter-detection or attack. Disaggregated, picket SUSVs and MUSVs could carry illuminator radars, and manned surface combatants could passively receive reflections to generate fire control-quality tracks. Multistatic radar will still be constrained by the horizon, preventing longer engagement times for incoming supersonic or hypersonic missiles.

Offboard RF sensors may not offer sufficient fidelity and responsiveness for the engagement of some threats, such as hypersonic ASMs. Against these weapons, surface forces may need to rely on satellite EO/IR sensors or employ monostatic radars on surface combatants such as the SPY-1 and SPY-6. Adversaries will be more likely to reserve their most capable ASMs for key U.S. shore facilities or capital ships. Therefore, monostatic radars use should be reserved for air defense of shore facilities or ships that lack significant protection against air attack, such as aircraft carriers and amphibious ships. Moreover, shore facilities and capital ships are likely to be further from enemy forces or territory because of their value, reducing the counter-detection risk incurred by a surface combatant employing monostatic radar.

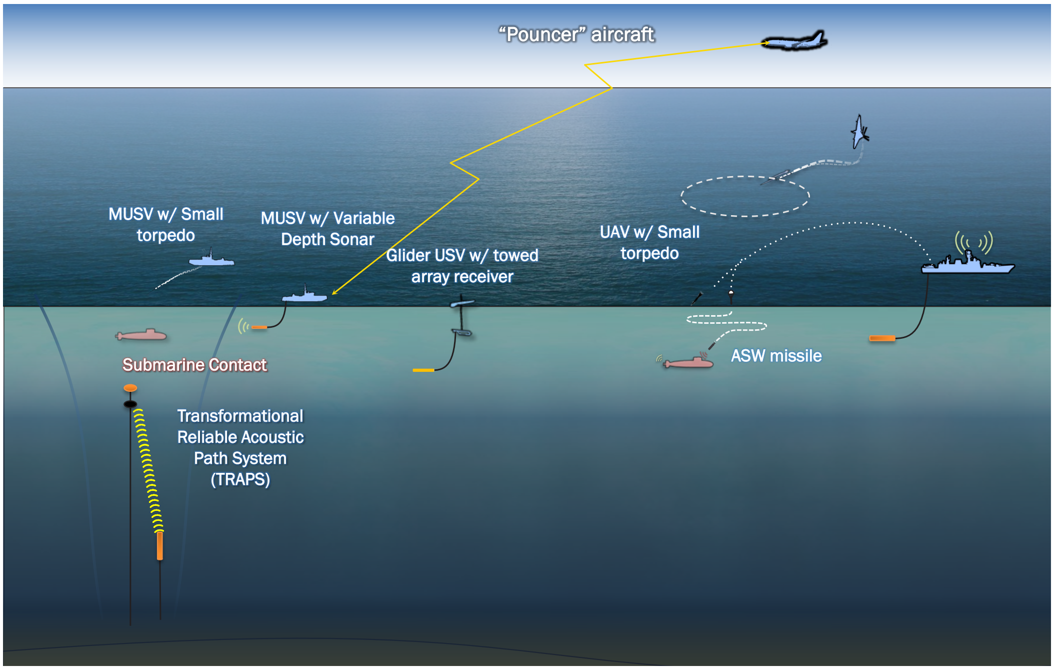
ASW and counter-UUV operations

Undersea-launched ASMs are potentially the most challenging AMD threat. Submarines or large and extra-large UUVs could more closely approach U.S. forces or do so from unexpected directions, reducing the time for U.S. air defenses to react. Submarine ASMs are also increasing in range, speed, and sophistication, improving their ability to circumvent U.S. air defenses and growing the area over which U.S. forces would need to conduct ASW.[78]

77 Ibid.

78 ONI, *The PLA Navy*, pp. 18–20; and ONI, *The Russian Navy: A Historic Transition* (Washington, DC: U.S. Navy, 2015), pp. 16–19, available at http://www.oni.navy.mil/Intelligence-Community/Russia/.

FIGURE 13: NEW APPROACHES TO ASW MISSIONS



Today, surface forces use passive towed array sonars to find submarines, which are then localized and attacked by MH-60R Seahawk helicopters using dipping active sonars and air-dropped torpedoes. With a total range of only 275 nm, MH-60Rs would not be able to attack submarines out to their maximum ASM range or sustain searches more than about 50 nm from surface forces.[79] Shore-based fixed-wing P-8A Poseidon maritime patrol aircraft could support surface forces with wide area ASW operations but would be vulnerable to detection by early warning radars ashore and attack by enemy aircraft armed with long-range air-to-air missiles.[80] The threat to P-8A ASW aircraft would be exacerbated by the need to search for submarines 200 to 1,000 nm from surface forces, which could put P-8As close to enemy forces or territory.

A new approach to wide-area search and engagement for theater ASW would use distributed networks of stationary and mobile unmanned sensors to search for enemy submarines over

79 "MH-60 Sea Hawk Helicopter," *Fact File,* U.S. Navy, February 6, 2019, available at https://www.navy.mil/navydata/fact_display.asp?cid=1200&tid=500&ct=1.

80 Chinese OTH backscatter radars have ranges of up to 1,500 nm depending on frequency and atmospheric conditions. See Bin-Yi Liu, *HF Over-the-Horizon Radar System Performance Analysis*, thesis (Monterey, CA: U.S. Naval Postgraduate School, 2007), p. 74, available at http://www.dtic.mil/dtic/tr/fulltext/u2/a474069.pdf; and Douglas Barrie, "It's Not Your Father's PLAAF: China's Push To Develop Domestic Air-To-Air Missiles," *War on the Rocks*, February 21, 2018. The PLAAF J-16 fighter has a range of 1,600 nm. See "Shenyang (AVIC) J-16 (Red Eagle)," *Military Factory*, available at https://www.militaryfactory.com/aircraft/detail.asp?aircraft_id=1157.

wide areas, coupled with ASW aircraft to suppress submarines using small, inexpensive weapons.[81] This approach is depicted in Figure 13.

In this new approach, stationary, relocatable sensors such as the Transformational Reliable Acoustic Path System (TRAPS) could be employed offensively to detect and track enemy submarines in areas where they are likely to operate, including near enemy ports or around chokepoints between enemy ports and open ocean or U.S. operating areas.[82] Unpowered glider USVs could tow passive arrays and, because of their long endurance, be used forward at chokepoints or other likely enemy operating areas where frequent replenishment of powered unmanned vehicles would be impractical and an operational security concern.[83]

Defensive ASW operations would rely on mobile unmanned search platforms operating at standoff range from surface forces employing active or passive sonars. MUSVs or medium UUVs such as the Navy's Mk-18 vehicle could tow passive sonar arrays to find relatively noisy submarines and remain in position near surface forces. Against quieter nuclear and diesel submarines, MUSVs could employ low-frequency active (LFA) variable depth sonar (VDS). Because they can be placed in the same water layer as the submarine and suffer less attenuation than high-frequency hull-mounted sonars, VDS are capable of detecting systems more than 60 nm away, depending on conditions.[84] Surface warships or MUSVs could also deploy small UUVs like the Riptide vehicle carrying the active Multistatic Acoustic Coherent (MAC) sensor used today in sonobuoys.[85] Unlike a sonobuoy, a UUV would be able to mitigate the effects of current and could be retrieved more easily and repositioned as the target or ASW group moves.

Surface combatants themselves would employ passive sonars to avoid counter-detection and take advantage of multistatic returns from LFA VDS deployed by MUSVs. In some situations, surface forces would need to use organic LFA VDS systems because MUSVs are not available or because a submarine is believed to have penetrated the outer layer of unmanned

81 For more information on this approach, please see Clark et al., *Regaining the High Ground at Sea*, pp. 80–84.

82 Tim Broderick, "Underwater Sensors Bolster Anti-Submarine Capabilities," *Defense Systems*, October 31, 2016; Cheryl Pellerin, "Tech-in the Future at DARPA, Wait, What?" *Armed with Science,* September 14, 2015; and Lisa Zurk, "Passive Detection in Deep Water Using the Reliable Acoustic Path," *Journal of the Acoustical Society of America* 125, no. 4, April 8, 2009, available at https://doi.org/10.1121/1.4783790.

83 Justin Manley and Graham Hine, "Unmanned Surface Vessels (USVs) as Tow Platforms: Wave Glider Experience and Results," conference paper, Oceanology International, September 2016.

84 "Surveillance Towed Array Sensor System (SURTASS)," and "Compact Low Frequency Active (CLFA) Sonar," in Director, Operational Test and Evaluation (DOTE), *FY 2014 Annual Report* (Washington, DC: DoD, January 2015), p. 253, available at http://www.dote.osd.mil/pub/reports/FY2014/pdf/navy/2014surtass_clfa.pdf; "ACTUV 'Sea Hunter' Prototype Transitions to Office of Naval Research for Further Development," *DARPA News and Events,* January 30, 2018, available at https://www.darpa.mil/news-events/2018-01-30a; and Gordon Tyler, "The Emergence of Low-Frequency Active Acoustics as a Critical Antisubmarine Warfare Technology," *Johns Hopkins APL Technical Digest* 13, no. 1, 1992, available at http://www.jhuapl.edu/techdigest/views/pdfs/V13_N1_1992/V13_N1_1992_Tyler.pdf.

85 "Multi-Static Active Coherent (MAC) System," in DOTE, *FY 2014 Annual Report*, p. 263.

ASW sensors. In those situations, the counter-detection risk of using active sonar would be outweighed by the longer detection ranges possible, particularly against quiet submarines.

Once submarines or larger UUVs were detected, land and ship-based aircraft and surface combatants would "pounce" on threats. This approach could allow shore-based P-8As to orbit in safe areas and enter contested airspace only to launch weapons. Ship-based aircraft such as MH-60R helicopters and MUX UAS could be orbiting, or on alert and deployed to engage threats. Localization of submarines before engagement, as is the practice today, would not be necessary because the purpose of ASW attacks in this concept would be primarily to suppress submarine operations by conveying to submarine crews that they have been counter-detected and will continue to be engaged. Because submarines lack high speed, significant self-defense systems, or high-fidelity sensors like radar that would show whether ASW attacks will succeed, submarine operators are likely to leave the area to regain their stealth. This objective was the de facto goal of previous ASW campaigns during the Battle of the Atlantic and the Cold War.[86]

The shifting of ASW objectives from primarily destroying submarines to suppressing them would also allow the Navy to shift the types of weapons ASW forces should employ. Pouncer aircraft could use smaller torpedoes such as the Compact Very Light Weight Torpedo (CVLWT) or depth bombs and reserve large and expensive torpedoes like the Mk-54 lightweight torpedo for situations where naval forces can localize and engage the submarine with high accuracy.[87] Similarly, the Navy could adapt the vertical launch ASW rockets (VLA) carried on surface combatants to carry smaller weapons or depth bombs that could allow it to travel farther than the approximate 12 nm range it has today.[88]

ASUW and STW

CVWs currently provide most of the Navy's maritime and land strike capacity. CVW aircraft are able to deliver munitions against targets afloat and ashore over a sustained period, as aircraft can reload their weapons from the aircraft carrier's magazines and the carrier can, in turn, be rearmed at sea.

The Navy's reliance on CVWs for ASUW and STW is unlikely to persist against great power competitors. Increasingly capable Chinese and Russian sensor and missile networks will force carriers to attack defended targets around 1,000 nm away from their significant ASM threats in order to reduce the potential ASM salvo size to within the capacity of carrier strike group

86 See Stillion and Clark, *What it Takes to Win*.

87 Joseph Trevithick, "U.S. Navy Looking to Arm Its Subs with Tiny Torpedoes that Intercept Incoming Torpedoes," *The Drive*, April 1, 2019, available at https://www.thedrive.com/the-war-zone/27386/u-s-navy-looking-to-arm-its-subs-with-tiny-torpedoes-that-intercept-incoming-torpedoes.

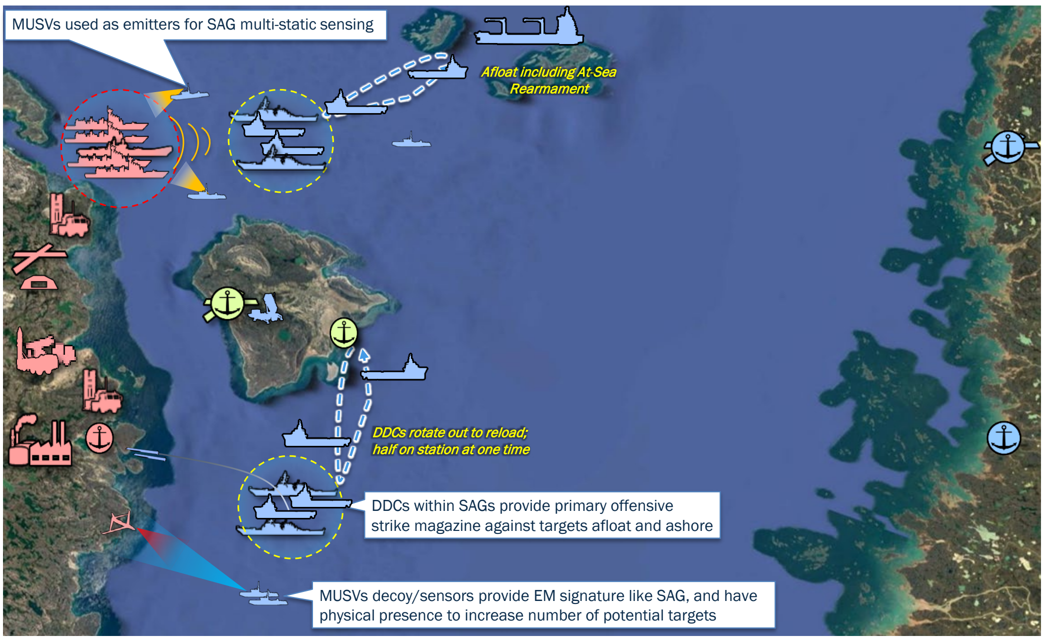
88 Stephen Valerio, *Probability of Kill for an ASROC Torpedo Launch*.

(CSG) defenses.[89] Operating from 1,000 nm away from targets will significantly reduce the number of weapons the Navy's planned CVWs will be able to launch, as shown in Figure 15.

The smaller salvo sizes possible with CVWs will increase the U.S. surface fleet's role in ASUW and STW. In addition to assuming some maritime and land strike missions from CVWs, surface combatants will be able to conduct prompt responsive attacks against enemy forces as part of the effort to delay, degrade, or deny aggression. Using the ISRT capabilities described above, U.S. surface forces should be able to "fire effectively first," in Wayne Hughes' formulation, by finding the enemy without revealing their own location.[90]

To permit sustained strike operations, surface combatants could shuttle between operational areas and ports or tenders where they can rearm, as displayed in Figure 14. Conducting rotational strike operations like this would likely require more surface combatants and could be facilitated by at-sea rearming capabilities.

FIGURE 14: NEW SURFACE FLEET APPROACH TO ASUW AND STW MISSIONS



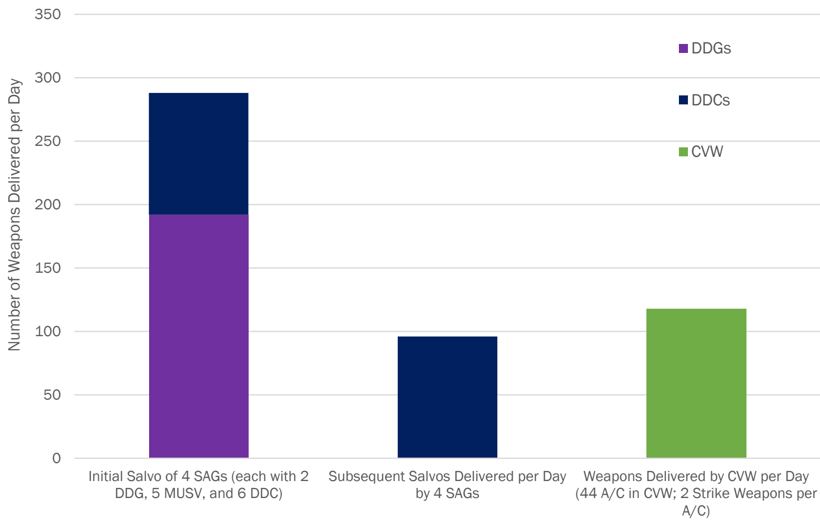
Fielding more surface combatants in a flat budget environment will require that they be smaller and less expensive than today's surface warships. Smaller surface combatants would also be more risk-worthy and could be optionally unmanned to enable them to operate closer to the enemy. As shown in Figure 15, four SAGs composed of destroyers and corvettes armed with strike weapons could conduct a larger initial strike than a carrier air wing against targets

89 At 800–1,000 nm from the Chinese mainland, Navy CSGs could face up to 600 ASMs in one salvo. This is about the air defense capacity of the a CSG. See Clark et al., *Regaining the High Ground at Sea*, pp. 17–18.

90 Wayne P. Hughes, *Fleet Tactics and Coastal Combat*, 2nd ed. (Annapolis, MD: Naval Institute Press, 2000), p. i.

1,000 nm away. By cycling small combatants to a safe area for reloading, the SAGs can launch almost the same number of weapons per day compared to the Navy's planned CVW.

FIGURE 15: OFFENSIVE CAPACITY OF SAG FORMATION VS. CSG



Four Surface Action Groups could deliver more weapons compared to a CVW initially and almost as many weapons each day thereafter. Each of these forces cost approximately the same to procure. This chart assumes missile-equipped DDC carry 32 missiles each and are reloaded in a location 1,250 nm away from the operational area. Taking into account a transit speed of 20 kn, an evasion factor of 15 percent, and reload time, it would take a bit over 6 days for a DDC to return from a reload trip. The initial salvo from the four SAGs launches all DDG strike weapons (24 per DDG) and assumes 25 percent of DDG missile cells are devoted to strike weapons. In both the initial salvo and subsequent salvos, the DDCs in each SAG fire 24 missiles and serially rotate off station to reload as their missiles are expended, while DDGs remain on station providing command and control and defense over the SAG. The CVW is composed of 44 strike-fighters, 70 percent of which are operationally available each day; eight fighters are devoted to air defense of the CSG. Strike-fighters fly their combat radius from the carrier and launch standoff strike weapons that travel the remaining distance to their target. Strike aircraft are assumed to use drop tanks and refueling provided by Navy MQ-25 aircraft in the CVW or Air Force tankers.

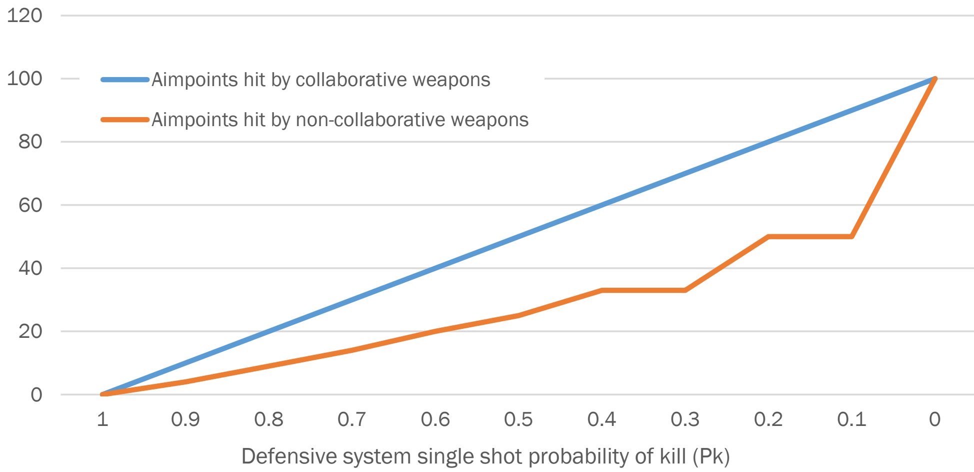
CVWs will nonetheless remain the more appropriate naval force for offensive operations in many situations. For example, for sustained operations over a wide area in which a moderate number of weapons are needed per salvo, CVWs would provide persistence and sustainability. Carrier-based aircraft also provide expeditionary AEW&C and strike options to commanders for scenarios where friendly land bases are not available due to host nation concerns or a lack of suitable runways.

Improving adversary air defenses are increasing the size and sophistication needed in maritime and land strike salvos. The Navy could take several approaches to reduce the salvo size needed in ASUW or STW operations. Collaborative munitions, such as the Long-Range ASM (LRASM), can coordinate their attacks to ensure all aimpoints are struck even if weapons are lost in flight.[91] As a result, the salvo only needs to be large enough to accommodate losses overall, rather than being large enough to ensure losses are accommodated for each ship or

91 Craig MacDermott, "Naval Precision Weapons Session PMA-201/OPNAV N98/JHUAPL," Precision Strike Association Annual Review 2012, March 20, 2012, available at https://ndiastorage.blob.core.usgovcloudapi.net/ndia/2012/annual_psr/McDermott.pdf.

aimpoint. The impact of weapons collaboration on salvo size for a notional attack using 100 weapons is shown in Figure 16.

FIGURE 16: SALVO OF COLLABORATIVE WEAPONS CAN STRIKE MORE AIMPOINTS THAN SALVO OF NON-COLLABORATIVE WEAPONS



A collaborative weapons salvo only needs enough weapons to accommodate total losses in the salvo, rather than losses for each aimpoint. As a result, more aimpoints can be struck by a salvo of 100 weapons. For collaborative weapons, this chart assumes weapons will self-organize to ensure the highest-priority aimpoints are struck, or that at least aimpoints on the target list are struck. For non-collaborative weapons, this chart assumes enough weapons need to be launched at each aimpoint to achieve a 90 percent assurance at least one weapon would make it to the intended aimpoint. For simplicity, the chart assumes defenders are engaging each incoming weapon once due to the short time of engagement and large salvo size.

The surface fleet could also increase its ASUW and STW capacity by employing more weapons that can conduct maritime or land strike, as well as other important functions such as air defense. Multi-mission weapons such as the SM-2 or SM-6 could enable each VLS cell on a surface combatant to support strike operations, if that is a higher priority than air defense at the time.[92] Weapons that can perform land and maritime strike such as the MST similarly expand each combatant's effective capacity for either mission compared to single-mission weapons.[93]

Ground forces can also contribute to maritime strike using modified version of strike weapons, as is being pursued today by the U.S. Marine Corps as part of its EABO concept and the U.S. Army in concert with MDO. Although the salvo sizes possible with distributed ground launchers will not be large, the existence of the threat and difficulty in finding and eliminating launchers will impose costs on adversary naval forces, which will need to defend against attacks from shore and may be more vulnerable to attacks from the sea.

92 Sydney J. Freedberg Jr., "Anti-Aircraft Missile Sinks Ship: Navy SM-6," *Breaking Defense*, March 7, 2016.

93 Paul McLeary, "Navy's New Tomahawk Plan Targets Ships, Bunkers and Distance," *Breaking Defense*, May 6, 2019.

MIW and counter-UUV operations

The continued improvement of mines and merging of UUV and mine capabilities create new challenges for access and sea control. The current U.S. MCM force consists of eight operational *Avenger*-class MCM ships, evenly split between Japan and Bahrain, and 29 MH-53E Sea Dragon helicopters. Both platforms are at or beyond their planned service life and suffer from readiness shortfalls and capability gaps.[94] The Navy intends to replace these specialized ships and aircraft with a combination of offboard unmanned systems deployed by surface combatants and new sensors for existing helicopters. The advent of unmanned MCM systems could enable greater scalability in mine laying or clearance compared to ship-based MIW approaches and allow a larger variety of ships and port facilities to support MIW operations.

The Navy plans to replace the *Avenger*-class minesweepers with *Freedom* and *Independence*-class Littoral Combat Ships (LCS), supplemented by forward-stationed Expeditionary Sea Bases (ESB).[95] However, technical problems in the MCM mission module have delayed transition from *Avenger*-class MCMs to LCS.[96] The Navy plans on replacing MH-53 Sea Dragon helicopters with MH-60S helicopters equipped with the Airborne Laser Mine Detection System and Airborne Mine Neutralization Systems. An MCM USV will replace the MH-53 in towing the AQS-20 mine-hunting sonar or a minesweeping payload delivery system (PDS) that replaces today's Mk-103 mechanical, Mk-104 acoustic, and Mk-105 magnetic sweep systems.[97]

The Navy's current and planned approach to MCM does not significantly increase capacity because it continues to rely largely on dedicated platforms. Although it should continue developing dedicated LCS MCM crews, the Navy should establish MCM crews and modules as independent stand-alone units that could deploy on a wide variety of ships, including ESB and Expeditionary Personnel Transports (EPF), or operate from a shore facility. The new stand-alone organizations, or Littoral Defense Units, could be viewed as successors to the now-disestablished Mobile In-shore Undersea Warfare units and would be charged with protecting important ports and waterways. Each unit would have the same equipment as MCM mission modules, including two MQ-8Cs and the helicopter-borne MCM systems that could be installed on an MH-60R. The units would also carry unmanned ASW sensors, Global Navigation Satellite System (GNSS) jammers, and a pair of workboats to deploy and recover

94 John Miller, "Revitalize Mine Countermeasures," *USNI Proceedings* 145, no. 8, August 2019, available at https://www.usni.org/magazines/proceedings/2019/august/revitalize-mine-countermeasures.

95 The Navy is developing a mine warfare plan that should be delivered to Congress by the end of 2019 and "will serve as certification to lawmakers that the service is prepared to retire legacy equipment." Justin Katz, "Navy Mine Warfare Plan will Serve as Defense Policy Bill Certification for MCM Capabilities," *Inside the Navy,* June 25, 2019.

96 Miller, "Revitalize Mine Countermeasures."

97 Megan Eckstein, "The State of LCS: Navy Moving to Add Firepower, Capability to Both Classes," *USNI News*, September 6, 2019; and Katherine Owens, "Navy Approves Testing for Unmanned Minesweeping System," *Defense Systems,* April 24, 2017, available at https://defensesystems.com/articles/2017/04/24/uiss.aspx.

MCM systems or mines. Additional systems such as mines, MH-60R helicopters, or MUSVs could be provided to Littoral Defense Units depending on the operation.

Littoral Defense Units would conduct MCM operations similar to the Navy's existing plans. The Unmanned Influence Sweep System (UISS), consisting of MCM USVs with minesweeping PDS, would attempt to rapidly clear an area of some mine types when urgent access is needed or in advance of more methodical mine-hunting and neutralization. Additional MCM USVs would follow, using AN/AQS-20A sonar to find mines and micro-UUV neutralizers to destroy the mines. This "one-pass" MCM approach is faster than today's need for separate search and neutralization operations. The shift of MCM operations to unmanned systems would allow mine clearance to be scaled more than is possible with today's dedicated MCM platforms.

Mining

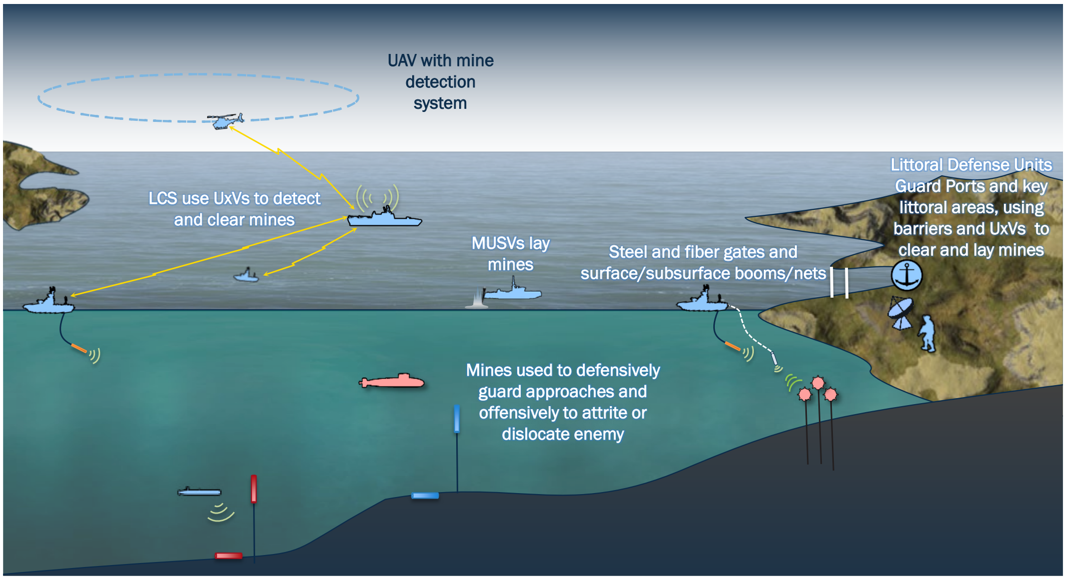
While mining is gaining prominence as a potential naval mission, new investments and doctrine are slow to follow. The Navy should take advantage of the merging of torpedo, mine, and UUV capabilities to field new offensive mines based on planned or existing medium and small UUVs. This approach would allow mines to self-deploy over relatively short distances, which could reduce the chances of alerting an enemy as to the mine's location, help obscure minelaying operations, and allow non-stealthy platforms such as surface combatants and maritime patrol aircraft to deploy mines that could travel into more highly contested areas. Candidate mine systems include Hammerhead, a mine that uses an encapsulated torpedo such as the Mk54 torpedo; the Clandestine Delivered Mine; and a modernized version of the Submarine-Launched Mobile Mine.[98]

Offensive mining could be employed in areas where enemy ships would travel to reach open ocean or U.S. and allied naval forces—such as straits or channels—as well as in enemy ports. Surface combatants or vessels of opportunity embarking Littoral Defense Units could deploy UUV-based mines into these areas, using the range of the UUV to provide U.S. vessels standoff from enemy weapons or platforms and reduce the enemy's ability to understand if and where minelaying is occurring. For even greater standoff, surface forces could use MUSVs to deploy UUV-based mines.

Mines could also be employed defensively to protect friendly ports and waterways from enemy submarines and larger UUVs. Although these areas are less contested, UUV-based mines would reduce an enemy's ability to predict mine locations by observing U.S. operations and could enable more precise mine placement. MUSVs could also deploy defensive mines to improve the efficiency of minelaying operations. This would enable Littoral Defense units to lay mines without needing a dedicated manned vessel. Figure 17 depicts future MIW operations.

98 Richard Burgess, "Latent Lethality: Offensive Mine Warfare Sees Renewed Focus in Era of 'Great Power Competition'," *Seapower Magazine*, July 29, 2019.

FIGURE 17: UNMANNED SYSTEMS WILL CONDUCT THE MAJORITY OF FUTURE MIW OPERATIONS



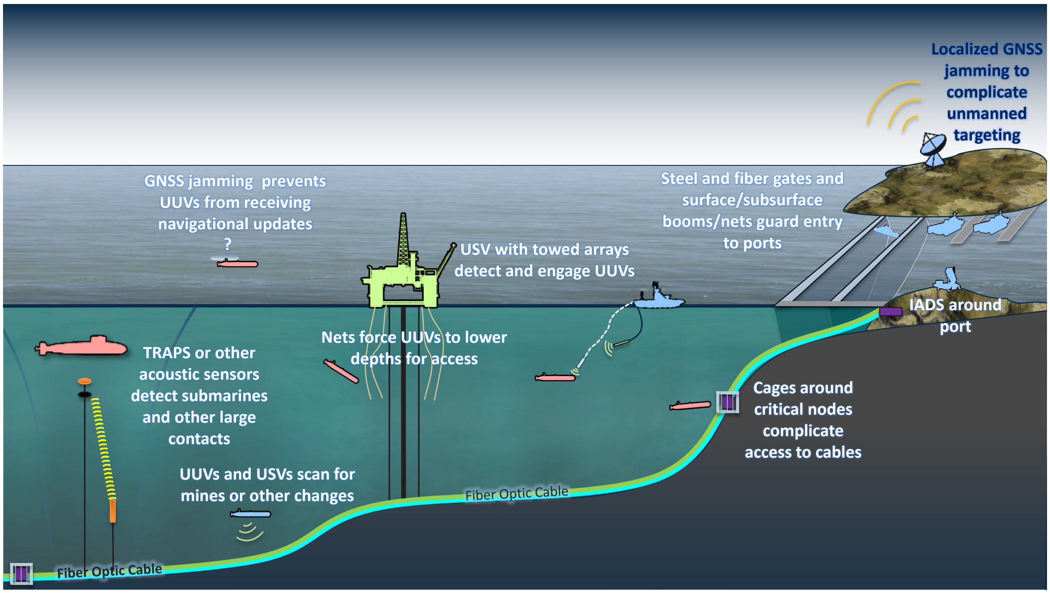
Littoral counter-UUV operations

In addition to conducting MCM, Littoral Defense Units could provide the Navy an expeditionary capability for defense of ports and coastal waters against UUVs. The Navy's planned MCM sensors may be effective against slow-moving small and medium UUVs, which are similar in size and composition to modern mines and may be repurposed as mines by an enemy. Against UUVs travelling faster than about 5 kn or large and extra-large UUVs, surface forces could employ ASW capabilities.

Around potential targets, Littoral Defense Units could employ a system of systems approach, as shown in Figure 18. Slow moving UUVs could be detected by mine-hunting sonars, and fast-moving UUVs will likely be noisy enough that they could be detected by passive sonar such as glider USV towed arrays or TRAPS. Once detected, UUVs could be engaged using mine-neutralization or sweeping equipment.

Some UUVs may evade active sonar and may be too quiet for passive detection. To reduce their effectiveness, Littoral Defense Units would employ GNSS jammers to prevent UUVs from obtaining navigation fixes, and they could work with port operators to install mechanical barriers at port channels (such as nets) and around likely UUV targets (such as pipeline or cable junctions and terminals as well as anchored or moored ships). These measures would require adversaries to employ UUVs with improved inertial navigation systems and active obstacle avoidance and mapping sonars that could be counter-detected and raise the cost of UUVs significantly.

FIGURE 18: LITTORAL DEFENSE UNITS WOULD EMPLOY A SYSTEM OF SYSTEMS APPROACH TO DEFEAT UUVS IN PORT AREAS



MSO

Surface combatants play a critical role conducting Maritime Security Operations (MSO), such as the inspection of ships at sea and search and rescue operations. The Visit, Board, Search, and Seizure (VBSS) of other vessels in uncontested and moderately contested environments is the most common MSO activity and is important for counter-trafficking, counter-piracy, and counter-terrorism missions. However, a particularly stressing case of VBSS is blockade or embargo operations. To enforce a blockade, surface combatants will need to be able to conduct VBSS of ships and, as previously discussed in the section on ASUW, may need to rapidly attack them.

CHAPTER 4

Capabilities of Future Surface Combatants

Surface forces will play an increasingly important role in the offensive elements of the defense strategy's operational approach. Ground forces in theater will be limited in their fires capacity; land-based air forces could be suppressed by missile attacks against bases and enemy counterair operations; undersea forces may need to preserve their stealth for specific high-value missions; and carrier aircraft will be constrained in their ability to deliver sustained fires at long ranges. This may leave missile-equipped surface naval forces as the U.S. military's first responders in the event of a rapid adversary attack.

The U.S. Navy should adopt a new approach to fleet design to support the growing importance of surface forces in U.S. strategy. Most importantly, naval forces should implement operational concepts and field capabilities that allow them to survive and fight in highly contested areas long enough to deny, degrade, or delay adversary aggression as it occurs, rather than responding after the fact. The operational concepts of Chapter 3 are designed to improve the survivability, offensive capacity, and agility of U.S. surface forces. This chapter describes the characteristics of combat systems, platforms, and enabling capabilities needed by surface combatants to implement these operational concepts as part of notional surface force packages. The implications of these characteristics for future surface combatants and fleet architecture are described in the following two chapters.

Combat System Capabilities

The operational concepts of Chapter 3 will require new sensors, EW capabilities, communication systems, and C2 tools, some of which were described in that chapter and are summarized below. Although these systems may already exist, in many cases they will need to be integrated into different ships or vehicles to enable more distributed and complex operations compared to today's surface fleet.

Sensor and counter-sensor capabilities

Sensing and counter-sensing will increasingly be the most important operations performed by surface combatants. Today, surface combatants employ highly detectable and identifiable monostatic radars for most sensing operations, complemented by communications and Electronic Support Measures (ESM) receivers for intelligence-gathering or to support EW operations. In the future, surface combatants will need less detectable or identifiable sensors to reduce the ease with which they can be targeted by an adversary.

Active electromagnetic sensors

Active radars will continue to be essential for tracking air and missile threats when the risk of counter-detection is low or when a commander assesses the increased precision, speed, and identification possible with an active sensor outweighs the increased risk of counter-detection. To minimize the risk of counter-detection, active radar operations should use the minimum power necessary, small beam widths, and frequency and waveform agility. For example, if provided an initial bearing or approximate location by another sensor, a monostatic radar can use a spot beam pointed at the target and the minimum power to reach it. The SPY-6 radar being fielded on DDG-51 Flight III and Enterprise Air Surveillance Radar (EASR) to be installed on new FFGs and CVNs should be better able to provide those attributes compared to their predecessor SPY-1 radar.[99]

Multistatic radar may be able to track incoming air and missile threats with sufficient fidelity to enable engagement with fully active interceptor missiles or EW systems. To enable responsiveness, the passive receiver—which could be a SPY-1, SPY-6, or EASR radar—should be on or co-located with the defended asset. Illuminators could be carried by unmanned vehicles or emitters of opportunity such as TV or mobile phone transmitters, provided they have sufficient signal strength and features to allow tracking small, fast moving missiles.

Unmanned vehicles can also host monostatic radars and transmit contact information to surface combatants. Because they will be constrained by the horizon, USV radar sensors would need to operate forward, closer to enemy forces. Alternatively, UAVs like the MUX could conduct radar operations from altitude near U.S. surface forces, giving them a range to the horizon of 100 nm or more. Although active emissions will expose the unmanned system to counter-detection and attack, the unmanned vehicle can operate far enough away to avoid drawing enemy fire toward U.S. surface combatants.

Passive electromagnetic sensors

Surface combatants and USVs will require passive sensors to provide initial detections and bearings to active radars as well as track contacts on their own. The SLQ-32 EW system includes passive RF receivers across a wide range of radar frequencies, and the Ships Signal Exploitation Equipment (SSEE) can detect signals across a wide range of communication

99 "Meet the Navy's Enterprise Air Surveillance Radar," Raytheon, available at https://www.raytheon.com/capabilities/products/easr.

frequencies. Both systems are being upgraded to improve their sensitivity, coverage, and accuracy. Further upgrades will be necessary as adversaries reduce their signatures. Coupled with a fully active interceptor missile like the ESSM Block II or RAM Block II, these passive sensors should be able to provide a sufficiently accurate bearing to engage an incoming missile that is emitting radar or communications signals.

The emerging generation of ASMs, however, often do not emit because they use passive RF or IR sensors instead of active radar or command guidance. To detect these missiles, surface combatants and offboard platforms like UAVs, USVs, or UUVs could use integrated EO, mid-wave IR, and long-wave IR sensors such as those in the Office of Naval Research's (ONR) Combined EO/IR Surveillance and Response System (CESARS) program.

Acoustic sensors

Counter-UUV and ASW sensing will need to shift to unmanned systems due to the increasing range of undersea-launched ASMs. Hull-mounted active sonars on surface combatants are not able to hear below the acoustic layer that lies at a depth of between about 100 and 300 feet, which tends to curve sound from the surface back toward the surface and sound from submarines back toward the bottom. Towed VDS LFA sonars such as that planned for the LCS ASW mission package and FFG(X) can operate below this layer, increasing detection ranges but exposing the associated platform to counter-detection by submarine sonars. Shipborne passive towed arrays are unlikely to provide sufficient reach to enable surface forces to engage submarines before they are within ASM range.

To reduce their risk, surface forces can deploy stationary passive sensors such TRAPS or USVs with passive towed arrays to detect submarines or surface ships and transmit target information to surface forces.[100] Against diesel, air-independent propulsion, and quiet nuclear submarines, passive sensors may not provide sufficient detection range. Instead, surface forces can use UUVs equipped with the MAC sonobuoy transducer or MUSVs with LFA VDS as sound sources and manned surface combatants or MUSVs with passive towed arrays as receivers to detect returns. This approach greatly increases the geographic coverage of ASW operations while reducing the counter-detection risk to manned surface combatants.

Counter-sensor operations

U.S. sensor countermeasures have focused for decades on the RF portion of the EMS. Surface combatants will require onboard capabilities such as HPM, lasers, and acoustic decoys to deny, degrade, and deceive the growing array of non-RF adversary sensors. To reduce the likelihood of countermeasures being used to cue adversary attacks, they should increasingly be carried by offboard unmanned vehicles. These offboard systems that can be launched from manned surface combatants, other naval forces afloat, or naval forces ashore to create greater

100 "Distributed Agile Submarine Hunting," DARPA, available at https://www.darpa.mil/program/distributed-agile-submarine-hunting; and Danielle George, "U.S. Navy Mine Warfare Programs," PMS 495 Mine Warfare, January 17, 2019, p. 9, available at https://www.navsea.navy.mil/Portals/103/Documents/Exhibits/SNA2019/MineWarfare-George.pdf?ver=2019-01-17-133139-817.

complexity and more potential targets that an adversary must engage to ensure defeat of a surface force.

Weapon capabilities

U.S. surface combatants will need new or improved weapons to defend themselves effectively and conduct rapid offensive operations in contested areas. Some of these systems were discussed in Chapter 3 and are included the summary below.

Defensive weapons

Surface forces should increase their reliance on weapons that boost their defensive capacity. To counter air and missile threats, surface combatants should focus on defeating enemy missiles at short-to-medium range, rather than engaging all ASMs at the longest ranges possible.[101] Large, long-range interceptors such as the RIM-66 SM-2 and the RIM-174 SM-6 should be reserved for high-priority targets like large aircraft and very fast missiles. By engaging most ASMs at medium ranges of 10–30 nm, surface combatants could employ smaller interceptors such as the RIM-162 ESSM Block II that can be loaded four per VLS cell.

Potential directed energy systems include HPMs similar to ones tested by the Army and Air Force that could be adapted for shipboard use or a 300-kW or higher power solid-state laser that could be installed on and supplied by a DDG-51 Flight III's shipboard power.[102] Gun projectiles including HVPs from the ship's main gun or smaller-caliber rapid-firing munitions such as those pursued by the MAD-FIRES program could be used to engage threats at short-to-medium range.

Although the threat of small boat attacks from rogue states like Iran has been a longstanding concern, the advent of China's People's Maritime Militia creates new opportunities for small boats to challenge U.S. surface forces. To defend against small, fast surface threats, surface combatants could use Hellfire missiles or Joint Air-to-Ground Missiles delivered by aircraft such as MH-60s or MUX. Surface combatants could also employ tube-launched small UAS like the Coyote or missiles equipped with an economical imaging IR seeker like that developed

101 For a more detailed discussion of this subject, see Clark, *Commanding the Seas*, pp. 16–22; and Clark et al., *Regaining the High Ground at Sea*, pp. 14–21.

102 In general lasers require approximately 300 kW of continuous power to affect threat ASMs on crossing shots. Higher power levels in the megawatt range are needed to affect threat ASM on head-on trajectories and to affect hardened ASMs, such as maneuvering reentry vehicles. In contrast HPMs require far less continuous power and may be capable of engaging a larger number of targets more rapidly than lasers. HPM can, however, generate side lobes that may cause electromagnetic interference. Accordingly, the Navy should develop ways to harden key areas around surface combatants in order to eliminate the risk from HPM side lobes and enable the fielding of broadband HPMs capable of engaging multiple classes of threats. See Clark, *Commanding the Seas*, p. 21; Ronald O'Rourke, *Navy Shipboard Lasers for Surface, Air, and Missile Defense: Background and Issues for Congress*, R41526 (Washington, DC: CRS, July 31, 2014), available at http://fas.org/sgp/crs/weapons/R41526.pdf; and Dan Parsons, "Raytheon Revives High-Powered Microwave for Counter-UAS Mission," *Defense Industry Daily*, June 20, 2016.

by ONR for the Low-Cost Guided Imaging Rocket program.[103] Swarms of UAS or missiles could be rapidly fired from small, trainable launchers aboard surface combatants into designated kill boxes to engage enemy vessels, especially fast attack craft (FAC), with small explosive charges. This capability could allow surface combatants to engage small enemy combatants at a range greater than the Hellfire missile included in the LCS Surface-to-Surface Missile Module (SSMM). Furthermore, this approach allows surface combatants to quickly engage a large number of rapidly maneuvering targets over a sizable area without having to rely on challenging organic targeting or the launch of a helicopter. As this capability could be deployed from trainable launchers, it could be easily retrofit onto existing combatants.

To defend against subsurface threats, surface combatants require improved torpedo countermeasures, ways to engage submarines at longer ranges, and more widely available MCM capabilities. Small UUV-based acoustic decoys and jammers could be used to confuse enemy torpedoes and possibly submarines. Coupled with kinetic anti-torpedo defenses, they could be used to defeat modern wake or acoustic-homing torpedoes.[104] These defenses should include hard-kill systems, like the now-cancelled Anti-Torpedo Torpedo (ATT) or the developmental SeaSpider interceptor torpedo.[105]

A key limitation of today's ASW approaches is an inability to engage submarines at the detection ranges of sonars deployed on surface combatants or by unmanned platforms. In response, a long-range ASW missile should be fielded to surface combatants. A follow-on to the current short-range VL ASROC based on SM-2s, SM-6s, or LRASMs would enable surface ships to rapidly and directly engage enemy submarines toward the outer limits of their ASM range. They could be employed when other ASW weapons platforms such as embarked helicopters or P-8As are not available. With a long-range ASW missile, surface combatants would be able to attack submarines at the limit of their organic sensors or based on cueing from external unmanned sensors as described in Chapter 3. The Navy should also field a smaller ASW weapon that can be carried in larger numbers by ships and aircraft to engage submarines at short range and cause them to break off an attack. Examples include affordable ASW torpedoes such as the CVLWT or Hedgehog-like depth bombs. These weapons can be used to suppress submarine operations at low cost.

103 Grace Jean, "ONR-Funded Guided Rockets Hit Fast-Moving Targets in Test," press release, Office of Naval Research, November 29, 2011, available at https://www.onr.navy.mil/en/Media-Center/Press-Releases/2011/LCITS-Guided-Rocket-Weapon-Test.

104 In 2018 the U.S. Navy suspended work on the surface ship Anti-Torpedo Torpedo Defense System (ATTDS) program. The U.S. Navy still lacks and requires a kinetic anti-torpedo defense capability. Joseph Trevithick, "The Navy Is Ripping Out Underperforming Anti-Torpedo Torpedoes From Its Supercarriers," *The Drive*, February 5, 2019, available at https://www.thedrive.com/the-war-zone/26347/the-navy-is-ripping-out-underperforming-anti-torpedo-torpedoes-from-its-supercarriers.

105 Sam LaGrone, "Navy Develops Torpedo Killing Torpedo," *USNI News*, June 20, 2013; and "Sea Spider," Atlas Electronik, available at https://www.seaspider.info/.

Offensive weapons

With an increased reliance on smaller, shorter-range interceptors, directed energy, and EW for AMD, surface combatants could devote more of their VLS magazines to offensive weapons. Offensive weapons (and some defensive weapons) could engage targets using the sensors organic to their launch platform or be fired remotely using targeting data provided by another platform. The use of multi-mission weapons can further increase the utility of each VLS cell. For example, SM-2 and SM-6 surface-to-air interceptors can be used to attack enemy aircraft or ships, and the Block V Tomahawk will be capable of anti-ship or land attack. To complement these existing or planned capabilities, the Navy should pursue a VLS-launched variant of the LRASM that would also be capable of land attack. Although LRASM has a shorter range than the Tomahawk, it has sensing and survivability enhancements that would make it more effective against well-defended targets.

The hypersonic Intermediate Range Conventional Prompt Strike (IRCPS) weapon under development by the U.S. Navy and Army could enable rapid engagement of targets ashore with a higher probability of success than existing cruise missiles such as Tomahawk. The prompt strike missile, however, will be larger than existing Mk-41 or Mk-57 VLS cells can accommodate and will be several times more costly than today's cruise missiles.[106] Because the IRCPS weapon will likely be procured in significantly smaller numbers than Mk-41 or Mk-57 capable weapons, the Navy should not adjust the design of surface combatants to carry large missiles like ICPRS. Instead, larger launchers could be incorporated as an option on new classes of small surface combatants, such as the corvette proposed later in this report.

As part of an effort to accommodate larger offensive missiles, the Navy should examine cold-launch VLS systems, diversifying from solely hot-launch VLS systems. Adoption of containerized launchers could facilitate global transport and installation across multiple Navy ship types, introducing additional fleet flexibility, and provide rapid options for reload afloat and ashore.[107] A containerized launcher—especially if it supports cold-launch—could also enable the integration of ASUW and STW weapons aboard commercially derived surface combatant designs and may provide a low-cost alternative to designing custom VLS cells sized for very large intermediate-range missiles, such as the IRCPS missile.

The U.S. surface force should also pursue trainable launchers that can adjust their launch orientation in azimuth and elevation for small countermeasures, UAS, or missiles. Trainable launchers replacing or complementing existing chaff launchers could increase the defensive

106 Megan Eckstein, "Navy Developing Prompt Global Strike Weapon that Could Launch from Sub or Surface Ship," *USNI News*, November 21, 2018.

107 Of note, China, Russia, and Israel have developed missile systems that can be disguised within containers and aboard cargo ships. See Jamie Seidel, "Israel and Russia Testing Missile Systems that Can Be Hidden Aboard Cargo Ships," *News Corp Australia Network*, June 23, 2017. New weapon reload technologies, including containerized launchers, could have a major impact on fleet design, increasing the combat utility of auxiliaries and a wide variety of commercial ship designs. For one discussion of using merchant designs as warships, see Steve Wills, "Merchant Warships and Creating a Modern 21st Century East Indiaman," *CIMSEC*, September 12, 2018, available at http://cimsec.org/merchant-warships-and-creating-a-modern-21st-century-east-indiaman/37576.

capability and capacity of ships by enabling the precise employment of new and existing countermeasures such as flares, passive and active RF decoys, acoustic decoys and jammers, and short-range munitions. Another advantage is that trainable launchers can be quickly reloaded from ship magazines, allowing ships to resupply their defensive capacity over the course of an engagement or battle.

Battle management capabilities

The need for prompt and simultaneous offensive and defensive operations in contested areas will place a premium on automated C2 and battle management. Quick assessment and action will be especially important for AMD as surface forces necessarily rely more on short- to medium-range air defense.

Battle management systems should be capable of directing the actions of the host platform in order to achieve specific objectives, such as avoiding ISRT threats and coordinating kinetic and non-kinetic defenses. In support of distributed operations, battle management systems should be able to manage the actions of groups of platforms and systems, including manned surface combatants, unmanned vehicles, and sensors. Battle management systems should also be "virtualized," in which the complete combat system is replicated using software. Virtualization would enable incorporating the same battle management capabilities into the mission systems of unmanned vehicles and manned combatants to improve their ability to coordinate their activities.

To support EMS operations, battle management systems should also be able to fuse data from various organic and inorganic sensors and determine how to manage emissions and employ countermeasures. These functions could be directly incorporated into an integrated combat system, but a near-term approach could link federated systems through a network and sensor manager such as the one in Figure 19.

Robust cyber protection and electromagnetic hardening should be incorporated into ship combat system hardware as well as software, rather than retroactively to patch gaps as they emerge. Protection would include automated systems to screen incoming signals and information, segment components of ship networks, and isolate potentially compromised systems; provide rapid and routine software, firmware, and hardware updates throughout the lives of ships; and routinely evaluate systems through realistic tests and exercises. Electromagnetic hardening should not only prevent electromagnetic interference between ship systems, but should also harden systems against adversary electromagnetic weapons, such as HPM.

FIGURE 19: SYMPHONY AFLOAT SPECTRUM MANAGEMENT DASHBOARD

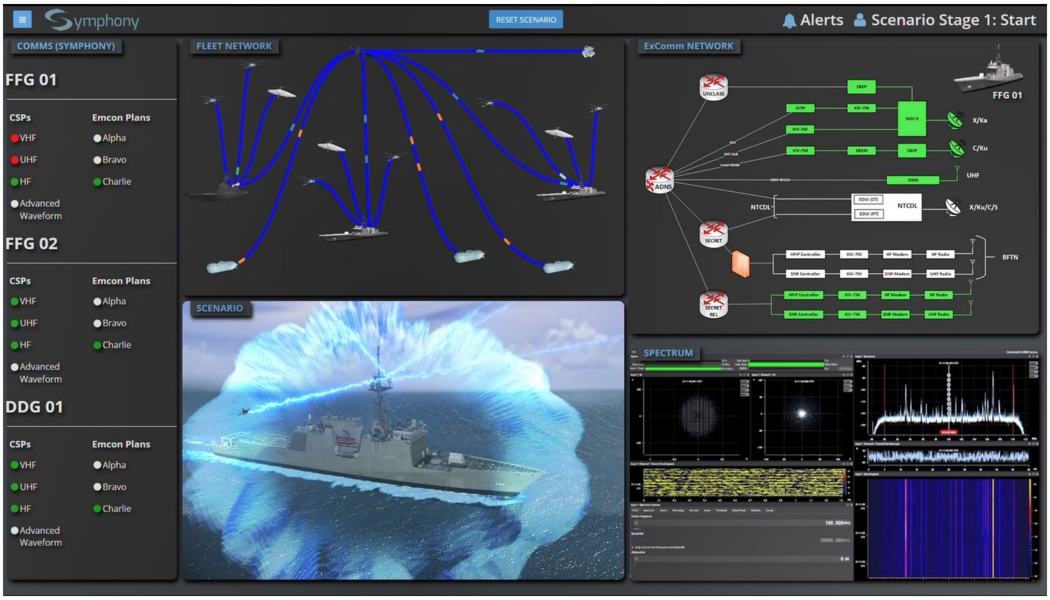


Image courtesy of L3Harris. Symphony is an example of a network manager in use by the U.S. Coast Guard and Allied navies. "Symphony® Communications Manager," L3Harris, available at https://www2.l3t.com/cs-east/pdf/datasheets/Symphony.pdf.

Characteristics of Future Surface Combatants and Unmanned Vessels

Trends in automation, power generation, energy storage, and maintenance provide opportunities to improve the sustainability and affordability of the surface fleet. To assess the return on investment of adopting these capabilities, the Navy should use total ownership cost (TOC), not solely procurement cost, as the prime consideration in ship and vehicle design choices.

Automation

Greater levels of automation are needed aboard future surface combatants for both operational and budgetary reasons. Automation would not take the place of humans; instead, it would allow operators to focus on tasks that require human judgement and accountability. For example, machine-enabled planning aids could rapidly craft courses of action (COA), including approaches an adversary may not expect, with the human commander choosing the COA to be implemented. During operations, autonomous battle management systems could also provide the speed necessary to coordinate prompt offensive and defensive actions within the boundaries and constraints set by human commanders.

Automation will also be important to reduce personnel costs. The surface fleet's Optimum Manning experiment in 2001 led to overworked crews that were not operationally proficient because manning reductions were not accompanied by automation.[108] In returning manning

108 Phillip M. Balisle, *Fleet Review Panel of Surface Force Readiness*, Final Report (February 2010), available at http://www.sailorbob.com/files/foia/FRP%20of%20Surface%20Force%20Readiness%20(Balisle%20Report).pdf.

to historical levels, the Navy has found a shortfall of approximately 6,200 sailors in the surface fleet; the gap will likely widen as the fleet grows during the next two decades and incorporates more ships with multiple crews such as FFG(X) and LCS.[109]

FIGURE 20: SPECTRUM OF SHIP AUTOMATION OPTIONS AVAILABLE FOR SURFACE COMBATANTS

Operation of Vessel: Manned – Unmanned

Percent Manned	Approximate Crew	Type	Current and Potential Combatant Types
100%	330	Fully Manned Vessel	DDG-51
50%	165	Highly Automated Manned Vessel	DDG(X) Flt I
25%	80	Highly Automated and Autonomous Manned Vessel	DDG (X) Flt II
7%	24	Optionally Unmanned Vessel	DDC
5%	15	Unmanned Vessel with Optional Force Protection Crew	DDC/LUSV
0%	0	Fully Unmanned Vessel	MUSV, CUSV, Wave Gliders

The automation of shipboard machinery could reduce the number of operators or watch standers needed aboard ships. To reduce the amount of work, however, automated solutions must reduce the human support needed for maintenance and damage control either by automating these functions or by improving system reliability and lowering maintenance requirements. High degrees of reliability will be especially important in USVs and optionally unmanned ships with small crews.[110] Automation aboard manned and unmanned ships can initially cost more in capital outlays than traditional manned ships; however, lifecycle costs may be significantly less.

109 For example, the original crew size of 329 personnel on a DDG-51 was reduced to 240 personnel by 2012. The Navy plans to increase the number of personnel to 318 by 2023. Sam LaGrone, "Fleet Forces: Navy Short 6,200 At-Sea Sailors Now to Meet New Manning Requirements," *USNI News*, February 26, 2019, available at https://news.usni.org/2019/02/26/fleet-forces-navy-short-6200-at-sea-sailors-now-to-meet-new-manning-requirements.

110 It is likely that highly automated vessels, in particular USVs, will not have the benefit of onboard sailors cleaning, providing preventative maintenance, or performing simple adjustments/repairs. Therefore, the platform may experience accelerated degradation compared to a manned platform, and this will need to be factored into life-cycle plans. Development of condition-based maintenance protocols would benefit both manned and unmanned platforms.

Power, energy storage, and cooling

The emerging generation of surface warfare capabilities depend on a platform's capacity to generate power, store energy, and cool systems. New radars like the SPY-6 and weapons including electromagnetic railguns and lasers will require more power and cooling than their predecessors.[111] Efficiency in energy usage will also take on greater importance as the surface force seeks to conduct more highly distributed operations and reduce its frequency of logistical support.

In general, the Navy can take one of two paths to meet future power and cooling demands: fixed or flexible. A fixed approach, as was generally followed in the design of the DDG-1000, sizes total power generation capacity to peak load conditions plus conservative margins for future growth.[112] As an all-electric ship, the DDG-1000 uses one set of main generators to power the entire ship, including propulsion, under all anticipated conditions. This approach provides immediate power availability for nearly any "worst case" scenario but is inefficient under the low load conditions that dominate surface combatant operations. High-capacity generators generally will consume more fuel under low load than a smaller generator operating at the same power level.

A flexible approach uses multiple smaller generators to meet ship power demands and allocates sufficient space and weight margin for more power generation and cooling to be added over the ship's service life. For example, electrical generators and propulsion engines are sized to meet the most frequent power demands; battery, fuel cell, or other energy storage devices are used to meet intermittent peak loads; and secondary higher electrical generators or engines can be added to meet occasional sustained high power demands. This approach can provide the ability to install additional energy storage and cooling systems later in a ship's life, reducing a platform's acquisition and lifecycle costs. It can also provide tactical advantages by providing greater fuel efficiency and, in turn, endurance while cruising.

Several new surface combatant designs, including DDG-1000, use integrated power systems, in which large electrical generators create power for all shipboard energy requirements including propulsion.[113] Integrated power systems provide the flexibility to shift power between propulsion and weapons or sensors to create greater effective power capacity, and they can be structured using the fixed or flexible approaches described above. Arguably, integrated power systems can more fully exploit the flexible architecture because they can use a set of identical electrical generators to power all shipboard requirements and simply increase or

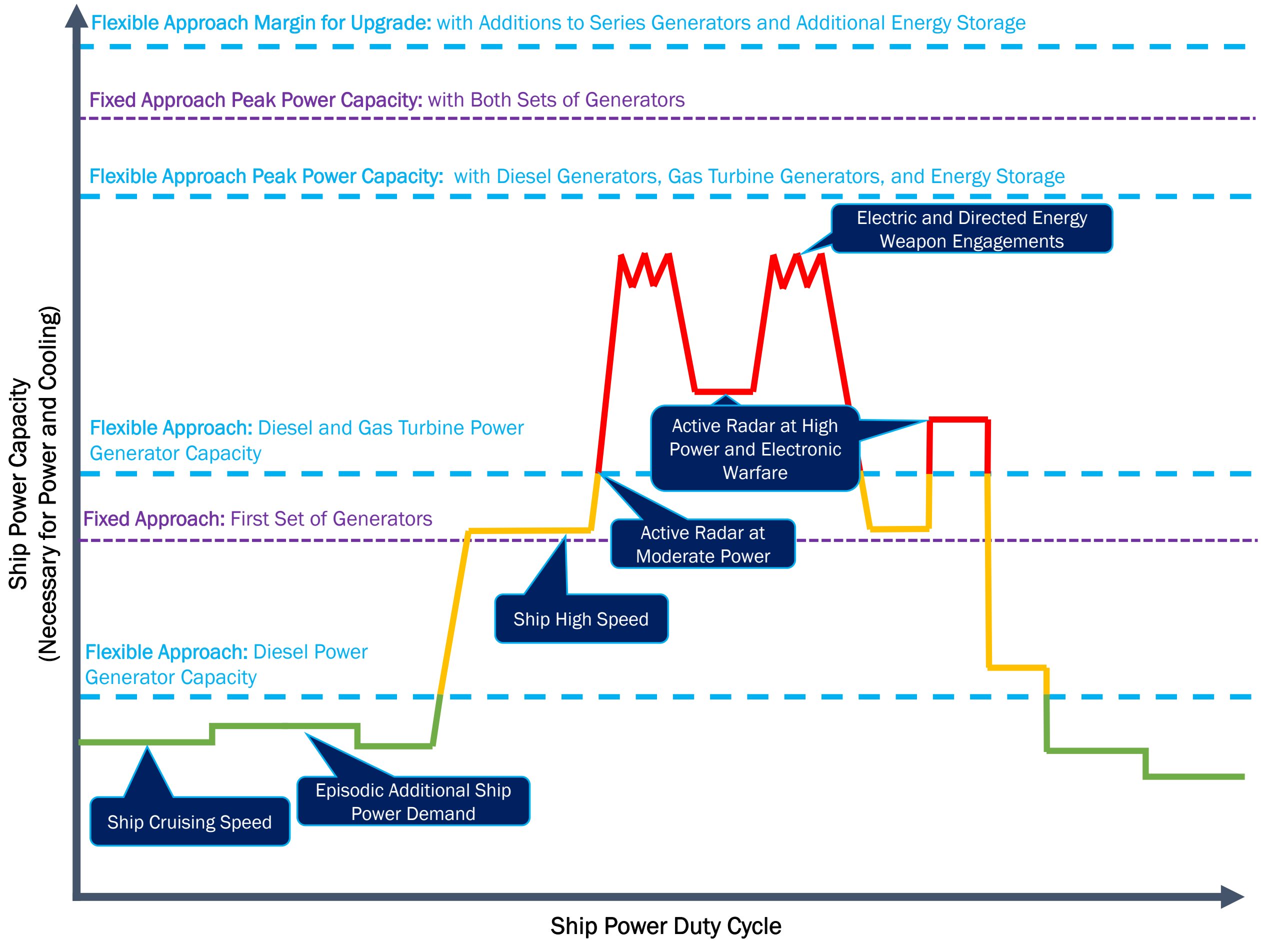
111 For radars, electromagnetic weapons, and directed energy weapons, the required operating profile (i.e., the duty-cycle) has a major impact on electrical system design and required amount of energy storage.

112 Other elements of this approach include n-1 power generation design feature (e.g., one power generation unit is assumed unavailable) and usage factors of combat systems equipment at or above 0.8 (usually on).

113 *Electric-Drive Propulsion for U.S. Navy Ships: Background and Issues for Congress* (Washington, DC: CRS, July 31, 2000), available at https://www.everycrsreport.com/files/20000731_RL30622_c288e8b1829d574fffb93ddf56d0891b36cff9fc.pdf.

decrease the number of generators on line at any time to provide the needed power level most efficiently. The disadvantage of all-electric ships is the loss of efficiency that occurs during the conversion of mechanical work in generators to electrical energy and then back to mechanical work in propulsion motors. As a result, electric ships need more space for engineering equipment, making integrated power systems more appropriate for larger combatants.

FIGURE 21: FIXED AND FLEXIBLE APPROACHES TO SHIP POWER GENERATION



Endurance will be an essential attribute in manned and unmanned surface vessels given the need for a more distributed posture and mobility to counter adversary targeting and weapons or to position for attacks. Future surface combatant designs should prioritize endurance through large fuel tanks and efficient propulsion and electrical generation. Long-endurance MUSVs or smaller USVs can improve endurance by incorporating sails or self-cleaning solar panels. These power systems could provide a primary or supplementary renewable energy source, which could sustain small platforms with low power demands.

Maintenance and repair capabilities and readiness cycles

The operational availability of surface combatants is a function of their maintenance requirements, the fleet's maintenance and repair capabilities, and the training cycle of ships' crews. As a force provider, the Navy is under pressure to maintain presence levels, even while establishing periods to improve the fleet's ability to learn, experiment, and adapt. For example, Combatant Commanders' demands for naval presence remained constant during the last two decades while the fleet shrank by almost 20 percent. The Navy deployed each ship longer and more frequently as a result, resulting in degraded material condition of surface ships, longer maintenance periods, and, in turn, less time available for training and experimentation.[114] Today the surface fleet has a significant backlog of increasingly expensive maintenance to address.[115]

Accelerating maintenance will be essential throughout the fleet, especially for ships operated by rotational crews like FFG(X) and LCS that require shorter, more frequent maintenance periods. To improve the ease with which ships can be maintained or repaired, ship design should incorporate increased modularity and commonality in shipboard systems. Equipment could then be more easily replaced, maintainers would become more proficient, and logistics would become less complicated. Affording more space on ships for access by repair personnel would also improve the efficiency of repair work.

The duration of maintenance periods could be further reduced through more accurate assessment of the work needed in advance of a maintenance period. To facilitate improved maintenance planning and estimates, surface combatants should incorporate systems that monitor components of ship hull, mechanical, electrical, and combat systems. The data from these systems could also enable condition-based and predictive maintenance and provide improved visibility regarding the fleet's readiness.[116] These approaches have been used for decades in the *Ohio*-class SSBN fleet, enabling effective use of short refit periods and enabling SSBNs to reach 42 years of operation, which is more than 10 years beyond their planned service lives.[117]

The introduction of unmanned and optionally unmanned surface vessels with small crews will require major changes to maintenance approaches. Light maintenance and repairs can be

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114 Joseph F. Campbell, "Readiness and Sustainment of the Navy's Surface Fleet," hearing before the House Armed Services Committee, Readiness Subcommittee, March 25, 2009. See Megan Eckstein, "Admirals: Fleet Readiness Plan Could Leave Carrier Gaps, Overwhelm Shipyards," *USNI News*, September 9, 2016; and Bill Gortney, "Predictability and Adaptability: West 2014," Power Point Presentation, United States Fleet Forces, February 12, 2014, available at http://www.afcea.org/events/west/14/documents/WEST2014PresentationFinalGortney.pdf.

115 David B. Larter, "Despite Record Budgets, the US Navy is Short Hundreds of Millions for Maintenance," *Defense News*, August 19, 2019.

116 Justin Katz, "Navy Preparing to Solicit Industry for App Development to Monitor Surface Fleet Vessels," *Inside the Navy*, August 2, 2019.

117 Megan Eckstein, "Ohio-Class Subs Approaching Several Firsts As Navy Prepares Them To Reach 42 Years of Service," *USNI News,* February 3, 2016.

conducted by crews or fly-away teams in the case of USVs. Deeper maintenance and repairs will need to occur in port or at a tender, supported by a dedicated repair team rather than the ship's crew or operators.

The Navy should also anticipate that lower-cost vessels, built to commercial standards and operating at sea more frequently than traditional manned surface combatants, will have shorter service lives than contemporary manned surface combatants. This study estimates corvettes will have 20-year service lives and MUSVs will have 15-year service lives. In spite of shorter per-ship service lives, these lower-cost vessels have the potential for much lower life-cycle costs than comparable manned vessels.[118]

Signature management, rather than reduction

Signature management—the control of RF, IR, acoustic, and visual emissions from a target—is an essential complement to counter-ISRT operations as discussed in Chapter 3. Onboard and offboard active countermeasures can help obscure surface forces and degrade adversary sensors, but only if the inherent signature of the protected vessels is small enough to hide. At the same time, however, decoys will be more effective if their signatures are similar to those of the platform being replicated. Therefore, surface forces will need to manage their own sensor and communications emissions, active countermeasure emissions, and emissions from decoys to maximize the number and complexity of plausible targets presented to the enemy.

An adversary is likely to use its sensors in a coordinated manner to localize and classify surface contacts as quickly as possible. SIGINT satellites have the widest coverage of likely adversary sensors, and will look for characteristic U.S. surface radar or communications emissions. To help increase the number of potential targets, both real and decoy surface combatants should emit similar RF signals that are representative of U.S. forces by using systems such as RTSO to monitor and manage emissions.

Potential targets detected by enemy SIGINT would likely be examined using other sensors to determine which are real and which decoys. For example, satellite-based SAR, IR sensors, and visual cameras would provide increasing fidelity at the expense of shrinking fields of regard. To slow adversary efforts to clarify the targeting picture, decoys could be equipped with radar reflectors or jammers that can simulate the return a ship would present to a SAR satellite as well as IR signal generators that approximate ship signatures. Although these signatures may not be precise emulations of real surface forces and would not address visual sensors, they could be good enough to slow efforts to differentiate between decoys and real targets, particularly if real targets are using SAR jammers and IR camouflage to reduce their signatures.

Using signature management to support counter-ISRT requires that unintended emissions be reduced or managed to be similar to decoys. Unintended signatures include radar returns, which could be reduced by minimizing sharp corners and vertical surfaces that can reflect

118 Please see Chapter 6 for additional information.

RF energy, housing systems within the hull or superstructure of the ship to reduce reflected RF energy and improve EMS shielding, and reducing magnetic signatures with economical and lightweight degaussers.[119] Similarly, wake signatures should be reduced to deny electro-optical or SAR detection over broad areas whenever possible, although the elimination of wakes useful to wake-homing torpedoes will likely be impractical.[120] Acoustic signatures from mechanical noise onboard ships could be reduced through passive means such as using sound isolation mounts to secure rotating machinery to foundations and to connect decks to hull frames.

By pursuing signature management instead of signature reduction, the U.S. surface force could more economically conduct counter-ISRT operations compared to an approach that reduces signatures in an effort to hide or creates perfect decoys to increase targeting complexity for the enemy. Developments in sensors and processing capabilities over the lives of many planned future surface combatants may outpace investments in signature reduction, and signature reduction efforts tend to be costly. Consequently, ship designers should carefully evaluate the costs and benefits of different options for lowering unintended signatures and creating realistic decoys.[121]

Enabling Capabilities for Surface Combatants

To implement the operational concepts of Chapter 3, the U.S. surface fleet will require improved enablers, including more resilient communication systems, additional munitions stocks, and new logistics capabilities.

Communications connectivity will be critical to coordinating complex ISRT and counter-ISRT operations and massing fires from distributed launchers. Significantly increasing investment in a communications architecture able to support theater-wide operations at high bandwidth in highly contested areas is an ineffective use of resources. Instead, modest investments should be made to ensure units can communicate within their force packages and critical information can be shared across a theater. Using the resulting communications architecture, context-centric C3 should be employed to adapt C2 structures to communications availability. Figure 22 depicts elements of the proposed communications architecture.

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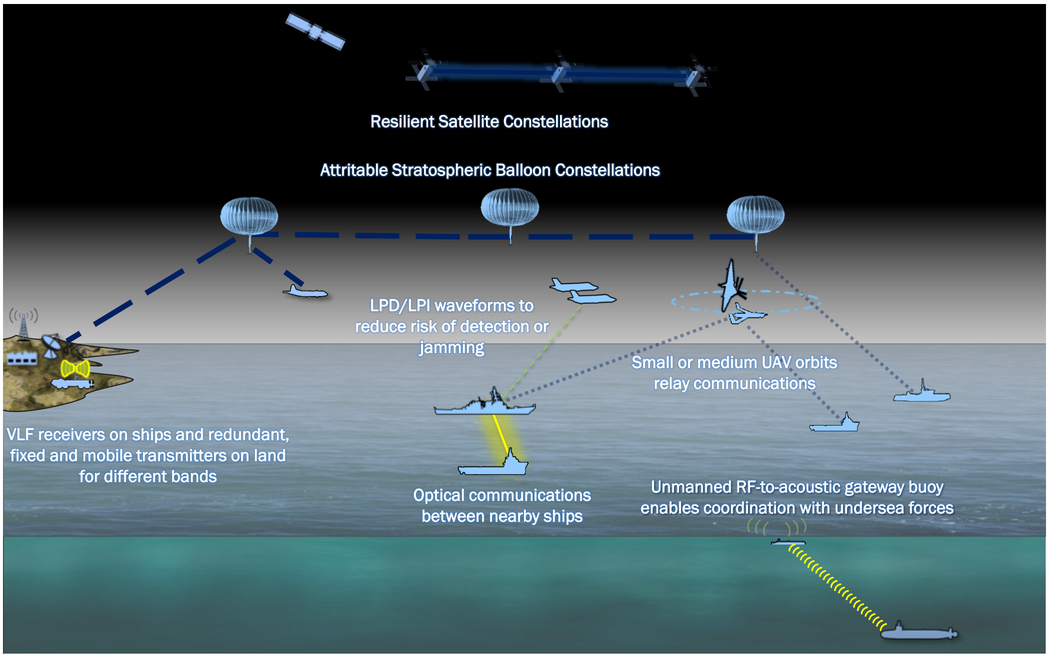
119 John W. McGillvray, "Stealth Technology in Surface Warships," *Naval War College Review* 47, no. 1, Winter 1994, p. 32; and Connie Lee, "Superconductors to be Installed on Navy Vessels," *National Defense*, May 30, 2019.

120 *Transforming the Navy's Surface Combatant Force* (Washington, DC: CBO, 2003), p. 31, available at https://www.cbo.gov/sites/default/files/report_0.pdf.

121 This study assumes robust Navy and Joint Force counter-ISRT operations will be conducted at different stages of the competition-conflict spectrum to create a degree of operational access for surface combatants in contested areas. Absent robust counter-ISRT operations, it may be very difficult for surface combatants to prevent their detection and, more importantly, their targeting by adversaries. If robust counter-ISRT operations were not possible or authorized, surface combatant fleet design may need to change to a smaller number of lower signature platforms, such as submersible ships. Submersible ships may still be an attractive platform for certain types of operations in highly contested environments, even if robust counter-ISRT operations take place.

FIGURE 22: REPRESENTATIVE COMMUNICATIONS ARCHITECTURE FOR SURFACE COMBATANTS



Numerous studies and Congressional testimony have highlighted shortages in DoD's and the Navy's overall and forward-based munitions stocks. Furthermore, the U.S. defense industrial base is unlikely to be able to surge production in the near term to offset wartime expenditures.[122] Accordingly, the Navy should increase its inventory of preferred munitions and expendables, building off of increased investment the past few years, and invest in production capacity of critical weapons components, similar to the recent investment in rocket fuel production under the Defense Production Act.[123]

Another key enabler for the surface combatant force is the logistics force. Distributed logistics are necessary to support distributed operations. However, the current maritime logistics force is too vulnerable in contested areas, is too few in number, and lacks the differentiation necessary to support the current surface combatant force conducting distributed operations, much less a larger one that includes different classes of manned and unmanned vessels.[124]

A logistics capability that would have a revolutionary impact on the surface combatant fleet, and possibly on U.S. fleet design, is the ability to rearm VLS cells at sea. Current surface

122 David Ochmanek, RAND Corporation, "Recommendations for a Future National Defense Strategy," testimony presented before the Committee on Armed Services, November 30, 2017, available at www.rand.org/pubs/testimonies/CT484.html.

123 Joe Gould, "Trump to Use Federal Funds to Prop Up US Bomb Makers," *Defense News*, January 16, 2019.

124 For additional information on this subject, see Timothy A. Walton, Ryan Boone, and Harrison Schramm, *Sustaining the Fight: Resilient Maritime Logistics for a New Era* (Washington, DC: Center for Strategic and Budgetary Assessments, 2019).

combatants are only capable of reloading VLS munitions in port or at anchor from a select number of logistics ships. This limitation greatly weakens the combat potential of the fleet and increases its risk. For example, in a notional conflict with China, if forward ports such as ones in Japan or the Marianas were unavailable because of enemy threats, surface combatants operating in the Western Pacific may need to transit back and forth across the Pacific to ports in Hawaii or California to reload. It could take five or more surface combatants to maintain one on station, assuming a moderate weapons expenditure rate. The resulting virtual attrition dramatically cuts down on the fleet's combat potential.

VLS rearming at sea would transform the Navy's ability to reload its primary magazines from a few fixed locations to many mobile ones and would dramatically increase the fleet's operational availability and lethality in a protracted conflict.[125] ONR and the commercial sector have developed new crane and mooring technologies that could be integrated to allow VLS at-sea rearming. This could take place from an Expeditionary Transfer Dock or from a dedicated, converted geared containership serving as a missile reload ship (T-AKM).

Logistical innovation is also needed in refueling and maintenance and repair. Light oilers derived from Offshore Support Vessel (OSV) designs could be equipped to refuel SAGs and independently operating manned and unmanned combatants in contested areas. This would allow large oilers and tankers to operate in more permissive areas. Most surface combatants will lack the maintenance capability to repair unmanned vehicles and are unlikely to be able to support larger, independent vehicles such as MUSVs or MUX. EPFs, Multi-Purpose Support Vessels, or larger vessels could act as light tenders for medium and large unmanned vehicles.

125 A VLS RAS capability from logistics ships in the Second Island Chain or Central Pacific would make it so that only two to three ships would be needed to keep one on station. For example, a VLS RAS capability in the Central Pacific on two to three ships could improve the forward presence of a wartime laydown of 48 cruisers and destroyers by approximately 5–18 additional cruisers and destroyers, depending on the fallback rearmament location (Hawaii or California). Viewed in this light, a fleet VLS RAS capability provides a "value" in equivalent combatants of about $11–37 billion, assuming a cost of approximately $2 billion for each cruiser or destroyer.

CHAPTER 5

Future Family of Surface Combatants

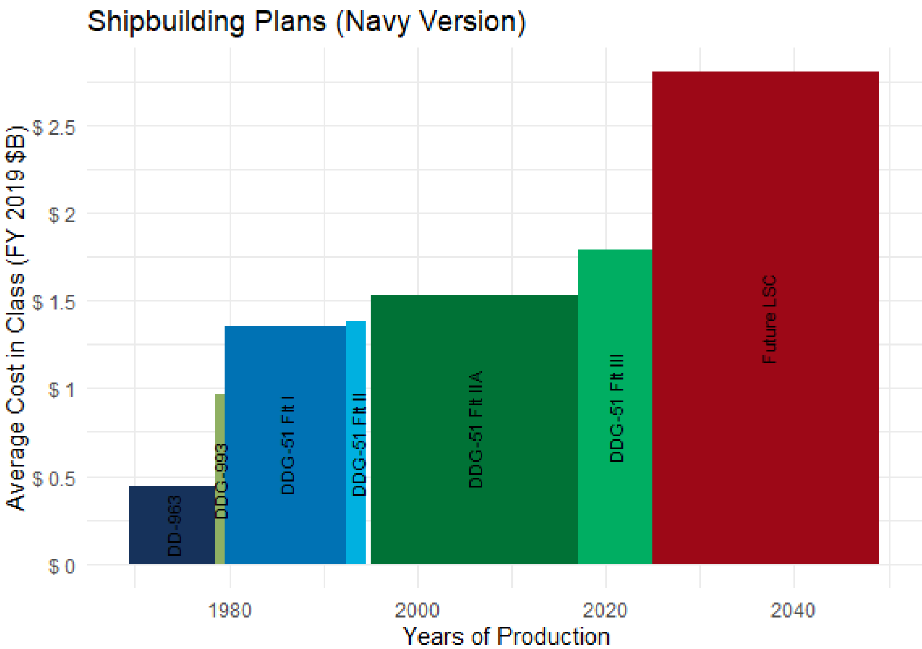
Today's U.S. surface fleet is not designed to implement the new operational concepts required by U.S. defense strategy. The surface force is weighted toward large combatants that are too expensive and manpower-intensive to achieve the inventory needed for distributed operations and relies on offboard or active sensors that will likely be inaccessible or create unacceptable vulnerabilities during combat against a great power like China. The Navy's current and planned small combatants lack sufficient defenses to protect themselves inside contested areas, but cannot be considered expendable due to their cost and crew size.

The Navy needs surface combatants that are more affordable to buy and own than current or planned ships if it is to implement new operational concepts for distributed surface and maritime strike, ISRT and counter-ISRT, and ASW or MIW. This imperative is at odds with the Navy's recent procurement history. The cost of individual surface combatants produced since the 1950s has increased with each new class of ship, as shown in Figure 23. Reshaping the U.S. surface fleet cost curve will require rebalancing the surface force toward smaller platforms that are less expensive with fewer crewmembers.

The operational concepts outlined in Chapter 3 describe new ways for U.S. surface forces to survive and fight inside contested areas and support their increasingly important role in U.S. defense strategy. The manned and unmanned surface combatants proposed in this chapter are intended to support notional force packages that would conduct these new operational concepts.[126]

126 This chapter does examine the capabilities of and improvements to ships currently in the fleet. It focuses its attention, however, on new ships that could be procured over the next 30 years. The Navy is pursuing some of these ships already, including the FFG(X) and MUSV. This chapter proposes new ships to augment those ships, describes the type and force packages of ships that should be procured to meet postulated competition and conflict phase requirements, and compares the projected performance of this alternative force with the force of surface combatants in the Navy's FY 2020 30-Year Shipbuilding Plan.

FIGURE 23: DESTROYER COST INCREASE OVER TIME



1950–2000 data comes from Figures 1.1 and 2.1 in Arena et al., *Why Has the Cost of Navy Ships Risen?* p. xv. The data for future surface combatants is derived from the Navy's 30-year shipbuilding plan.

In assessing missions for manned and unmanned vessels, the force design approach of this study identifies capabilities that need to remain on manned ships to enable and support necessary human operators, such as naval force commanders, Marines embarked on amphibious ships, or vessel boarding parties and trainers on surface combatants. The study uses unmanned surface combatants to either deliver other capabilities or provide additional capacity for capabilities already carried by manned vessels. All manned and unmanned surface vessels above the size of small USVs are assumed to be counted in the Battle Force because they could carry weapons and mission systems, conduct combat operations, and self-deploy to their operating areas.

Small Manned and Unmanned Surface Combatants

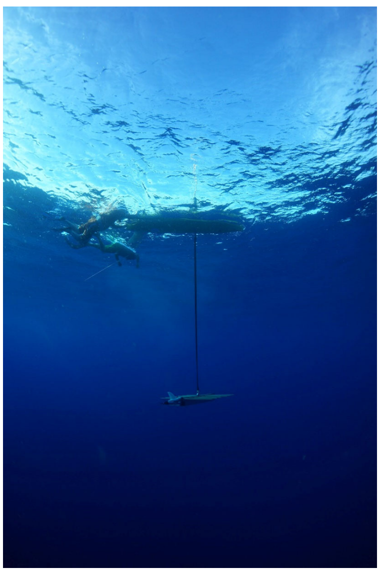
The proposed fleet rebalances surface forces toward larger numbers of smaller combatants to support new operational concepts for ISRT and counter-ISRT, ASW, and high-volume distributed fires. These concepts will require surface combatants to defend themselves from air and missile threats long enough to effectively use their offensive weapons. To that end, every manned and optionally unmanned small surface combatant would be equipped with at least one AMD system, such as a stand-alone SeaRAM launcher or by carrying ESSM Block II interceptors in its missile magazine. To reduce platform cost, completely unmanned vessels would not be equipped with organic AMD systems. Manned and unmanned surface combatants would carry small UAVs, MALE UAVs such as the MUX, or helicopters to conduct ISRT, counter-ISRT, and relay line-of-sight communications.

Small USVs

To conduct ISRT, counter-ISRT, ASW, and MCM, the surface combatant fleet will require a range of small USVs. Some of these will be operated locally from larger surface combatants, while others will operate independently.

Wave glider USVs, shown in Figure 24, are independently deploying small USVs that can be used for long-duration undersea surveillance. Gliders use wave action and small electric motors recharged by solar panels for propulsion; a small mast allows them to use RF communications. Their power and propulsion sources allow gliders to patrol until they require maintenance or cleaning, which is about every 6 months. Gliders can carry low-power passive sensors such as towed sonar arrays or SIGINT equipment.[127] The Common Unmanned Surface Vehicle (CUSV), also shown in Figure 24, is the same size as existing small craft such as the Rigid Hull Inflatable Boat (RHIB). Launched from surface combatants afloat or operating from shore stations, CUSVs are primarily used for MCM and surveillance missions, but could be employed for other operations such as countering enemy small boats.

FIGURE 24: GLIDER AND CUSV UNMANNED SURFACE VEHICLES



Glider photo by Stephen Chin. https://www.flickr.com/photos/steveonjava/10438390015 (Attribution 2.0 Generic (CC BY 2.0))
CUSV U.S. Navy photo by Lance Cpl. Nicholas Guevara. https://www.navsea.navy.mil/Media/Images/igphoto/2002175366/.

127 Geoff Fein, "Northrop Grumman Conducts Advanced Unmanned Systems Teaming," *IHS Jane's International Defence Review*, September 5, 2016, available at http://www.janes.com/article/63436/northrop-grumman-conducts-advanced-unmanned-systems-teaming.

MUSVs

The proposed CSBA surface combatant fleet introduces MUSVs as its smallest Battle Force-counted ships. These fully unmanned vessels would play an essential role conducting distributed counter-ISRT, ISRT, ASW, and MIW missions, where their long endurance and risk-worthiness enable them to expand the area and duration of surface warfare operations. In support of their missions, MUSVs could carry and launch small UAVs, tow passive or active sonar arrays, deploy mines, tow minesweeping gear, and carry RF and IR decoy equipment. Their relatively small radar signature and long endurance would enable them to participate in force packages without substantially increasing the risk of counter-detection.

FIGURE 25: ACTUV MUSV PROTOTYPE

U.S. Navy photo by John F. Williams

MUSV designs should take advantage of improvements in automation and reliability from the commercial unmanned vessel sector and DARPA's ASW Continuous Trail Unmanned Vessel (ACTUV) program, shown in Figure 25.[128] The Navy is considering MUSV designs capable of carrying a payload equivalent to a 40-ft shipping container, operating on its own for at least 60 days, possessing the ability to be refueled at sea, cruising autonomously at 16 kn with a minimum range of 4,500 nautical miles, and communicating via a government-provided

128 "Peru's Largest Fishing Company First to Order Flexible New Sounder USVs from Kongsberg," Kongsberg, April 9, 2019, available at https://www.kongsberg.com/maritime/about-us/news-and-media/news-archive/2019/perus-largest-fishing-company-first-to-order-flexible-new-sounder-usv-from-kongsberg/. "ACTUV 'Sea Hunter' Prototype Transitions to Office of Naval Research for Further Development," DARPA, January 30, 2018, available at https://www.darpa.mil/news-events/2018-01-30a.

communication relay system.[129] The Navy's planned MUSV would be between 12 and 50 meters long, or something between the size of an 11-meter RHIB and the *Cyclone*-class PC.[130] Some MUSV variants focused on persistent ISRT or similar missions could employ sails or solar power as primary or supplementary sources of energy. The payload(s) carried onboard should be a significant portion of an MUSV's cost.

For most missions, MUSVs should be unarmed. Rather than carrying self-defense weapons, MUSVs should be employed in such a manner that reduces their risk of capture and be equipped with a sophisticated suite of tamper-prevention systems that would be activated in case the MUSV or personnel supervising its operation suspected it was at risk of being captured or compromised. Features of such a system include advanced maneuvering to avoid surface and airborne threats. Autonomous self-destruct systems would electronically erase sensitive data on systems, physically destroy key portions of systems with digitally activated thin thermite plates, and scuttle the vessel.[131]

MUSVs could be armed to conduct missions in which a loss of communications would have minimal effect on their effectiveness and ability to avoid fratricide. For example, MIW-focused MUSVs could lay mines, with mine locations decided in advance and mines equipped with sensing and automation to only engage targets exhibiting electronic and acoustic signatures consistent with enemy forces. ASW-focused MUSVs could be armed with CVLWT or Hedgehog-like depth bombs. These weapons have short ranges and could be employed by MUSVs in "ASW-free" areas where U.S. submarines are not operating.

Optionally unmanned DDCs

The proposed surface combatant fleet introduces a new class of 2,000-ton optionally unmanned DDCs to conduct ASUW, STW, and AMD, as well as support amphibious operations. DDCs could be based on the design of OSVs, or they could be a clean-sheet design built to commercial standards. They could take advantage of developments in automation from the DARPA ACTUV and the Office of the Secretary of Defense Strategic Capabilities Office Ghost Fleet programs to operate with crews of around 15–24 personnel, consistent with commercial OSVs. DDC operators would focus on supervising largely autonomous ship operations, light maintenance, and security.

The Navy's planned LUSV would also be an approximately 2,000-ton ship based on an OSV design.[132] In contrast to the optionally manned LUSV, the DDC would be an optionally

129 Megan Eckstein, "Surface Warfare Directorate Still Considering Large Combatant Requirement; MUSV RFP Released," *USNI News*, July 17, 2019.

130 Ibid.

131 Improved anti-tamper and self-destruct systems could also be useful for future optionally unmanned or manned platforms, given that casualties could inhibit the systematic destruction of key systems onboard manned ships.

132 Sam LaGrone, "Navy Wants 10-Ship Unmanned 'Ghost Fleet' to Supplement Manned Force," *USNI News*, March 13, 2019.

unmanned vessel that would normally operate with a crew.[133] By having small crews, DDCs could contribute to peacetime training, engagement, maritime security, and deterrence. DDCs would also have a lower risk compared to unmanned vessels of being captured or herded out of operating areas by adversary forces like China's People's Maritime Militia. During conflict, personnel could be removed, and the DDCs could operate autonomously in highly contested areas. However, the presence of crews onboard, primarily to protect sensitive systems and weapons, would be preferred throughout competition and conflict.

FIGURE 26: OFFSHORE SUPPORT VESSEL

U.S. Navy photo

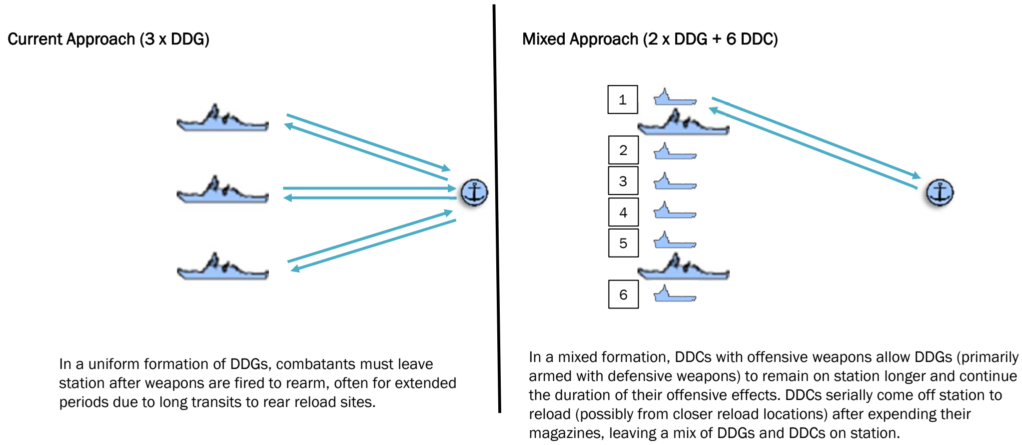
DDCs would operate forward with other surface combatants, where they could independently conduct peacetime security and engagement operations or participate in force packages in which their missile magazines are used to augment the package's offensive or defensive capacity. A smaller portion of the DDC force could operate with CSGs to provide additional weapons capacity.

DDCs would operate primarily as offboard magazines for manned surface combatants and could carry 24–32 weapons in VLS cells, containerized launchers, or both. DDCs should be capable of moderate speeds and high endurance commensurate with FFGs and DDGs to enable operating in their force packages. Manned surface combatants operating nearby with line-of-sight communications or other forces using beyond-line-of-sight communications would often control the firing of DDC offensive munitions, although the DDC crew could

133 The requirement to support small numbers of personnel onboard (e.g., 15–24) would not significantly impact the cost of the vessels, especially since many ships sized to carry large payloads (such as 24–32 VLS cells or equivalents) will already have habitability in their design for a similar number of personnel.

do so if they are aboard. Multiple DDCs in each SAG could carry long-range ASUW, STW, and surface-to-air missiles. They could be rotated from the operating area to reload as their weapons are expended, as shown in Figure 27.[134]

FIGURE 27: USE OF DDCS AS OFFBOARD MAGAZINES



Aggregate SAG Capacity and Presence with DDCs Cycling									
Formation	Formation Cost ($M)	# of VLS Cell Equivalents	VLS Cell Equivalents Fired by Formation per Day	Reloading from Forward Port (800 nm away)		Reloading from VLS RAS Ship (1,250 nm away)		Reloading from Pearl Harbor (4,000 nm away)	
				Time SAG on Station	# VLS Fired in 30 Days	Time SAG on Station	# VLS Fired in 30 Days	Time SAG on Station	# VLS Fired in 30 Days
3 DDG-51	$5,400	288	24	58%	416	49%	354	23%	216
2 DDG-51 + 6 x DDC	$5,400	384	24	100%	720	100%	720	40%	288
*Each DDG equipped with 96 VLS. Each DDC equipped with 32 VLS or VLS equivalents (such as in containerized launchers) for this example.									

By offloading missile capacity onto DDCs, the fleet could distribute its combat power and reduce the size and cost of future large surface combatants. Additionally, DDCs with containerized launchers would be candidates for launching large weapons such as the IRCPS missile that would not fit in the Mk 41 or Mk 57 VLS cells on DDGs and CGs. This approach would eliminate the need for future large surface combatant designs to accommodate large weapons

134 A mixed formation of DDGs with DDCs has multiple advantages over an all-DDG formation. First, depending on the cost of the DDC, the formation may cost less, enabling a net cost saving or a reallocation to other requirements. Second, it has both greater net missile capacity and higher missile availability, measured in firing cycles over 30 days, as the DDCs fire and rearm. The latter advantage stems from the fact that assuming the SAG of all DDGs would exhibit a relatively uniform firing rate, it would likely need to collectively retire upon reaching a minimum weapons capacity threshold (here modeled as 25 percent of VLS cells) in order to maximize protection. In contrast, the mixed formation could have its DDCs act as offensive shooters, while the DDGs would not expend munitions and could apportion a relatively higher proportion of munitions for defensive purposes. Employing a serial firing doctrine in which the first DDC in the formation fires until out of weapons then retires and the second DDC in formation takes its place firing, when the DDCs run out of munitions, they would individually retire to reload and then rejoin the formation. In a formation of six DDCs with a capacity of 32 VLS cell equivalents each, this cycle of DDCs would ensure that there is always at least one DDC per DDG-51 available to fire, as long as the formation's operating radius does not exceed the shuttle times of its DDC. Third, the mixed formation may be able to risk reloading the less expensive DDCs at more contested support locations, like a forward port, where it might be more dangerous due to enemy action for large, high-value ships such as DDG-51 to dock for a prolonged period of time. Fourth, the larger number of platforms in the mixed formation may also be more difficult to comprehensively defeat than the formation of three DDG-51s. Augmenting surface combatant VLS magazines with offboard capacity is a promising concept that may increase operational effectiveness and logistical supportability.

along with competing demands for greater power generation, endurance, sensor capacity, and space for maintenance access and upgrades.

DDCs should be armed with self-defense AMD systems such as SeaRAM and VLS-launched ESSM Block II missiles; they need to survive long enough to expend their offensive weapons and withdraw if a conflict breaks out when they are operating independently. Like MUSVs, DDCs should also have self-protection features to reduce the likelihood and consequence of enemy capture or tampering.

The Navy should consider a DDC-based variant that could carry Marines and their equipment as part of Expeditionary Strike Groups or during smaller amphibious operations. These smaller expeditionary ships would enable Marine forces to be more distributed during movements than on larger amphibious warships. This would better support smaller amphibious operations at the scale of one to two companies, such as establishing an EAB. These vessels could have smaller missile launchers than the DDC to free up weight and space for Marine equipment or include a loading ramp in the bow similar to a Tank Landing Ship.

In order to support their acquisition in large numbers and operation as risk-worthy assets, DDCs should be low cost compared to larger surface combatants such as FFGs and DDGs. As with MUSVs, the cost of DDC combat systems such as sensors, weapons launchers, and missiles should approach or exceed the cost of the vessel itself.

LCSs

In the proposed fleet, LCSs would be used primarily to perform MSO, MIW, and ASW in uncontested or moderately contested areas. The Navy is upgrading some LCS to carry the Naval Strike Missile, which could enable them to support SAGs conducting ASUW. Consistent with the Navy's plans, LCSs would be operated by rotating crews and specialize in ASW, ASUW, or MIW and carry the same mission package during periods between major overhauls or their entire service lives.[135] This specialization will save costs and cultivate crew proficiency in specific warfare areas. Furthermore, in the proposed architecture LCSs would specialize by hull form as well. The *Independence*-class trimaran hull ships should be used for MIW and ASW, since their larger mission bay improves their ability to act as an unmanned vehicle support vessel for those operations. The monohull *Freedom*-class ships should be used primarily for MSO and MIW. The two different hulls should be based in locations appropriate for their missions. For example, *Freedom*-class ships should be forward-stationed in Bahrain, and *Independence*-class ships should be forward-stationed in Bahrain and Singapore.

Throughout the lives of the ships, the Navy should introduce low-cost, high-payoff improvements to upgrade the combat systems on LCSs. Improved integration and modernization of radars and EO/IR sensors and the introduction of MAD-FIRES munitions to their 57-mm main guns would greatly improve terminal AMD capabilities and could possibly allow LCSs

135 An LCS focused on MSO would employ the Surface Warfare Mission Package.

to operate in moderately contested environments. LCSs could also host new small unmanned vehicles and medium UAVs and UUVs as they join the fleet.

FFGs

Consistent with the Navy's plans, the FFG would serve as a multi-mission small surface combatant capable of conducting local AMD, ASUW, ASW, ISRT, and counter-ISRT.[136] The FFG's final capability mix is not yet decided but at a minimum will include an Mk-110 57-mm deck gun, a 21-round RAM launcher, a passive SEWIP Block 2 EW suite, EASR, over-the-horizon surface-to-surface missiles, a 32-cell VLS magazine, and the ability to host one manned helicopter and various unmanned vehicles. Additional systems could include the AN/SQQ-89F sonar processing suite, AN/SQS-62 LFA VDS, TB-37 multi-function towed array, and EO/IR sensors. To maximize the time each FFG spends at sea, the ship should be designed to support rotational crewing, including rapidly maintaining the ship in between deployments or patrols.

Large Surface Combatants

The proposed surface fleet decreases the proportion of large surface combatants compared to today's surface force. It focuses large surface combatants on conducting C2 and using their larger active radars to provide AMD for formations and assets that could come under heavy air and missile attack but lack organic air defense capacity such as CSGs, civilian maritime units, logistics formations, and important shore facilities.

To conduct targeting and support line-of-sight communications, large surface combatants would carry small UAVs, MALE UAVs like the MUX, and conventional helicopters. While large surface combatants may be capable of launching and recovering a small number of SUSVs or small and medium UUVs, ship designs should not prioritize the transport of significant numbers of unmanned systems in a "mothership" approach; rather, large surface combatants should be capable of commanding and controlling such systems that may be delivered by other platforms or self-deploy into the theater.

Current Large Surface Combatants (CG-47, DDG-51, and DDG-1000)

As described in Chapter 3, the changing nature of surface warfare operations would enable FFGs and DDCs to replace DDGs in a growing number of missions. DDGs could focus on C2 of surface operations and AMD of high-value targets at sea and ashore. With a smaller number of large surface combatants needed, the Navy could reduce sustainment and manpower costs by foregoing service life extensions of older CGs and DDGs.

136 Ronald O'Rourke, *Navy Frigate (FFG[X]) Program: Background and Issues for Congress* (Washington, DC: Congressional Research Service, June 25, 2019), p. 5.

This study's proposed approach to surface combatants retires all CG-47 cruisers between FY 2021 and FY 2031 as new DDG-51 Flight III and Flight IIIAs enter the fleet and retires DDG-51 Flight Is and IIs as they reach the end of their service lives. DDG-51 Flight IIAs are modernized by retrofitting them with the AN/SPY-6(V)4 radar, which is a smaller version of the SPY-6(V)1 incorporated on the DDG-51 Flight IIIs. The integration of AN/SPY-6(V)4 would enable DDG-51 Flight IIAs to remain effective until retiring at a rate of two-per-year starting in FY 2039. The three-ship DDG-1000 *Zumwalt*-class is retained and employed for experimentation and concept development, with periodic deployments for ASUW or STW operations overseas.

New DDG-51 Flight III and Flight IIIAs

As planned by the Navy, DDG-51 Flight IIIs are delivered in the proposed plan from FY 2023 to FY 2028. These ships provide improved AMD capability with the SPY-6(V)1 radar. Equipped with 37 Radar Modular Assemblies (RMA), the SPY-6(V)1 S-band radar and radar suite controller is 30 times more sensitive and can simultaneously handle more than 30 times the targets of the existing AN/SPY-1D.[137] Working with the SPQ-9B X-band high-resolution phased-array radar, the SPY-6(V)1 could address larger and more complex raids than today's DDG radars.[138]

The proposed CSBA shipbuilding plan procures a new class of DDG-51 Flight IIIA from FY 2025 to FY 2030. This ship design would be largely based off of the DDG-51 Flight III but would incorporate additional passive EO/IR and RF sensors and improved power and cooling to host directed energy weapons. The Flight IIIA would serve as a gap-filler until the Navy has matured technologies and designs for a follow-on large surface combatant, which this study calls DDG(X).

DDG(X)s

A new large surface combatant class is necessary for the fleet, but the Navy should change its approach to provide it. The Navy is considering procuring Future Large Surface Combatants in the mid-2020s, which will likely not provide sufficient time to mature key technologies and designs needed for the ship, which will increase the risk the ship will be over cost and behind schedule.[139] Of greater concern, Navy leaders have said that their top three desired attributes for the Future Large Surface Combatant are the ability to host air defense commander staffs,

137 Jason Sherman, "Navy determines SPY-6 radar three times stronger than original requirement," *Inside Defense*, May 3, 2019.

138 "Raytheon's SPY-6 Leads Family of Advanced Radars," *Seapower Magazine*, February/March 2019, p. 37, available at https://www.raytheon.com/sites/default/files/2019-03/Seapower%20Magazine_FebMar%20Snapshot_2019.pdf.

139 Megan Eckstein, "Navy Considering More Advanced Burke Destroyers as Large Surface Combatant Timeline Slips," *USNI News*, August 8, 2019.

launch large weapons, and employ a large radar.[140] This combination of characteristics could result in a very large, power-dense, and expensive ship design, consistent with a cruiser.[141]

A cruiser would likely be too costly to acquire in the number necessary for distributed operations. The Congressional Budget Office estimates the Navy's planned Future Large Surface Combatant to cost an average of approximately $2.8 billion per ship.[142] In addition to reducing the number of ships the Navy could build, this expense may crowd out investment funding for the capabilities necessary to make surface combatants more lethal.

In contrast to the Navy's planned approach, CSBA's proposed fleet includes a new large surface combatant called DDG(X) to provide advanced AMD capabilities, a new hull design suitable for future capability and capacity growth, and reduced crew size. DDG(X) would also be capable of conducting maritime or land strike and ASW organically or integrated with optionally unmanned and fully unmanned vessels and aircraft. The DDG(X) would be introduced in FY 2030, instead of the Navy's planned FY 2025 program start, to ensure key technologies for automation, electric propulsion, and directed energy weapons are matured first.

The DDG(X) design would prioritize requirements necessary to support emerging operational concepts as part of force packages instead of as an independent platform. The use of DDCs for additional missile capacity would reduce the need for DDG(X) to have a large VLS magazine. Similarly, making the new large surface combatant able to carry very large missiles would significantly constrain the space and weight available for sensors, fuel, personnel, and the larger integrated power systems needed for an all-electric ship. Larger weapons are unlikely to be affordable in large numbers, which would result in constraining the combatant design to accommodate a weapon that may not be carried by every ship of the class. Placing large missile tubes or launchers on some DDCs instead would afford ship designers more flexibility because DDCs have fewer competing design imperatives than a large surface combatant.

Figure 28 compares key attributes of this study's proposed DDG(X) with the Navy's planned Future Large Surface Combatant based on public reports. DDG(X) should incorporate passive EO/IR sensors and RF receivers capable of generating tracks using a target's emissions or returns from multistatic radar. An advanced active radar capability, such as that provided by the 37-RMA SPY-6(V)1, should also be incorporated. However, DDG(X) should not employ a

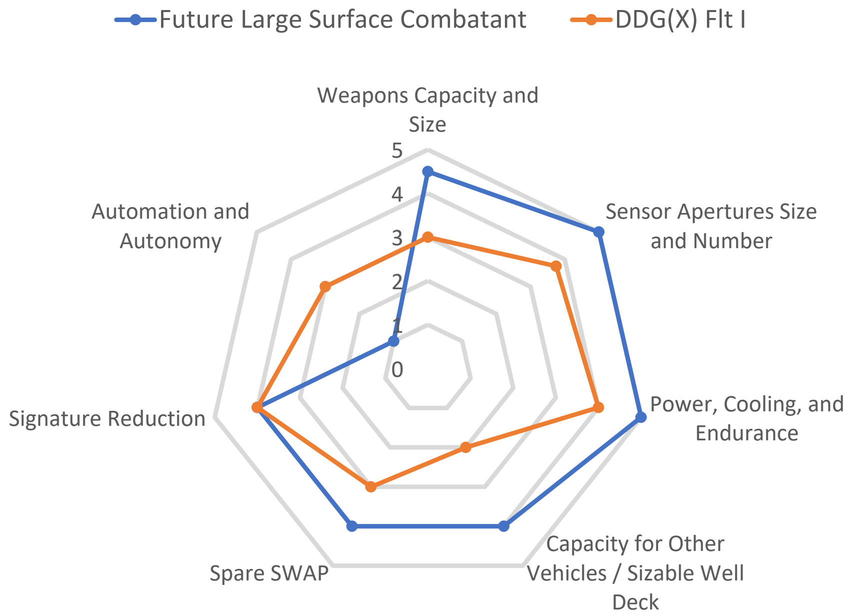
140 Megan Eckstein, "Navy Considering More Advanced Burke Destroyers as Large Surface Combatant Timeline Slips," *USNI News*, August 8, 2019.

141 RAND analysis of trends in shipbuilding costs has found that "light ship weight (LSW) and power density (i.e., the ratio of power generation capacity to LSW) correlated most strongly with ship costs." In short, heavier and more power-dense ships are more expensive. Additionally, RAND found "the Navy's desire for larger and more-complex ships has been a significant cause of ship cost escalation in recent decades." Mark V. Arena et al., *Why Has the Cost of Navy Ships Risen? A Macroscopic Examination of the Trends in U.S. Naval Ship Costs Over the Past Several Decades* (Santa Monica, CA: RAND Corporation, 2006), p. xv.

142 "Table 5. Comparison of the Navy's and CBO's Estimates for the Construction of Major New Ships Under the Navy's 2020 Plan," in Eric Labs, *An Analysis of the Navy's Fiscal Year 2020 Shipbuilding Plan* (Washington, DC: CBO, 2019), p. 20.

radar larger than 37 RMAs, since the DDG(X) will predominantly employ passive detection and tracking methods or offboard ISRT. Using an existing radar will also reduce the ship's cost compared to one with a new radar design. In terms of acoustic sensors, the DDG(X) should carry a towed passive array and LFA VDS, if space and weight allow.

FIGURE 28: FUTURE LARGE SURFACE COMBATANT AND DDG(X) ATTRIBUTES



Radar chart denotes level of emphasis on attributes. A value of zero signals no emphasis and five a very high degree of emphasis. Values based on CSBA estimates of attributes of its proposed DDG(X) and potential attributes of the Navy's proposed Future Large Surface Combatant, as described in "Large Surface Combatant RFI - Systems Providers," Naval Sea Systems Command, April 1, 2019, available at https://www.fbo.gov/index?s=opportunity&mode=form&id=d32ac2da038abec9893f997dbcfff831&tab=core&_cview=1; Eric Labs, *An Analysis of the Navy's Fiscal Year 2020 Shipbuilding Plan* (Washington, DC: Congressional Budget Office, 2019); and Megan Eckstein, "Navy Considering More Advanced Burke Destroyers as Large Surface Combatant Timeline Slips," *USNI News*, August 8, 2019.

To operate in contested environments and protect other ships, DDG(X) will also require a suite of counter-ISRT systems including laser dazzlers to defeat EO/IR sensors on aircraft or satellites, EW systems to defeat missiles and degrade adversary surface search and space-based radars, and towed acoustic jammers or decoys to confuse torpedoes. DDG(X) should also be capable of carrying and deploying offboard counter-sensor deception systems such as USV- and UAV-based RF and IR decoys and UUV-based acoustic decoys.

DDG(X) should be capable of operating weapons for AMD, ASUW, STW, and ASW in a primary missile magazine equivalent to the DDG-51 Flight III's 96 VLS cells. As previously discussed, additional surface combatant missile capacity in terms of size or numbers should be economically offboarded to DDCs. To increase DDG(X) weapons capacity compared to the DDG-51, it should incorporate small, trainable kinetic weapon and decoy launchers, an HPM weapon, and a laser at power levels of 500 kW or higher that would be capable of missile defense.

DDG(X) should employ a combat system common throughout the fleet that integrates manned and unmanned platforms and sensors across domains, kinetic and non-kinetic weapons, and provides cyber resilience. Moreover, through the use of automated and cognitive planning tools, modestly sized command staffs onboard DDG(X) should be able to orchestrate complex operations of numerous manned and unmanned systems under the concept of context-centric C3.

DDG(X) provides an opportunity for the Navy to embrace more automation on large surface combatants. The technology maturation being pursued for unmanned surface vessels and occurring in the commercial maritime industry may enable the Navy to lower the crew size of large surface combatants from around 330 to less than 200. Advances in automation matured on DDCs may enable further reducing crew sizes. To avoid the challenges encountered by the Optimal Manning experiments of the early 2000s, the surface force should only harvest manning reductions after the viability of new automation and reductions in workload have been realized.

After maturing the technology through a dedicated program of research, development, and testing between FY 2020 and FY 2030, DDG(X) should incorporate an integrated power system with electric propulsion. The ship should be designed to have long endurance not only at economical cruise speeds but also the higher speeds necessary to support CSG operations. DDG(X) could incorporate a flexible power approach using fuel-efficient diesel generators for normal energy demands and gas turbine generators to enable the ship to sustain high speeds and power levels.[143] Energy storage magazines such as batteries, fuel cells, or mechanical devices could be used to augment gas turbines during the ship's most demanding periods in which all sensors and electric and directed energy weapons are operating at their highest power levels and the ship is at maximum speed.

Proposed Force Posture

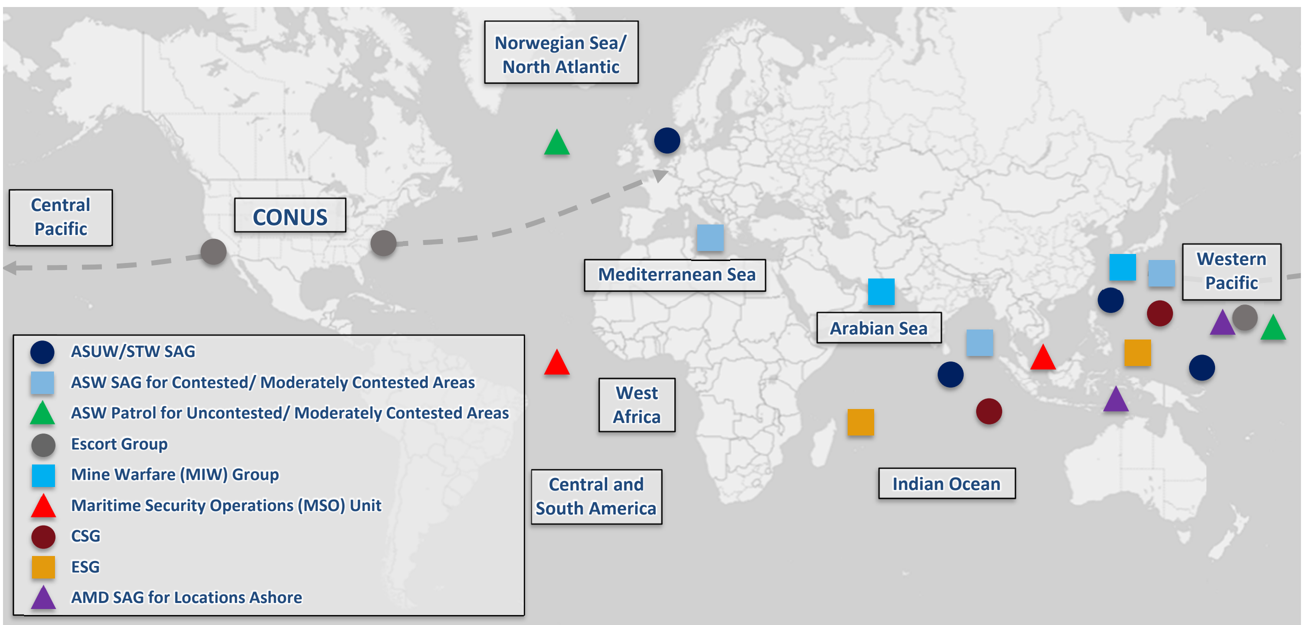
The deployed posture proposed by this study organizes manned and unmanned surface combatants in force packages and postures them appropriate to the operations needed in each region. Proposed force packages are described in Table 1, and the resulting laydown is depicted in Figure 29.

143 These engines could be mounted with a rafting solution to reduce structure-borne noise.

TABLE 1: SURFACE COMBATANTS IN PROPOSED FORCE PACKAGES

Force Packages			DDGs	LCS	FFG	DDC	MUSV
SUW/STW SAG	Number of Force Packages	4	2	0	0	6	5
	Total Vessels		8	0	0	24	20
ASW SAG for Moderately Contested / Contested Areas	Number of Force Packages	3	0	0	2	0	5
	Total Vessels		0	0	6	0	15
ASW Patrol in Uncontested / Mod. Contested Areas	Number of Force Packages	2	0	2	0	0	2
	Total Vessels		0	4	0	0	4
CSG	Number of Force Packages	2	4	0	0	3	7
	Total Vessels		8	0	0	6	14
Escort Group	Number of Force Packages	3	1	0	2	0	4
	Total Vessels		3	0	6	0	12
AMD SAG for Locations Ashore	Number of Force Packages	2	2	0	0	4	0
	Total Vessels		4	0	0	8	0
ESG	Number of Force Packages	2	1	0	1	3	7
	Total Vessels		2	0	2	6	14
MIW Group	Number of Force Packages	1	0	5	0	0	4
	Total Vessels		0	5	0	0	4
MSO Unit	Number of Force Packages	2	0	1	0	0	0
	Total Vessels		0	2	0	0	0
Number of Deployed Vessels by Type			25	11	14	44	83
Total Deployed Vessels							177

FIGURE 29: GLOBAL LAYDOWN OF SURFACE COMBATANT FORCE PACKAGES

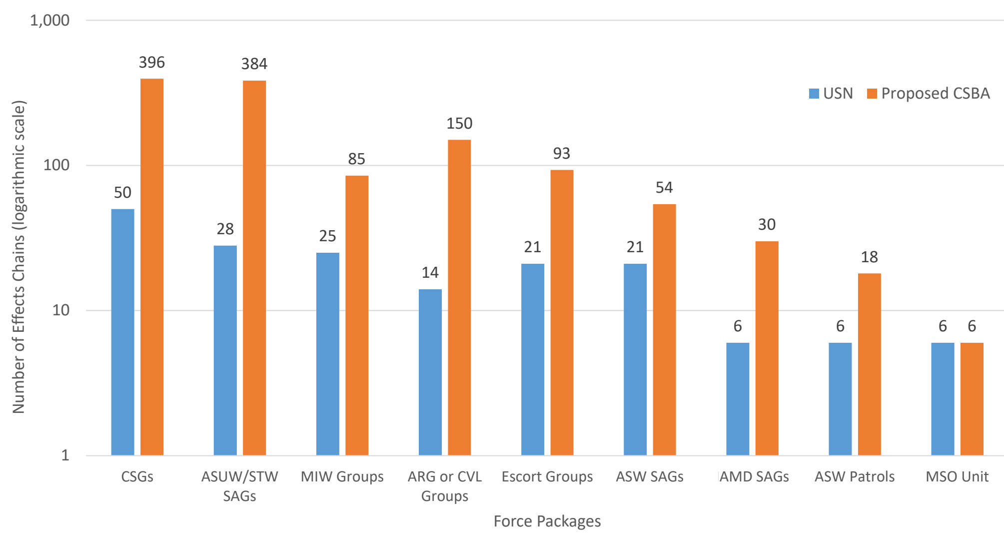


The total number of deployed platforms multiplied by the rotation factor for each platform type results in the total inventory needed for each class of manned or unmanned surface combatant.

Assessing proposed surface forces

The surface force packages proposed by this study are designed to increase surface force complexity to degrade an adversary's decision-making or grow the salvo size needed for the enemy to conduct a successful rapid attack against a U.S. surface force. Compared to force packages of current or planned Navy surface platforms that accomplish the same missions at comparable cost, the proposed force packages include almost three times more platforms, which provides additional targets for an adversary to discriminate and more ways to complete effects chains. As a result, each of the nine types of proposed force packages are capable of generating more than five times the number of separate effects chains than traditional force packages for the same missions.[144] Because the proposed force packages comprise 71 percent unmanned or lightly manned risk-worthy platforms, they are also better able to absorb losses and degrade more gracefully than today's surface fleet of expensive large surface combatants.

FIGURE 30: COMPARISON OF THE COMPLEXITY OF TRADITIONAL AND PROPOSED DEPLOYED SURFACE FORCE PACKAGES



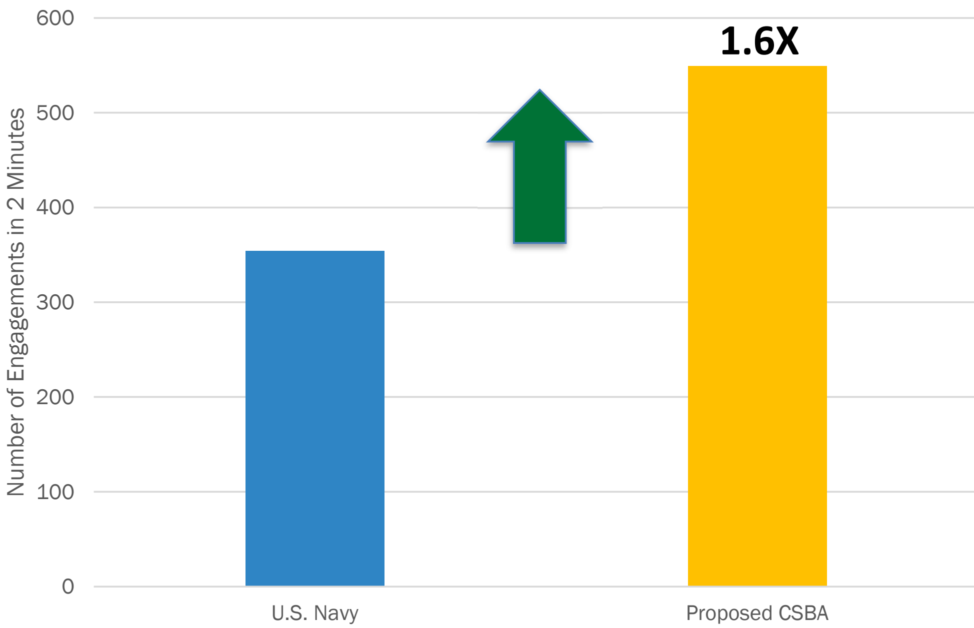
In total, CSBA's proposed deployed surface fleet in Table 1 is capable of generating approximately 1,200 separate effects chains, almost seven times as many possible with today's surface force. This provides increased resilience to force packages, since it may be more difficult for an

144 This estimate assigns ships C2/Multi-Function, Effectors, or Sensor/Counter-Sensor functions. It then assesses all possible effects chains within a force package, which are the combinations involving three or fewer ships, with C2/Multi-Function ships being able to take on all roles and Effectors or Sensors only taking on that role.

adversary to effectively destroy key nodes and eliminate all possible means of executing effects chains. Figure 30 compares current and proposed surface force package complexity.

The air defense capacity, counter-ISRT capabilities, passive and multistatic sensing, and distributed posture of the proposed force packages could all increase the number of weapons an adversary would need to launch to destroy the deployed fleet. Compared to force packages of current and planned Navy platforms that accomplish the same missions at comparable cost, the proposed force packages on average provide 19 percent more air and missile defensive capacity in the 10–30 nm range. Summing the total salvo capacity of the deployed fleet in Table 1, the proposed force could fire 14,000 defensive shots, compared to 10,500 in a comparable traditional fleet.

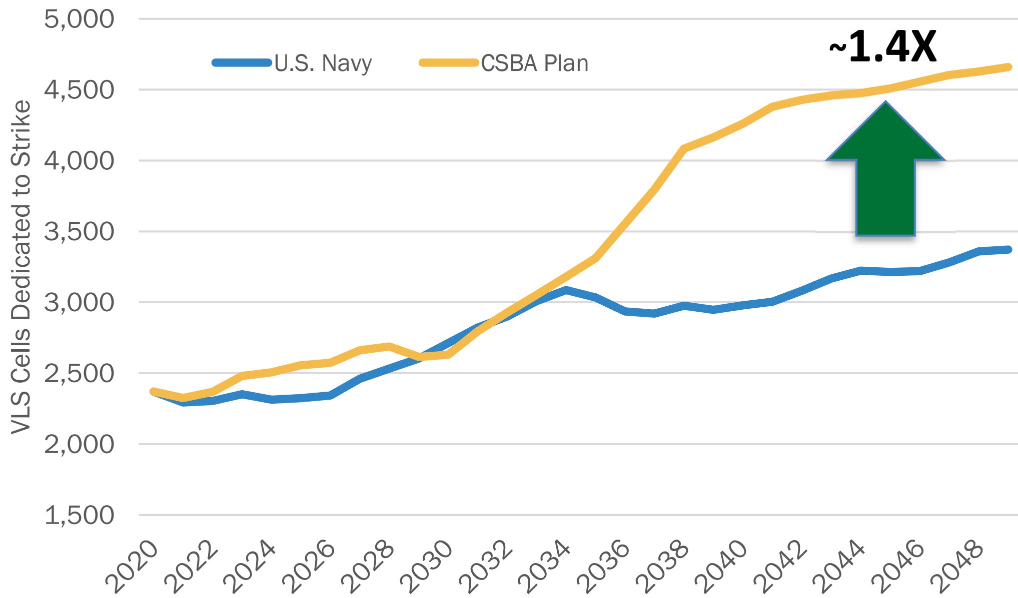
FIGURE 31: SURFACE ACTION GROUP DEFENSIVE CAPACITY



Simply imposing a large salvo cost on a potential aggressor will be insufficient to deter an act of aggression if the adversary perceives no threat to its own forces. A great power competitor like China or Russia could accept the cost of defeating U.S. forces and move on to its nearby objective unopposed. Therefore, U.S. surface force improvements should also be evaluated on their ability to reserve offensive capacity, even if that capacity is used as surface combatants withdraw to regroup and reload.

The proposed force packages provide greater offensive capacity than force packages that accomplish the same missions at comparable cost using the Navy's current or planned platforms. It also offsets the impact of *Ohio*-class guided missile submarines retiring during the 2020s. The proposed force packages on average provide 65 percent more offensive missile capacity than traditional force packages and 75 percent greater aggregate offensive missile capacity. Notably, more than half of surface combatants armed with offensive weapons are risk-worthy DDCs, distributing the fleet's offensive potential and enabling more graceful degradation of offensive capacity as ships are lost. By introducing DDCs able to rotationally fire their offensive weapons and reload, the proposed fleet is also capable of sustaining a much higher rate of fire than traditional force packages.[145] The proposed deployed fleet could maintain an average daily firing rate of approximately 230 offensive missiles, assuming all forces had access to a secure reload point 1,250 nm away, compared to only approximately 64 missiles per day from the Navy's programmed force using the same laydown.

FIGURE 32: SURFACE COMBATANT FLEET STRIKE CAPACITY



This chart is based on data for a proposed CSBA plan and the Navy's Long-Term Shipbuilding Plan. The estimate of Navy strike missile capacity in the figure assumes 25 percent of VLS cells in DDGs, CGs, and FFGs are allocated to strike. It also assumes 100 percent of submarine VLS are allocated to strike. CSBA's proposed plan follows the same allocation as the Navy estimate, with the exception of DDCs. DDCs operating in non-CSG force packages allocate 100 percent of their magazines to strike, while DDCs operating in CSG force packages allocate 25 percent of their magazines to strike.

Summary

Without significant changes to surface fleet tactics, systems, and platforms, the Navy risks fielding a force unable to conduct complex distributed operations that would degrade adversary decision-making or increase the number of enemy weapons needed for a successful attack. Moreover, the Navy's planned surface fleet would lack the offensive capacity or lethality to threaten denial of adversary aggression. Using new operating concepts, the proposed mix of surface combatant types and force packages would improve the surface fleet's ability to support U.S. national and operational strategies. The aforementioned ship designs and force

145 For additional information, please see Figure 31.

packages either exist or leverage technologies that could be deliberately matured and incorporated onto future surface combatants by the early 2030s. The next chapter presents a plan to evolve the fleet into that future vision.

CHAPTER 6

Implementing a New Surface Fleet Architecture

The preceding chapters described shortfalls of the current U.S. surface fleet, constraints that prevent the Navy from simply expanding the number and capability of today's surface combatants, and proposed new surface warfare operational concepts, platforms, force packages, and posture to better support U.S. defense strategy. This chapter translates the proposed force posture into a required surface fleet composition and mix by assessing how many of each combatant type is needed to sustain the posture, taking into consideration factors such as readiness cycles, basing locations, and transit time to each deployment area. Together, the number and type of surface platforms and mission systems, basing, posture, and readiness cycles comprise the surface fleet architecture. The chapter closes by proposing a revised shipbuilding plan and a detailed roadmap for the Navy to field the proposed surface force by the early 2030s.

Surface Fleet Readiness Models

U.S. naval forces currently operate in rotational cycles consisting of deployments, maintenance, training, and certification for the next deployment. The number of each type of vessel needed in the surface fleet results from the number deployed at any given time and the rotational readiness cycle that prepares surface units for deployment.[146] For example, a unit that deploys for 6 months of each 2-year cycle will need at least four units to maintain one continuously deployed.

Platform types use different rotational cycles based on their maintenance requirements and complexity of training. Rotational cycles also differ between forces based in CONUS and those based overseas. Compared to the current practice of U.S. surface forces, the approach

146 For additional information on readiness cycles, please see Clark et al., *Restoring American Seapower*, pp. 101–107.

to readiness generation proposed by this study provides more time and greater scheduling stability for surface forces to train, experiment, adapt, and conduct maintenance between deployments.

Most surface force packages contributing to the Contact layer in the proposed surface fleet follow a higher operational tempo readiness cycle like that used today by Forward Deployed Naval Forces (FDNF) in Japan and Spain. In this readiness model, ships are available for operations 50 percent of each year and spend the other 50 percent conducting training or maintenance. This relatively high operational tempo is made possible by basing most Contact layer ships in forward areas, which reduces transit time to operating areas and constrains ships' operating areas to the region in which they are based. Crews would either be based overseas with their ships or rotationally deploy from CONUS.

The training time needed by Contact layer surface forces could be reduced and the proficiency of surface forces increased by focusing them on the narrow set of scenarios, allies, and adversaries in their deployed region.[147] Forward-stationed MUSVs and other unmanned vehicles are assumed to sustain a higher operational availability than manned ships because they are simpler and require less maintenance. Unmanned vehicles also do not have dedicated crews; the vehicles could remain forward while their operators rotationally deploy.[148]

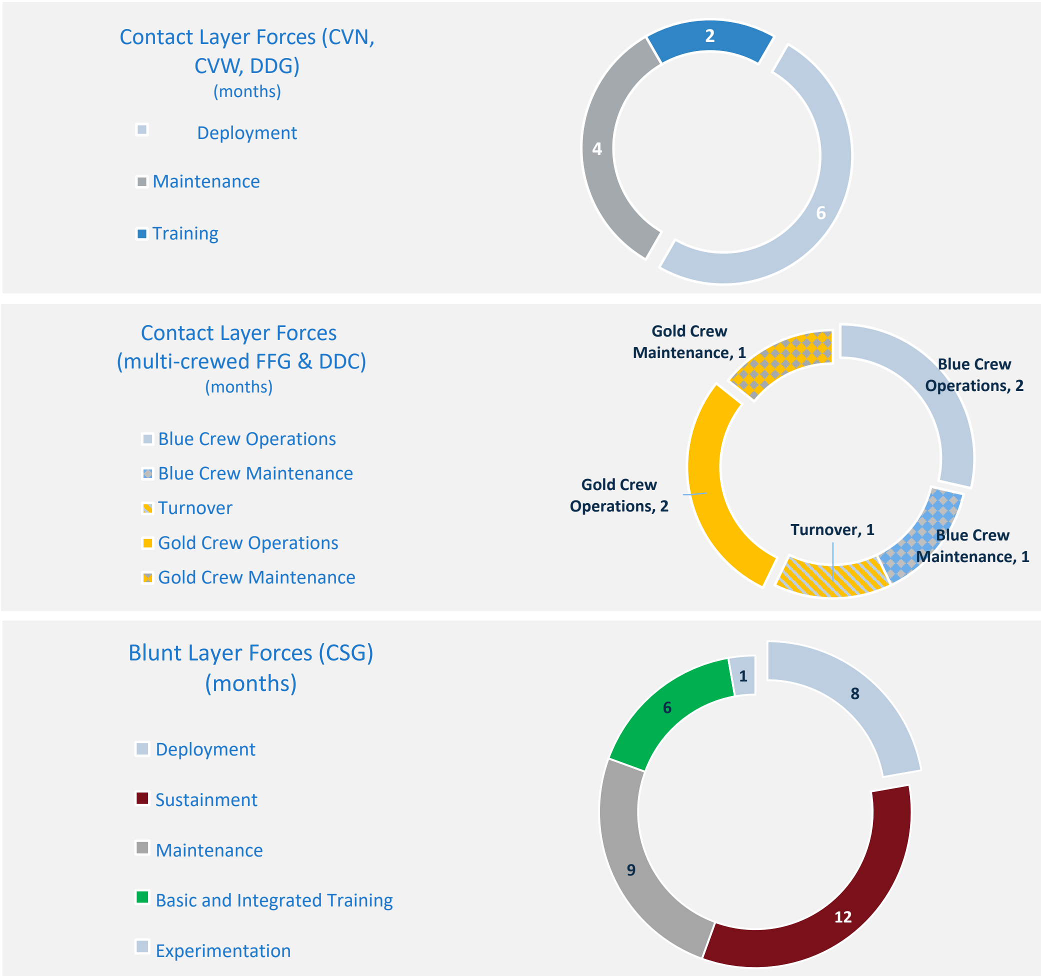
Surface fleet force packages contributing to the Blunt layer, such as ESGs and CSGs, would follow the 36-month Optimized Fleet Response Plan (OFRP) readiness cycle of one 7-month deployment and about 12 months of additional operational availability during the Sustainment phase. Surface forces contributing to the Blunt layer would be predominantly homeported in CONUS, with the exception being the CSG based in Japan, which would follow the FDNF readiness model described above. Compared to the readiness cycle of the Contact layer forces, the lower-tempo OFRP cycle would afford surface forces time to:

- Exercise, including multi-carrier operations, near CONUS to establish and improve proficiency for high-end combat against a peer competitor;
- Experiment with new fleet operating concepts;
- Participate in large-scale exercises overseas to improve interoperability and effectiveness with allies and partners; and
- Conduct deterrence and reassurance operations such as shows of force or port calls in forward areas to deter adversaries and complement Contact layer forces.

147 Some ships would be based in CONUS or Hawaii due to the space and maintenance challenges associated with overseas home-porting.

148 Smaller unmanned vehicles and possibly even MUSVs could be classified as "weapon systems" rather than vessels, allowing them to be maintained overseas or under large multi-platform contracts.

FIGURE 33: READINESS CYCLES BY OPERATING LAYER



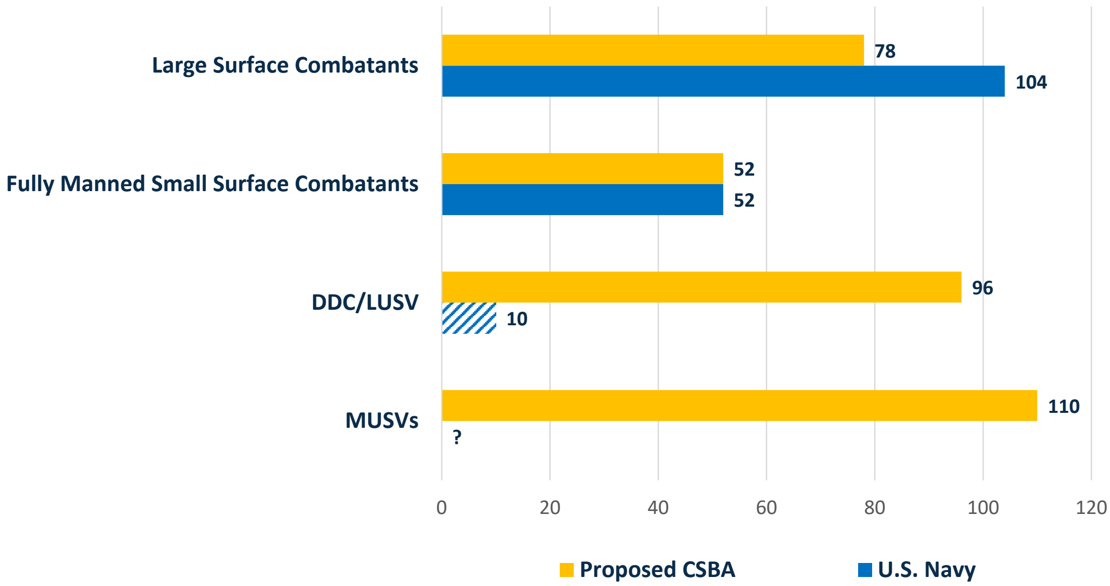
Implementing the proposed posture will be challenging due to the larger number of units overall and increased number of forward stationed or homeported ships in the proposed architecture. These factors will increase the expense and complexity of training and maintenance. Estimates for these costs based on today's FDNF units are incorporated into the analysis that follows.

Composition of the Proposed Fleet

Using the readiness cycles described above, the overall number of surface combatants required to support the naval posture of Chapter 5 can be calculated. In addition to supporting the rotational readiness cycle, the proposed fleet architecture includes additional ships to account for the time ships are in transit and the long-term maintenance that takes ships out of their readiness cycle. Further, this study assumes that the rotation base of non-deployed surface combatants is sufficient for wartime surge requirements.

Figure 34 depicts the required composition of the proposed CSBA surface fleet. In total, the fleet consists of 336 surface combatants that would fall under the Navy's battle force counting rules, assuming revisions to add MUSVs.[149] The proposed surface fleet requires far fewer manned large surface combatants than the Navy's planned force (78 instead of 104) and more small surface combatants (258 instead of 52), which include DDCs and MUSVs. The surface combatant fleet would incorporate additional sensors and vehicles, such as shipborne small USVs and UUVs, UAVs, and helicopters.

FIGURE 34: PROPOSED CSBA SURFACE FLEET COMPOSITION COMPARED TO THE U.S. NAVY'S PLAN.



The proposed CSBA surface fleet results in a force capable of generating greater complexity, more robust defenses, and more offensive capacity compared to the Navy's current and planned surface force. The proposed fleet disaggregates the surface force into more than twice as many platforms as the Navy's plan, almost two-thirds of which are different types of optionally unmanned or fully unmanned vessels. The proposed force greatly increases the salvo size or time needed by an adversary to conduct a successful attack against U.S. surface forces. It achieves this in part by fielding 73 MUSVs focused on decoy and counter-ISRT operations, which will challenge an enemy's orientation and targeting process and increase the time or number of weapons needed for a successful immediate attack.

149 For the proposed CSBA 30-Year Shipbuilding Plan Surface Combatant Battle Force, please see Appendix A. For information on fleet counting rules, please see Secretary of the Navy, *General Guidance for The Classification of Naval Vessels and Battle Force Ship Counting Procedures*, SECNAVINST 5030.8C (Washington, DC: U.S. Navy, June 14, 2016), p. 2.

The proposed fleet has greater offensive capacity than the programmed force and distributes it in a more resilient manner among more surface combatants. By FY 2049, the CSBA force has almost 42 percent more weapon cells available for strike from surface combatants in the fleet than the Navy's plan. More than half of the proposed fleet's strike capacity is on optionally unmanned DDCs that may be capable of operating as risk-worthy assets in contested areas. The CSBA fleet plan has approximately the same average number of offensive missiles per ship as the Navy's plan—21 missiles per ship—but distributes them across an armed fleet that is 44 percent larger, and thus more difficult to defeat in detail.

The Navy's Planned Fleet

The Navy's FY 2020 Long-Term Shipbuilding Plan increases the required number of large surface combatants from 94 to 104 and small surface combatants from 30 to 52. Achieving this larger fleet would require real annual shipbuilding expenditures on surface combatants to rise from around $6.6 billion to $9.1 billion per year—an increase of more than a third. Annual operation and support costs for surface combatants would need to grow from around $6.4 billion today to about $8.7 billion in real terms by 2049—also an increase of more than a third.[150]

Within the Navy's FY 2020 shipbuilding plan, approximately 63 percent of surface combatant procurement cost is allocated to a single ship design, the Future Large Surface Combatant. Compared to the FY 2019 Long-Term Shipbuilding Plan, the FY 2020 plan accelerates introduction of the Future Large Surface Combatant from FY 2030 to FY 2025. To follow shipbuilding best practices, the Navy should develop needed technologies and complete ship designs before beginning construction.[151] The Navy's plan to accelerate procurement of the Future Large Surface Combatant without first developing and maturing relevant technologies is likewise liable to result in a ship that is delivered late, over budget, and falls short of requirements. Moreover, the estimated $2.8 billion cost of the Future Large Surface Combatant continues the Navy on a trajectory toward a smaller fleet of expensive ships.

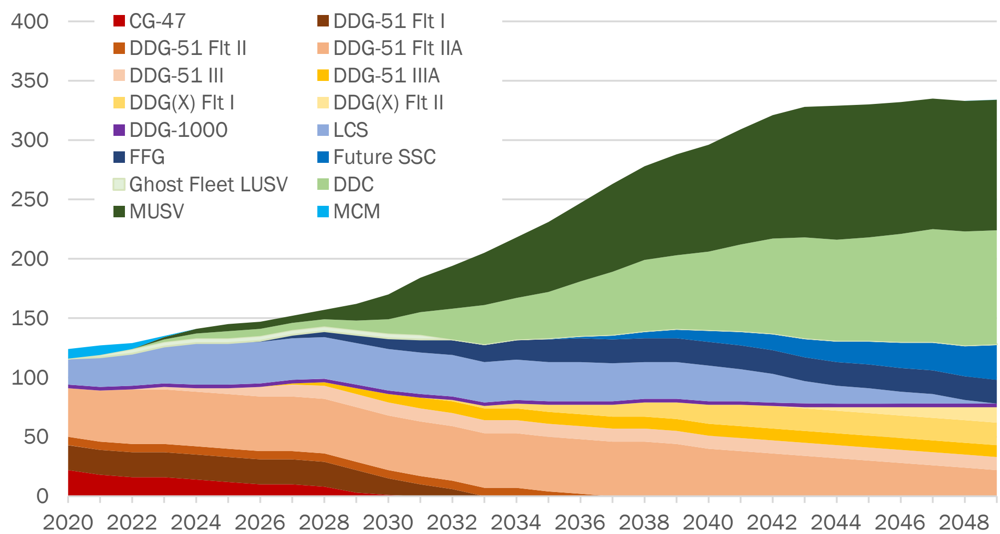
150 This report estimates direct operation and support costs—the costs to pay crews, purchase fuel and supplies, and repair and maintain ships. Additional indirect and overhead costs are not captured in this report. For additional information on operation and support cost estimation, please see Appendix B.

151 Shelby S. Oakey, *Navy Shipbuilding Past Performance Provides Valuable Lessons for Future Investments*, GAO-18-238SP (Washington, DC: U.S. Government Accountability Office, June 2018), pp. 14–15, available at https://www.gao.gov/assets/700/692331.pdf.

Building the Proposed Surface Fleet

The shipbuilding plan for the proposed CSBA surface fleet, depicted in Figure 35, will lead to a battle force that meets the requirements for large surface combatants, LCSs, and FFGs by FY 2035. It should meet all surface fleet requirements, to include DDCs and MUSVs, by FY 2048. The lag in fully meeting force structure requirements can be understood by accounting for industrial base limits in introducing large numbers of DDCs and MUSVs into the fleet, financial constraints, and the organizational changes needed to field new platform types.

FIGURE 35: BATTLE FORCE INVENTORY FROM PROPOSED CSBA SHIPBUILDING PLAN

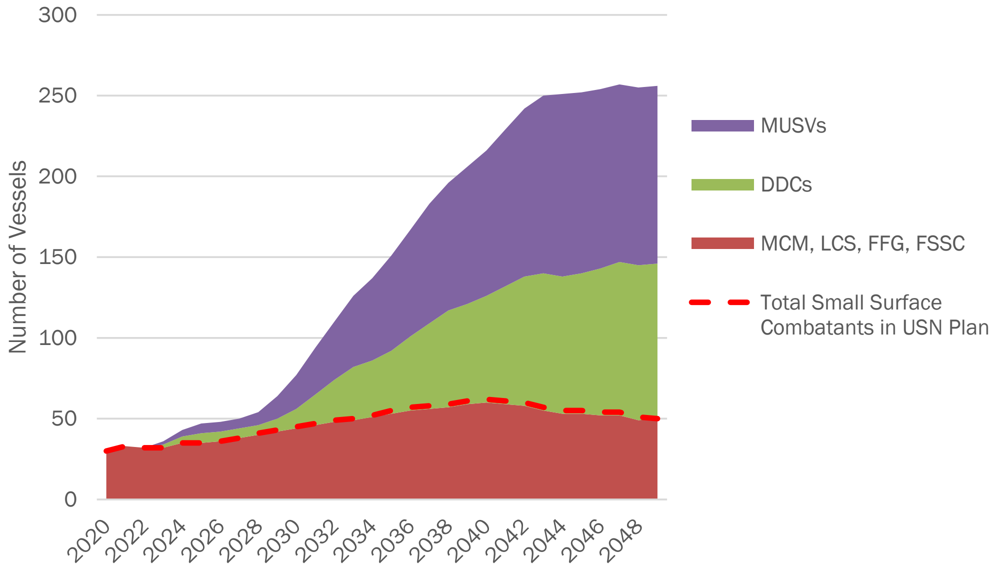


Small Surface Combatants

The Navy's PB 2020 shipbuilding plan includes procurement of 58 small surface combatants: 20 FFGs and 38 Future Small Surface Combatants. CSBA's proposed shipbuilding plan procures the same type and number of FFGs and Future Small Surface Combatants on a similar schedule to the Navy's plan, estimating they will have an average cost of $1.2 and $1.3 billion each, respectively. CSBA's plan also retires MCM-1 minesweepers as planned by the Navy and replaces them by allocating existing LCS to the MIW mission. Starting in FY 2033, LCS begin retiring as well.

The major difference regarding small combatants between CSBA and Navy plans is the CSBA plan invests in additional MUSVs and builds DDCs instead of LUSVs. In order to evaluate the desired attributes and concepts for new DDCs and MUSVs, the CSBA plan procures six experimental MUSVs and DDCs at a rate of two each per year between FY 2021 and 2023. The MUSV would build on technology maturation from the ACTUV program and commercial autonomous vessel market. The DDC program would be based on commercial OSVs to reduce risk and allow the Navy to focus on maturation of key C3 and weapons launcher technologies.[152] The CSBA shipbuilding plan incorporates a 4- or 5-year delay, respectively, between delivery of the first MUSVs and DDCs before sustained procurement begins to incorporate lessons from the experimental vessels into the final platform design.

FIGURE 36: SMALL SURFACE COMBATANT INVENTORY UNDER PROPOSED CSBA SHIPBUILDING PLAN



The CSBA shipbuilding plan assumes that the MUSV will cost $30 million and the DDC $300 million per vessel. Starting in FY 2027, MUSV procurement grows to an average rate of approximately 6.5 MUSVs per year over the rest of the shipbuilding plan. For DDCs, starting in FY 2028, procurement grows to an average rate of approximately 4.5 DDCs per year over the rest of the shipbuilding plan.[153] Throughout the plan DDCs are procured in 5-year blocks, which provide opportunities for technology insertion, design revision, and shipbuilding

152 DDCs would operate as autonomous small combatants with small human crews (e.g., 15–24 personnel) focused on supervision, force protection, and light maintenance. They could be episodically operated autonomously without human intervention. This would provide more versatility in the vessels' use during periods outside of conflict, and it would enable a human crew to intervene in the event of harassment or attack when rules of engagement may not allow an unmanned vehicle to respond with deadly force. Under certain operational circumstances, the crew could be removed from the vessel so that it could operate in a fully unmanned fashion, or it may be preferable to keep a human crew onboard at all times. Given that most envisioned DDC designs based off of Platform Supply Vessels or other OSVs already have adequate space and berthing for 15 or more personnel, and that they are economically built at a number of U.S. yards, the placement of a small crew on these vessels will not significantly add to the cost of the vessel. A manned crew will, however, greatly reduce the technical and operational risk of this program, aiding the swift incorporation of this type of vessel, which provides an offboard magazine to other manned surface combatants and enables more distributed fires to the fleet.

153 These high production rates are necessary to meet the proposed requirement of 110 MUSVs and 96 DDCs within the 30-Year Shipbuilding Plan, in part due to the short service lives of MUSVs and DDCs. As MUSVs and DDCs will be built to commercial standards, operated at high tempos, and produced at relatively low cost, this study estimates they will have 15- and 20-year service lives, respectively. These short service lives result in 38 MUSVs and eight DDCs being retired by FY 2049.

competition. MUSVs are procured continuously but could also be divided into blocks. The smaller size, higher production rates, and commercial shipbuilding standards of MUSVs and DDCs may offer opportunities for construction to take place at a broader range of shipyards, which could reduce shipbuilding costs.

Large Surface Combatants

The proposed CSBA shipbuilding plan calls for procurement of 63 DDGs between FY 2020 and FY 2049 compared to 76 in the Navy's shipbuilding plan. CSBA's plan acquires 13 DDG-51 Flight IIIs from two shipyards between FY 2020 and FY 2025, and then 10 DDG-51 Flight IIIAs between FY 2025 and FY 2030.[154] This approach delays construction of a new large surface combatant, which the CSBA plan calls DDG(X), to FY 2030 from the Navy's planned FY 2025.[155] To reduce technical, cost, and schedule risks for a new large surface combatant, the CSBA plan invests in developing and maturing key surface combatant technologies between FY 2021 and FY 2029, including prototyping at land-based test sites and on selected DDG-51 Flight IIIAs.

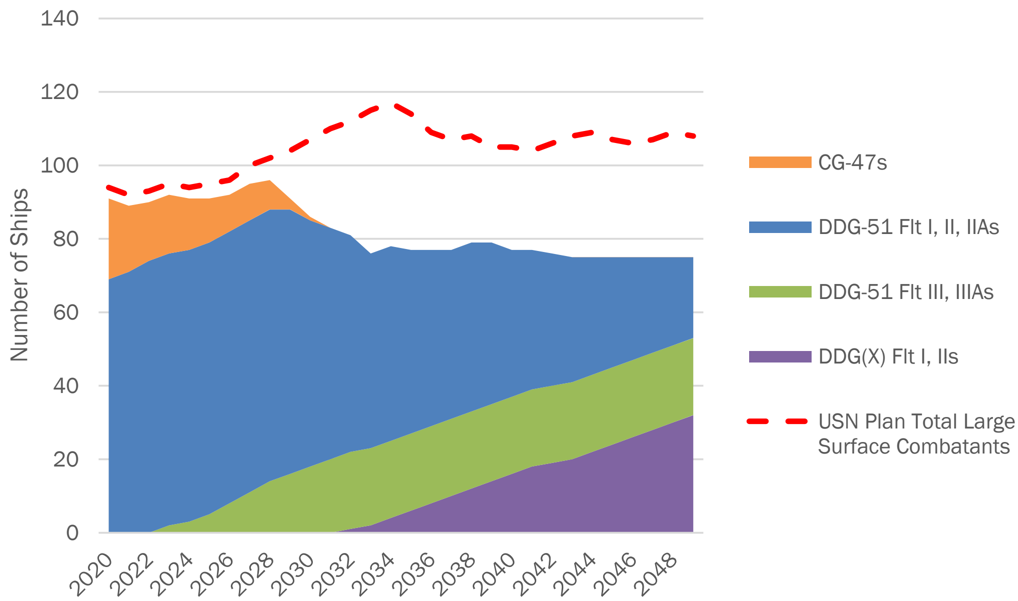
In CSBA's proposed plan, DDG(X) Flight Is are built at a mostly two-per-year build rate from FY 2030 to FY 2040 for a total of 19.[156] This construction could take place at a single shipyard or two separate yards. In FY 2039, DDG(X) Flight II procurement would start at a rate of one-per-year before increasing to a sustained two-per-year rate.

154 From the period FY 2026 to FY 2029, the size of the CSBA large surface combatant fleet grows from 94 to 99 ships, which is beyond the CSBA requirement of 78 large surface combatants. This growth is necessary in order to introduce new DDG-51 Flight IIIAs with advanced capabilities into the fleet and to maintain shipyards that could reliably construct the new design DDG(X) in a healthy state, which is necessary in order to quickly introduce the DDG(X) Flight I into the fleet in the 2030s in order to address capability gaps. By FY 2043, the CSBA fleet reaches its large surface combatant requirement of 78 ships and remains there throughout the 30-Year Plan.

155 An alternative approach CSBA considered was to procure an initial Large Surface Combatant flight in FY 2025 or FY 2026 based off an existing hull (such as DDG-1000) with the same combat systems as DDG-51 Flight IIIs and traditional propulsion, shipboard power, and cooling technologies. Once new combat system, propulsion, shipboard power, and automation (essential to reducing manning requirements) technologies had matured around 5 to 10 years later, the Navy could procure another Large Surface Combatant flight that incorporated those technologies. However, after analysis, CSBA found that the considerable budgetary opportunity costs of fielding an initial Large Surface Combatant flight may crowd out the research and development funding needed for those new technologies. Additionally, rushing the procurement of a new ship by FY 2025 or FY 2026 ran the risk of leading to a program that would deliver later than desired, run over cost, and underperform technically.

156 Under the proposed acquisition approach to DDG(X), the Navy should take the period of FY 2020 to FY 2030 to fully mature the technologies necessary, such as automation; combat systems; and power generation, cooling, and energy storage systems. From FY 2020 to FY 2025, the Navy could pursue a Surface Warfare Technology Roadmap to research and develop new technologies. From FY 2026 to FY 2028, the Navy could test promising prototype systems with digital twin hardware-in-the-loop testing and land-based test sites. In FY 2029, the Navy could test some systems afloat on barges or test ships and finalize the maturation of systems. In terms of design, after a consultative requirements evaluation process from FY 2020 to FY 2025, the Navy could issue initial design contracts to multiple firms in FY 2026. In FY 2028, the Navy could refine requirements and provide additional design funding to the best-performing design firms. By the end of FY 2029, the Navy could finalize all technologies and systems to be incorporated on DDG(X) and issue a request for proposal to be awarded in FY 2030. This sequential process of technology maturation and design will increase the likelihood that the shipyard(s) awarded construction contracts in FY 2030 will be ready to quickly and cost-efficiently build DDG(X) and that, upon delivery, the ship will fully meet requirements and will not have a long post-delivery period.

FIGURE 37: LARGE SURFACE COMBATANT INVENTORY UNDER PROPOSED CSBA SHIPBUILDING PLAN

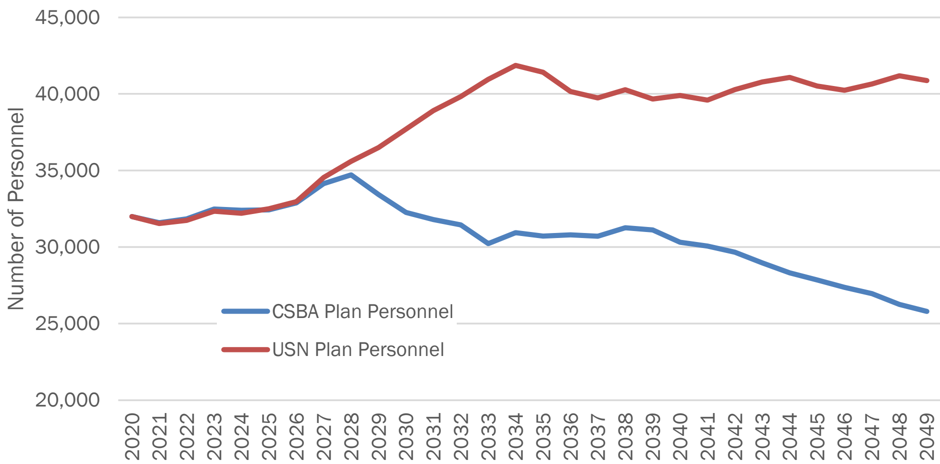


Personnel

CSBA's proposed plan retires aging large surface combatants at the end of their service lives to free up funding for MUSVs and DDC, rather than extend their lives as under the Navy's FY 2020 Shipbuilding Plan. By the end of the CSBA plan, a mix of retirements, reductions in the number of large surface combatants, and the introduction of more automated ships results in a proposed surface combatant fleet that requires approximately 6,200 fewer seagoing billets than the current fleet and 15,000 fewer seagoing billets than the Navy's proposed fleet.[157] These savings could be used in part to provide personnel to shore training and maintenance organizations for DDCs and MUSVs, which would be new or larger than anticipated in the Navy's plans.

157 A higher degree of ship automation and autonomy is achieved by allocating more funding toward maturing automation and autonomy technologies that could be used not only on DDCs (24-person crew) and MUSVs but also DDG(X) Flight I (165-person crew), DDG(X) Flight II (80-person crew), and the Future Small Surface Combatant (65-person crew).

FIGURE 38: COMPARISON OF PLANNED USN AND PROPOSED CSBA SHIP PERSONNEL



Costs

The proposed CSBA 30-year shipbuilding plan supports the recommended force posture with a surface fleet that is larger, more operationally effective, and significantly less expensive to procure and sustain than the Navy's planned force. The proposed plan takes an evolutionary approach to developing and fielding new capabilities to generate a more capable and sustainable fleet in the medium-to-long term. To free up funding for additional capacity and new capabilities, the CSBA plan delays immature programs and retires obsolescing ships at the end of their service lives rather than extending them.

The proposed shipbuilding budget balances the need to implement the proposed surface fleet architecture with the imperative to manage costs. Overall, CSBA's proposed shipbuilding plan costs nearly $28 billion less than the Navy's FY 2020 plan with almost half the savings occurring during the first decade of the plan. The largest source of procurement cost difference between the two plans stems from the CSBA plan delaying a next-generation large surface combatant from FY 2025 to 2030 and pursuing a $2.25 billion DDG(X) instead of a $2.8 billion Future Large Surface Combatant. Lower shipbuilding costs during the first decade of the plan allow the Navy to invest in focused research, development, test, and evaluation of future technologies that could be integrated on DDG(X) and other ship designs.

CSBA's proposed plan costs approximately $34 billion less overall for operations and support than the Navy's plan. During the first decade of both plans, Navy and CSBA costs are approximately equal. However, choices in the first decade of the CSBA plan to not extend CGs and DDGs past their original service lives and field DDCs and DDG(X) with smaller crews generate operation and support cost savings of approximately $15 billion in the second decade when compared to the Navy's plan. This savings in operation and support costs is realized even as the CSBA plan fields scores of DDCs and MUSVs. By the third decade of the plan, CSBA's fleet costs $18 billion less than the Navy's to operate and support.

FIGURE 39: COMPARISON OF NAVY AND PROPOSED CSBA SHIPBUILDING COSTS

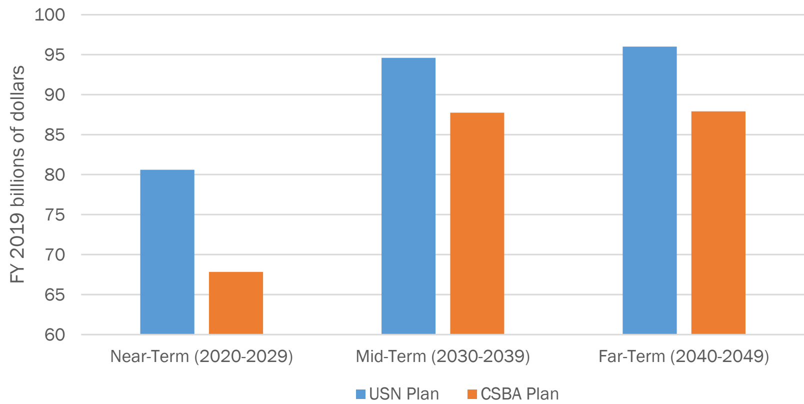
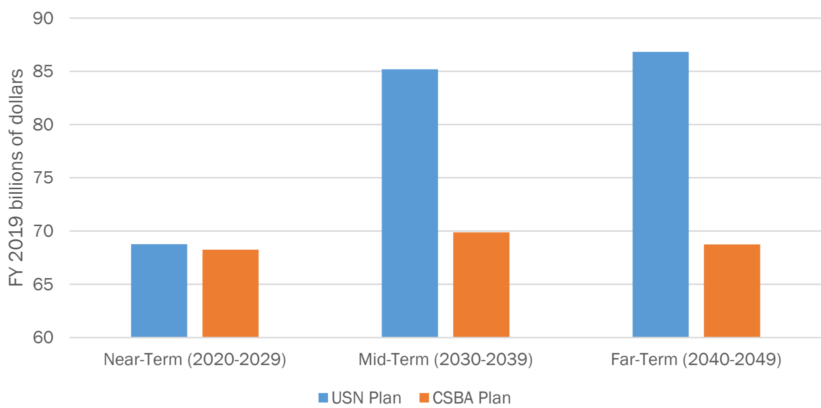


FIGURE 40: COMPARISON OF NAVY AND PROPOSED CSBA OPERATION AND SUPPORT COSTS

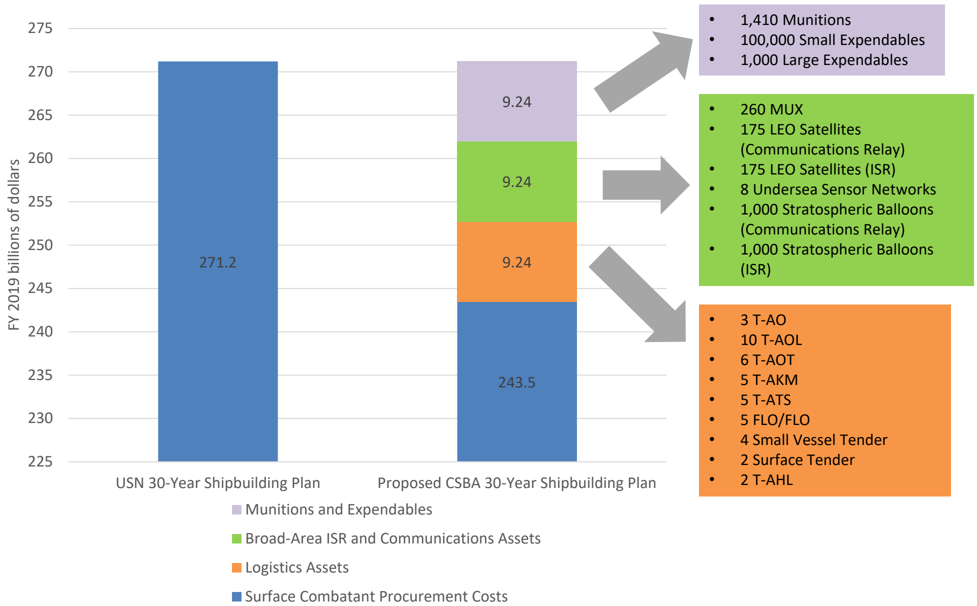


Surface Warfare Enablers

A more affordable surface force yields savings that can be invested as part of a balanced approach to fleet design in key surface warfare enablers such as munitions and other expendable payloads, broad-area ISRT and communications systems, and logistics platforms and equipment. Without additional investments in these areas, it is unlikely that even CSBA's proposed force packages and fleet would be capable of fighting effectively, especially for a prolonged period.

Figure 41 depicts the distribution of savings from procurement costs into munitions, broad-area ISR assets and communications relays, and logistics. Additional savings from operation and support costs could also be allocated to these or other enabling capabilities. They could also provide the additional research and development funding necessary to mature vital automation and autonomy technologies. Overall, investments into these surface warfare enablers will have an outsized effect on the lethality of the surface combatant force—even if they come at the cost of some surface combatant hulls.

FIGURE 41: OPPORTUNITIES TO INVEST PROCUREMENT SAVINGS INTO CRITICAL SURFACE WARFARE ENABLERS



Collaboration with Allies and Partners

The proposed surface fleet posture has benefits for cooperation with allies. Surface force packages operating in an FDNF-like readiness cycle will be focused on specific regions for each deployment, enabling them to gain familiarity with the local allies, adversaries, and geography. Crews attached to surface units in a region will establish deeper relationships with friendly forces, and the readiness cycle will provide sufficient time for experimentation with new operating concepts and participation in large-scale exercises with other countries.

The deliberate approach proposed for ship acquisition also provides opportunities for collaboration with allies and partners. As the Navy fields its DDCs and MUSVs, both classes may appeal to allies and partners who would like to increase their warfighting capacity at a modest cost and who have embraced a force package approach to fleet design. Moreover, given the proposed 10-year planning period before DDG(X) acquisition, it may be possible to engage allies or partners as participants in the program, either receiving ships built from U.S. yards or utilizing the same design, increasing opportunities for greater interoperability. Lastly, the Future Small Surface Combatant provides a prime opportunity for collaborating with allies and partners in designing a ship that meets many warfighting requirements at a modest cost and involves advanced automation and some autonomy.

Below the level of ship acquisition, collaboration on a wide range of surface combatant systems and components could take place. A deliberate approach to acquisition provides enough time to signal plans to allies and partners and coordinate bilateral or multilateral technology development and maturation, as well as system or component acquisition.

CHAPTER 7

Conclusion

The U.S. Navy's surface fleet is at a crossroads. Today's surface force lacks the size, resilience, and offensive capacity to contribute effectively to degrading, delaying, or denying aggression. These shortfalls are especially problematic because the surface fleet will have an increasing role in the U.S. Navy's ability to counter enemy offensives rapidly. Today's fleet is also fiscally unsustainable due to the growing costs for operations and support of its highly integrated and manpower-intensive surface combatants. New technologies for unmanned systems, sensors, weapons, C3, and countermeasures could allow significant improvements in the fleet's ability to create complexity for an adversary and harden surface forces from attack while improving the surface force's capacity for maritime or land strike. Freeing up the resources to fund new technologies and fielding platforms able to incorporate them will require dramatic changes to the Navy's current shipbuilding and capability development plans.

CSBA's proposed architecture of operational concepts, force packages, posture, readiness cycles, and platforms would improve the U.S. surface fleet's ability to support the U.S. defense strategy and become more sustainable. The proposed CSBA fleet is not the only answer, of course, but the Navy will need to pursue many of the same initiatives to break from its current trajectory of fewer, more expensive platforms manned by growing crews of highly trained sailors. U.S. carrier aviation is constrained in range and capacity and challenged by rising sustainment costs. The submarine force is shrinking. As a result, the surface fleet will have an increased importance in deterrence, reassurance, and warfare. U.S. Navy leaders should make the hard choices needed to ensure the surface fleet can meet that challenge.

APPENDIX A

CSBA Proposed Surface Combatant Fleet

TABLE 2: PROPOSED CSBA FY 2020 30-YEAR SHIPBUILDING PLAN SURFACE COMBATANT BATTLE FORCE

		Fiscal Year																													
		20	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**31**	**32**	**33**	**34**	**35**	**36**	**37**	**38**	**39**	**40**	**41**	**42**	**43**	**44**	**45**	**46**	**47**	**48**	**49**
LSC	**CG-47**	22	18	16	16	14	12	10	10	8	3	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	DDG-51 Flt I	21	21	21	21	21	21	21	21	21	19	14	10	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	DDG-51 Flt II	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	4	2	0	0	0	0	0	0	0	0	0	0	0	0	0
	DDG-51 Flt IIA	41	43	46	46	46	46	46	46	46	46	46	46	46	46	46	46	46	46	46	44	40	38	36	34	32	30	28	26	24	22
	DDG-51 III	0	0	0	2	3	5	8	10	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11
	DDG-51 IIIA	0	0	0	0	0	0	0	1	3	5	7	9	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
	DDG(X) Flt I	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	4	6	8	10	12	14	16	18	19	19	19	19	19	19	19
	DDG(X) Flt II	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	3	5	7	9	11	13
	DDG-1000	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
	Total LSC	**94**	**92**	**93**	**95**	**94**	**94**	**95**	**98**	**99**	**94**	**89**	**86**	**83**	**78**	**79**	**78**	**78**	**78**	**80**	**80**	**78**	**78**	**78**	**78**	**78**	**78**	**78**	**78**	**78**	**78**
SSC	**LCS**	22	25	27	31	35	35	35	35	35	35	35	35	35	34	34	33	33	32	31	31	30	27	24	19	15	13	10	8	3	0
	FFG	0	0	0	0	0	0	1	3	5	7	9	11	13	15	17	19	20	20	20	20	20	20	20	20	20	20	20	20	20	20
	Future SSC	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	4	6	8	10	12	14	16	18	20	22	24	26	30
	Ghost Fleet LUSV	0	2	4	4	4	4	4	4	4	4	4	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	DDC	0	0	0	2	4	6	6	6	6	8	12	19	26	33	35	39	46	53	60	62	66	73	80	85	85	87	91	95	96	96
	MUSV	0	0	0	2	4	6	6	6	8	14	21	29	36	44	51	59	66	74	79	85	90	97	104	110	113	112	111	110	110	110
	MCM	8	8	5	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Total SSC	**30**	**35**	**36**	**40**	**47**	**51**	**52**	**54**	**58**	**68**	**81**	**98**	**110**	**126**	**137**	**151**	**167**	**183**	**196**	**206**	**216**	**229**	**242**	**250**	**251**	**252**	**254**	**257**	**255**	**256**
Total Vessels in Fleet		**124**	**127**	**129**	**135**	**141**	**145**	**147**	**152**	**157**	**162**	**170**	**184**	**193**	**204**	**216**	**229**	**245**	**261**	**276**	**286**	**294**	**307**	**320**	**328**	**329**	**330**	**332**	**335**	**333**	**334**

APPENDIX B

Cost Estimation Methodology

To evaluate the feasibility of the proposed surface combatant fleet architecture, this study includes estimates of the cost of new ship construction and operation and support for both the Navy's FY 2020 Long-Term Shipbuilding Plan and CSBA's proposed shipbuilding plan.

Ship Construction Estimates

For existing vessels and vessels projected by the Navy, CSBA ship procurement estimates used average ship costs as estimated by Eric Labs of the Congressional Budget Office.[158] For new vessels proposed by CSBA that are similar in concept to existing vessels (i.e., DDG-51 Flight IIIA and DDG[X]), CSBA estimated the desired ship power density and lightship weight of the proposed vessel and used the relationship between lightship weight, power density, and cost developed by RAND to estimate the average cost of the ship type.[159] For new vessels that did not have easily comparable ship types (i.e., Ghost Fleet LUSV, DDC, and MUSV), cost estimates were derived from an examination of publicly released Navy budget submissions and consultations with industry.

Operation and Support Estimates

To estimate direct operation and support costs of the Navy's plan and CSBA's proposed plan, CSBA first identified the average annual operation and support cost per ship type using three different methodologies:[160]

1. For existing ships, CSBA used operation and support cost data from CSBA's 2017 alternative fleet architecture study, which drew from the Naval Visibility and Management of Operating and Support Costs Ships database and the Military Sealift Command database.[161]

158 Labs, *Analysis of the Navy's 2020 Shipbuilding Plan*.

159 Arena et al., *Why Has the Cost of Navy Ships Risen?* p. 37.

160 This report estimates direct operation and support costs—the costs to pay crews, purchase fuel and supplies, and repair and maintain ships. Additional indirect and overhead costs are not captured in this report. For additional information on operation and support costs and the Congressional Budget Office approach to modelling operation and support costs (the same approach taken in this report), please see *The U.S. Military's Force Structure: A Primer* (Washington, DC: CBO, July 2016), available at www.cbo.gov/publication/51535.

161 For additional study on the aforementioned costing approach, see Clark et al., *Restoring American Seapower*, particularly pp. 128–129.

2. For DDG-51 Flight III and DDG-51 Flight IIIA, which are ships that are in development and are based off an existing U.S. design, CSBA used the operation and support costs of the parent ship type, DDG-51 Flight IIA.

3. For entirely new ships (Future Large Surface Combatant, DDG[X] Flight I, DDG[X] Flight II, Future Small Surface Combatant, Ghost Fleet LUSV, DDC, and MUSV), CSBA used Congressional Budget Office data to examine the percentage of operation and support costs by ship type in terms of personnel, fuel, and other (mostly maintenance) categories.[162] It then used that data to extrapolate a cost per person, a fuel cost per ton of displacement, and other costs per ton of displacement. Using personnel and displacement estimates for the new ships, CSBA then estimated projected operation and support costs for the new ship types.

Furthermore, CSBA applied a 1.35 percent direct operation and support cost growth above inflation to arrive at the total operation and support cost for each type of ship over the 30-year span of the shipbuilding plan.

162 Letter about O&S costs for Navy ships from Douglas Elmendorf, Director of the Congressional Budget Office, to U.S. Senator Jeff Sessions, April 28, 2010, p. 8, available at https://www.cbo.gov/sites/default/files/111th-congress-2009-2010/reports/04-28-sessionsletter.pdf

LIST OF ACRONYMS

ASM	anti-ship missile
AAW	Anti-Air Warfare
AEW&C	Airborne Early Warning and Control
AMD	air and missile defense
ASROC	ASW rocket
ASUW	anti-surface warfare
ASW	anti-submarine warfare
ATT	Anti-Torpedo Torpedo
C2	command and control
C3	command, control, and communications
CAS	close air support
CEASRS	Combined EO/ IR Surveillance and Response System
CEC	Cooperative Engagement Capability
CG	guided missile cruiser
CIWS	Close-In Weapons System
CLF	Combat Logistics Force
CONUS	Continental United States
CSBA	Center for Strategic and Budgetary Assessments
CSG	carrier strike group
CUSV	Common USV
CVLWT	Compact Very Light Weight Torpedo
CVN	nuclear-powered aircraft carrier
CVW	carrier air wing
DARPA	Defense Advanced Research Projects Agency
DDC	corvette
DDG	guided missile destroyer
DMO	Distributed Maritime Operations
DoD	U.S. Department of Defense
EAB	Expeditionary Advanced Base
EASR	Enterprise Air Surveillance Radar
EM	electromagnetic
EMS	electromagnetic spectrum
EMW	Electromagnetic Maneuver Warfare
EO	electro-optical
EPF	Expeditionary Fast Transport
ESB	Expeditionary Sea Base
ESG	Expeditionary Strike Group
ESM	Electronic Support Measures
ESSM	Evolved Sea Sparrow Missile

EW	electronic warfare
FAC	fast attack craft
FDNF	Forward Deployed Naval Force
FFG	guided missile frigate
GNSS	global navigation satellite system
GPS	Global Positioning System
HPM	high-power microwave
HVP	hyper-velocity projectile
IR	infrared
IRBM	intermediate-range ballistic missile
IRCPS	Intermediate Range Conventional Prompt Strike
ISRT	intelligence, surveillance, reconnaissance, and targeting
LACM	Land attack cruise missile
LCS	Littoral Combat Ship
LEO	low Earth orbit
LFA	low-frequency active
LHA/LHD	amphibious assault ship
LOCE	Littoral Operations in a Contested Environment
LPI/LPD	low probability of intercept/low probability of detection
LRASM	Long-Range ASM
LUSV	Large USV
MAC	Multistatic Acoustic Coherent
MAD-FIRES	Multi-Azimuth Defense Fast Intercept Round Engagement System
MAGTF	Marine Air-Ground Task Force
MCM	mine countermeasures
MIW	mine warfare
MPA	maritime patrol aircraft
MRBM	medium-range ballistic missile
MSO	Maritime Security Operations
MST	Maritime Strike Tomahawk
MUSV	medium USV
MUX	Marine Air-Ground Task Force (MAGTF) Expeditionary Unmanned Aerial System
NATO	North Atlantic Treaty Organization
NDS	National Defense Strategy
NIFCA	NIFC-CA
OFRP	Optimized Fleet Response Plan
ONR	Office of Naval Research
OSV	offshore support vessel
PC	patrol craft

PDS	payload delivery system
PLA	People's Liberation Army
PLAAF	People’s Liberation Army Air Force
PLAN	People's Liberation Army Navy
RAM	Rolling Airframe Missile
RAS	Rearming at Sea
RF	radiofrequency
RHIB	rigid hull inflatable boat
RMA	radar modular assembly
RTSO	Real-Time Spectrum Operations
SAG	surface action group
SAR	synthetic aperture radar
SEWIP	Surface Electronic Warfare Improvement Program
SIGINT	signals intelligence
SoS	system of systems
SOSUS	sound surveillance system
SSEE	Ships Signal Exploitation Equipment
SSMM	Surface-to-Surface Missile Module
SSPK	single shot probability of kill
STW	strike warfare
SUW	surface warfare
T-AKM	missile reload ship
TOC	total ownership cost
TRAPS	Transformational Reliable Acoustic Path System
UAV	unmanned aerial vehicles
UISS	Unmanned Influence Sweep System
USN	U.S. Navy
USV	unmanned surface vessel
VBSS	visit, board, search, and seizure
VDS	variable depth sonar
VLA	vertical launch ASW rocket
VLS	vertical launch system

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