Naval War College Review

Volume 73
Number 3 *Summer 2020*

Article 7

2020

Twenty-First-Century Innovation Pathways for the U.S. Navy in the Age of Competition

James A. Russell
Naval Postgraduate School

TWENTY-FIRST-CENTURY INNOVATION PATHWAYS FOR THE U.S. NAVY IN THE AGE OF COMPETITION

James A. Russell

As the Trump administration assumed the reins of power in 2017 with the promise of a maritime revival, it took command of a USN surface fleet primarily consisting of vessels designed during the Cold War. This fact is not surprising, since ships' life cycles can span many decades. The leadership of the Navy believes, perhaps rightly, that its Cold War–era surface fleet may be ill equipped to deal with myriad future threats on the high seas over the rest of a century that will be marked by near-peer competition. The new century promises a range of new hardware and technologies combining with different maritime strategies, operations, and tactics that could challenge U.S. primacy on the world's oceans.

For example, both China and Russia actively are pursuing maritime strategies involving the extensive use of land-based precision-strike complexes that feature long-range, accurate munitions and a new generation of digital sensors. China in particular has developed a new suite of "gray-zone" tactics that seek to test the limits of how states apply force on the high seas. These different strategies and tactics are integrating new weapons and technologies, ranging across accurate, long-range missiles launched from land, sea, and air; emerging cyber capabilities that potentially can disable critical parts of naval ships; small-boat swarms that can complicate countermeasures and targeting; and new systems yet to be fielded that integrate artificial intelligence, robotics, and modern manufacturing processes such as three-dimensional printing.

James A. Russell serves as associate professor in the Department of National Security Affairs at the Naval Postgraduate School (NPS) in Monterey, California. He teaches courses on U.S. foreign policy, national security strategy, and military innovation. Prior to his arrival at NPS in 2001, he worked in the Office of the Assistant Secretary of Defense for International Security Affairs, Near East–South Asia. He holds a PhD in war studies from King's College London.

Naval War College Review, Summer 2020, Vol. 73, No. 3

As Admiral John M. Richardson emphasized repeatedly when he was U.S. Chief of Naval Operations (CNO), the Navy believes it may be falling behind its opponents at sea. Underlying Richardson's disquiet was the assumption that time and fate are not necessarily on the Navy's side—a view that American political leaders echoed consistently. After nearly two decades of antijihadist campaigns, there is a belief that in the digital age adversaries are adapting more quickly than the U.S. Navy, so it needs to innovate now—and fast—to keep pace with, let alone preserve any advantage over, its rivals. Richardson clearly believed that the Navy is entering a new adapt-react cycle with adversaries such as Russia and China, which informed his call for a twenty-first-century fleet redesign.[1] The new cycle coincides with a shift in U.S. security strategy away from irregular warfare and terrorism back to the geopolitical competition reminiscent of earlier eras.[2]

Admiral Richardson's call for a reinvigorated fleet would not mean much without high-level political support, especially in Congress. Perhaps not coincidentally, a number of recent studies (some of which the Navy funded) have recommended that the Navy increase the size of its surface fleet.[3] Perhaps more importantly, there appears to be strong political support in Congress for the idea that the Navy should get bigger.[4] Thus, at least three important sources of energy are in place with which to revitalize a twenty-first-century fleet: (1) a general recognition that adversaries are adapting quickly to challenge the United States on the high seas; (2) internal Navy emphasis on overhauling and expanding the fleet; and (3) political support to make available the funds necessary to pay for it. Even three such ingredients, however, do not ensure the success of the kind of naval revival the U.S. Navy has made previously at various points in its history. Most importantly, the Navy needs programs that will take a redesigned twenty-first-century fleet from the drawing board to the production line.[5]

As the Navy stands on the threshold of the largest naval buildup since the halcyon John Lehman days in the Reagan administration, the irony of this situation is painfully apparent. Just as a consensus has emerged among stakeholders in the Department of Defense, the White House, and Congress that the Navy needs to increase its fleet from 308 to 355 ships, the Navy must address serious shortcomings in its capacity to conceive, develop, and build ships fit for battle.[6] Recent programs such as the littoral combat ship (LCS), the *Zumwalt*-class guided-missile destroyer, and the *Ford*-class aircraft carrier all have highlighted the Navy's failure to produce innovative, affordable ships in the quantity and of the quality needed to configure a larger, redesigned fleet. Unless the Navy can address mistakes made in these programs it will have difficulty innovating as Richardson has suggested—with potentially disastrous consequences. This article argues that the Navy needs to examine critically its largely failed attempts at innovation during the post-1990s era if it is to meet its twenty-first-century challenges.

The article particularly focuses on the naval innovation cycle of the modern era, an era that flowed from the 1990s. This period featured the so-called revolution in military affairs (RMA) and the absence of near-peer competitors on the high seas in the wake of the 1990–91 Gulf War. Despite massive investments and the waterfall of 1990s digital technologies, most observers would agree that the Navy has not been successful at generalizing innovations into a new fleet design. Attempts to introduce three important ship classes (the LCS, the *Zumwalt*-class destroyer, and the *Ford*-class carrier) have been nothing short of disastrous. The Navy intended that these ships would be cornerstones of the twenty-first-century fleet, but each ship class foundered, for a variety of reasons. The Navy gave up on purchasing its planned complement of LCSs and now is planning on decommissioning the first four ships in the class a decade early (opting for a new frigate instead); it stopped construction altogether on the *Zumwalt*-class destroyer; and the *Ford*-class carrier program remains mired in technical problems, schedule delays, and cost overruns.

This article addresses the U.S. Navy's initial attempt to assemble a twenty-first-century fleet. Starting, as it did, with the world's largest and most combat-effective navy, the United States, in its efforts to design, build, and field a fleet, provides the world's best case study by which to examine the intersection of innovation, maritime strategy, and fleet design.[7] The article nests the ongoing efforts to assemble a twenty-first-century fleet within cycles of naval innovation and maritime strategy over a period that, for purposes of this analysis, began in the 1880s and extends to the present.

This article explores the reasons why the post-1990s innovation cycle failed to move the Navy successfully in the direction for which Admiral Richardson advocated. Identifying and addressing the causes of failure in the latest innovation cycle are critical if the Navy hopes to design and build a twenty-first-century fleet successfully. If the problems of the post-1990s innovation cycle are not resolved the same mistakes likely will be repeated, catapulting the U.S. Navy into a dark future amid great-power competition; the Navy will be designing the future fleet continuously even as the present fleet continues its slow, expensive erosion. The result will be a future fleet design that remains an alluring, but ultimately a cursed, chimera—always offering a promise that cannot be realized, because of the array of impediments identified in this article.

INNOVATION CYCLES—PAST, PRESENT, AND FUTURE

Admiral Richardson's call to focus on the future fleet is not new, but rather is a time-honored tradition for all militaries seeking to position themselves favorably to meet future strategic uncertainties. The Navy envisioned a redesigned twenty-first-century fleet long before Richardson arrived on the scene. Ideas derived in the 1990s called for development of a host of innovative platforms stuffed full of new technologies and advanced capabilities that were to form the basis of the twenty-first-century fleet.

This article does not argue that the Navy has not introduced new operational concepts or integrated new, innovative capabilities into the fleet since the 1990s—far from it. The Navy has digitized the existing fleet, adding new radars, sensors, communications equipment, and weapons to its existing ships, all of which have improved operational awareness and given crews afloat, as well as in the air, more-accurate, longer-range missiles to strike targets ashore and at sea. Looking to the future, it currently is experimenting with new operational concepts such as distributed maritime operations; launching programs to explore the possibilities that remotely piloted vessels offer; and introducing an array of new, digital-age technologies into the fleet that are meant to help win the next war on the high seas. Be that as it may, it still is hard to argue that the post-1990s innovation cycle has delivered fully on its promise of a twenty-first-century fleet design that looks dramatically different from that of the Cold War era.

One can argue that there have been three major cycles of naval innovation, spanning the late nineteenth, the twentieth, and now the twenty-first centuries. These cycles had many characteristics in common: continuous and iterative changes to organizational structures to accommodate new equipment and new operational concepts; the integration of new technologies to improve capabilities; different platforms and new weapons; and the operational concepts behind these systems, which in turn drove manning and training so as to integrate all the above into an effective operational force.

The glue binding these cycles together was the myriad organizations capable of generalizing the ideas and producing them in repeatable form—bureaucracies that successfully managed, and even directed, the innovation cycles.[8] Indeed, a characteristic of the support bureaucracy is that it also changed during the innovation cycles, becoming ever more task specialized so it could manage the increasingly complex systems being fielded during the twentieth century. This task specialization has produced its own unintended consequences, as will be discussed later.

The first cycle saw the rise of the new Navy in the 1880s, with a transition to the big-gun dreadnought and the airplane and aircraft carriers of World War II—a fifty-year endeavor. The second cycle extended through the end of the Cold War, featuring nuclear weapons and reactors, radars and other electronics, and long-range missiles—a forty-year effort. Today we are in the midst of the third cycle, which began in the early 1990s under the rubric of the RMA.[9] Defining these cycles as discrete, definable phenomena is a bit of scholarly artifice, since all the cycles overlapped in detail and were related to one another even as the geostrategic circumstances surrounding the cycles shifted over time. For example, the fielding of the Aegis guided-missile cruisers in the 1980s represented a continuation of efforts to equip carrier battle groups with air-defense systems that could hit targets with greater accuracy and at far greater ranges in the face of Soviet tactics than initially had been the case when carrier battle groups were conceived during World War II. Another factor binding the cycles is the inherent nature of fleets themselves; they are composed of surface ships, submarines, and airplanes as the principal platforms. In the case of ships, their life cycles, stretching over many decades, ensured that ships built to battle the Soviet fleet on the high seas continued patrolling the world's oceans in the post–Cold War era; therefore, they performed a variety of different missions created by a new strategic environment, one of post-1991 strategic dominance and of post-2001 strikes against jihadi insurgents. Nonetheless, segregating these distinctive eras is useful for illustrative purposes to address the phenomenon of designing a twenty-first-century fleet—an activity that itself resulted from twentieth-century innovation cycles.[10]

It is no coincidence that these three innovation cycles correspond to different eras of maritime strategy: the period of naval rivalry in the imperial age that began in the late nineteenth century and extended through the end of World War II; the Cold War, which pitted the United States and its allies against the Soviet Union on the high seas; and the post-1990 era that, until recently, saw the United States in its celebrated unipolar moment. During the 1990s, for example, the Cold War–era carrier battle group gradually was abandoned and carriers often operated essentially independently, since such vessels faced no real threats on or under the water or from the skies. That has changed in the twenty-first century as states such as North Korea, Iran, China, and Russia aggressively have developed precision-strike complexes with land-based sensors and long-range ballistic missiles.[11] A conclusion of this article is that the conceptual drift in maritime strategy in the third cycle profoundly shaped the Navy's initial attempts to design and build a twenty-first-century fleet.

Each of these innovation cycles introduced new capabilities and operating concepts into the fleet. It is easy to forget, however, that each of the cycles was fueled by one important common denominator: money, as an expression of policy and legislative will. Without money, none of the innovation cycles could have been brought to fruition—another timeless truism, which speaks to enduring realities about how defense and arms work in American politics and the record of the U.S. Navy in modern history. A regrettable and potentially devastating feature of the modern era's innovation cycle is a cost growth of ships, aircraft, and projectiles that is unsustainable, even given a U.S. defense budget that in 2018 was almost larger than the defense expenditures of the rest of the world combined. In addition to programmatic ship-construction problems, significant cost growth has characterized virtually every major procurement program the Navy has undertaken in the period. In short, the post–Cold War innovation cycle ran aground in the minefield of unacceptably high costs—even in a time when the defense budget topped $700 billion in fiscal year (FY) 2018.[12]

The exemplar of this phenomenon is the $406 billion F-35 Joint Strike Fighter program, currently estimated to be the most expensive weapons program in American history.[13] Regrettably, the experience of the F-35 has proved emblematic for the Navy's twenty-first-century fleet-design aspirations. The cost growth of air and sea platforms initially conceived in the 1990s has all but ensured that the Navy will be unable to field large numbers of the new *Ford*-class aircraft carriers, *San Antonio*–class amphibious transport dock LPD-17 ships, and *Virginia*- and *Columbia*-class submarines—all of which, like the LCS and DDX, were intended to be cornerstones of the twenty-first-century fleet. The Navy's newly conceived FFG(X) guided-missile frigate is anticipated to cost nearly one billion dollars per vessel.[14] The Congressional Budget Office has estimated that the Navy would need an increase in its shipbuilding budget averaging 60 percent annually for the next thirty years to reach its desired end state of a fleet of 355 ships between 2035 and 2047—which is significantly more than Congress has appropriated for shipbuilding at any time over the last thirty years.[15] An undeniable feature of the post–Cold War innovation cycle is that the Navy is pricing itself out of business with underfunded shipbuilding plans—at a time when Russia and China are expanding the sizes of their respective fleets.[16]

THE STRATEGY-INNOVATION NEXUS

A purposeful adapt-react interaction between and among rivals drove the innovation cycles of the late nineteenth and twentieth centuries, as the Navy sought to lead its allies and keep ahead of its enemies. Cycles of action and reaction between adversaries are not new; indeed, they are a timeless feature of international politics. Early international relations theorists of the realist school noted that states seek armaments both to defend themselves and because they see them as a way to influence friends and adversaries.[17] Like land and air forces, the navies of developed states inherently are nested within this larger phenomenon. Navy fleets historically have been deemed a vital, even a foundational, part of national power.[18] This underlying tension of international politics produces a timeless rule applicable to these interactions: as nations arm themselves, they create insecurity in both friends and rivals, who then feel compelled to take corresponding actions, resulting in arms races.[19]

Innovation by antagonists in arms races is a central feature of the phenomenon, as each participant strives to counter the capabilities of the other.[20] Navies around the world went through such an adapt-react cycle in the dreadnought era.

It happened again in the aircraft carrier era in the first half of the twentieth century—a cycle in which the U.S. Navy undeniably came out on top of its enemies.[21] Importantly, these two adapt-react cycles occurred during an era (approximately 1880–1990) in which strong navies were thought of as synonymous with national power.

The experiences of World War II confirmed already-held beliefs about the importance of strong navies as instruments of national power and the strong influence that arms races had on the nature of the forces fielded on the high seas. During World War II, two types of maritime conflict unfolded, both of which were central to the Allied victory. In the Battle of the Atlantic, navies served in a more purely maritime role, in a context in which control over the seas enabled the application of force on land.[22] Allied navies successfully overcame the U-boat challenge, moved the Army (and the Army Air Forces) across the Atlantic to Great Britain (as well as supplies to the Soviet Union and across the Mediterranean to North Africa), and then managed to deliver the Army across the channel into Europe. In the Pacific theater, navies sailed close to shorelines to land troops and deliver fire directly onto the enemy, and they engaged in naval combat at sea among surface ships, as naval strategist Alfred Thayer Mahan had suggested they would.[23] The Battle of the Philippine Sea in 1944 was the largest sea battle in history, and it came on the heels of significant sea-based battles in the Coral Sea, at Midway, and elsewhere that have gained prominent places in the historical annals of the war in the Pacific. In both theaters, Atlantic and Pacific, navies correctly were seen as instrumental to the Allies' ultimate victory in the greatest maritime campaign in history.[24]

After World War II, the Cold War featured its own adapt-react cycle, in which the United States and its allies on one side and Soviet-bloc countries on the other moved through various attempts to gain and maintain the upper hand. As an example of the cycle, the Soviet submarine buildup during the Cold War spurred the U.S. Navy to develop a formidable antisubmarine warfare (ASW) capability that incorporated ships, helicopters, and fixed-wing aircraft, and a fixed sonar network on the ocean floor, not to mention several classes of nuclear attack submarines.[25] For both adversaries, a host of innovations appeared during the cycle. In the Cold War, the United States developed shipborne missile-launch systems (including deployment of tactical nuclear weapons at sea), in combination with radar, both to defend the fleet from new generations of Soviet aircraft and missiles and to attack targets at long range with sea-launched cruise missiles.[26] Perhaps most significantly, the Navy deployed strategic nuclear missiles on submarines, stabilizing nuclear deterrence and the balance of terror. Importantly, these arms-race and innovation cycles depended on the ability of large institutions to produce generalizable innovation—new capabilities that were introduced into the fleet on a widespread basis.

During the Cold War, the U.S. Navy's missions expanded to focus on deterrence and supporting overseas military operations in Korea and Vietnam. In addition to these missions it fulfilled and interactions it had with adversaries, interservice rivalries represented another shaping factor in the Cold War innovation cycle. While the newly created Air Force received principal responsibility for delivering the strategic nuclear deterrent, the Navy decisively clawed back an important part of that mission through the Polaris and later the Trident submarine ballistic-missile programs, beginning in the early 1960s.[27] In this period, the Navy served as an important instrument of U.S. national power exercised under the strategy of containment. During the Cold War, the Navy operated at sea on a continuous and global basis, which established a concept of operations that continues to this day. In the 1980s, Navy Secretary John F. Lehman Jr. famously conceived of the Maritime Strategy to give the Navy an offensive strategic role in a potential war with the Soviet Union. The Maritime Strategy sought to take the war to the Kola Peninsula and the Soviet Pacific bases, to secure NATO's northern flank in Scandinavia and secure Japan, and to bottle up the Soviet navy with its submarine fleet in its northern bastions.[28] Lehman's concept simply repackaged a version of the Navy's maritime contributions during the Pacific War, updating them by applying the same ideas to a European war with the Soviet Union.

As had been the case in the era prior to and during World War II, Cold War assessments of adversary capabilities drove the Navy's innovation efforts, with the bureaucracy operationalizing them into weapon-system requirements. Those assessments called for continuous iterative improvements in weapons, operating platforms, and operating concepts that were focused principally on defeating the adversary, both via direct confrontation at sea and by applying maritime power to support a land war. Despite civil-military tension and legislative rancor, the Defense Department bureaucracy operationalized these requirements successfully, for the most part, which ensured that Navy ships were equipped with newer, better radars; more-accurate, longer-range missiles; successively better jet aircraft; shipborne helicopters; and, for submarines, the capability to stay submerged for longer periods, resulting in greater stealth.[29] With the support of Congress, the Navy procured, fielded, and—importantly—generalized throughout the fleet weapons, platforms, and technologies that were new, improved, or both. This description is not intended to romanticize a bygone era in any way; its intent simply is to emphasize that the bureaucracy successfully operationalized change, adaptation, and innovation that were linked to strategy, in the form of programs that delivered systems to the fleet.

However, the strategy-innovation nexus that had functioned with a certain logic during the first two cycles entered a new period in the post-1990 era, with important consequences for the processes that had worked successfully in the first two cycles. Following the first Gulf War in 1991 and a brief period of a "peace dividend," the Defense Department and its allies in Congress and industry successfully fought off attempts to reduce dramatically the defense budget and the size of the military departments. New planning and operational scenarios emerged in response to threats from "rogue states" such as Iran, Iraq, and North Korea; this preserved force structures, missions, budgets, and programs. Attention focused particularly on such threats as the proliferation of chemical and biological weapons as well as long-range missiles—threats that came not from near-peer competitors but from weak states that chafed under a U.S.-led global order. As the 1990s progressed, the Defense Department moved away from specific war planning and eventually divorced the development of new weapons and operating concepts from those our enemies were developing. Instead, "capabilities portfolios" were emphasized, with risk trade-offs between the portfolios, to guide decision-making on what to develop and buy.[30] This way of planning provided civilian decision makers with tools with which to evaluate the military departments' choices on how to spend their money.[31]

BUREAUCRACY AND INNOVATION

To be successful, all innovation cycles in any military organization depend on *bureaucracy*—an organizational structure created to produce repeatable and predictable outputs, among other purposes. Bureaucracy has a well-deserved reputation for being resistant to change; in fact, it could be argued that bureaucracy is designed to prevent change. For military organizations, repeatable output is a foundation of military effectiveness. Military organizations therefore are reluctant to abandon output, in the form of a practice in the field that has proved its worth. Conversely, however, it is equally the case that bureaucracy is instrumental to the process of change and innovation in military institutions. The tension between accepted practice and change sits at the heart of all questions of military innovation.

A truism for all modern militaries is that bureaucracy effectively functions as a translation agent in the innovation process; it takes the ideas for change, then develops a kind of source code that allows each idea to be generalized in the ways initially envisioned. It falls to bureaucracy to manage the process of innovation and change. The bureaucracy's source code for innovation comes in the form of research-and-development (R&D) programs that mature into weapons-procurement programs and fielded systems, or as guidance that can change operational practice. To be completely successful, however, innovation cycles must reach the point of generalizability, so the change can be adopted on an affordable, organization-wide basis.

For all military organizations, including navies, the idea of generalizability is arguably the critical feature of efforts to innovate and produce new systems, new operational routines, or both.[32] As noted in the previous sections, during the Cold War the Navy successfully fielded new systems, built new organizations, and implemented new operational praxes. Many factors spurred the successful innovation cycle; one was a leadership that saw the potential of new systems, such as the nuclear-powered reactor for submarine propulsion, sea-launched ballistic and cruise missiles, radars capable of tracking multiple targets simultaneously, and missile-defense launch systems integrated on ships. These successful innovations also flowed from assessments of adversary capability, internal advocates within the organization who sought to develop a new theory of victory, a changing strategic environment that translated into a demand for new missions and capabilities, and interservice rivalries—whose existence is never to be gainsaid—that spurred organizations to propose new ideas and systems to preserve their missions and budgets.[33]

Also worth noting is that during the Cold War the strategic and operational tasks facing the Navy and its force structure were relatively consistent with the uses of naval forces that had evolved over the course of the twentieth century. When the Soviet Union dissolved, however, the U.S. Navy found itself without a competitor on the high seas. In the 1990s, the Navy realized it had to think about what it wanted its fleet to look like in the twenty-first century—a future that it would have to conceive of well before it could field a new fleet to operate in it.

So during the '90s the Navy began to plan to field a twenty-first-century fleet—for us today, the fleet of the present. In the '90s the Navy envisioned a twenty-first-century fleet that would push the boundaries of its previous ship designs and incorporate a host of new capabilities enabled by the digital revolution. The Navy clearly wanted a twenty-first-century fleet that would incorporate the newest, most advanced technologies and operational concepts, which would preserve its leadership position well into the future. The digital revolution of the 1990s offered the Navy smaller, faster microprocessors that created a new generation of sensors and more-accurate, longer-range weapons and better intelligence capacities; real-time communications enabled via the Internet; enhanced situational awareness that promised to pierce the fog of movements at sea; and missile-defense systems to protect ships and shore-based installations. The hopefulness of the era of the RMA was not lost on the Navy (or the other military departments), which aggressively moved to operationalize its vision. Plans for a variety of new ship classes emerged during the period: the LPD-17 *San Antonio*–class amphibious transport dock, the SSN-774 *Virginia*-class nuclear attack submarine, two different variants of the DDG-51 *Arleigh Burke* destroyer (Flights I and II), the LCS, the *Zumwalt*-class destroyer, and the *Ford*-class carrier. What follows focuses on three of these programs: the LCS, the *Zumwalt* class, and the *Ford* class.

The Twenty-First-Century Fleet: Program "Highlights"

This section briefly details the history of three ship-construction programs: the LCS, the DDX, and the *Ford*-class CVN. All were products of the 1990s-era innovation cycle.

Both the LCS and DDX grew out of decisions the Navy made in 2001 to reorient an R&D program started in 1994 called the SC-21 program (from Surface Combatant for the 21st Century). The SC-21 program itself grew out of studies dating to the late 1980s that called for ships that could operate in the Norwegian Sea during a potential war with the Soviet Union. The main idea was to develop a robust ship capable of attacking targets on land. The 1990s research programs focused on a number of vessel options, in sizes ranging up to forty thousand tons. One of its most celebrated proposals was the *arsenal ship:* a thirty-thousand-ton vessel stuffed with hundreds of cruise missiles and a vertical launch system. Then-CNO Admiral Jeremy M. Boorda championed the concept. Research efforts continued throughout the 1990s and up to the 2001 decision to proceed with two programs: the LCS and the DDX.[34]

The LCS Program. The LCS program began in 2001; initial procurement occurred in 2005; yet as of mid-2019, the LCS has not been deployed to the field in support of combatant command requirements, owing to persistent technical problems.[35] The Navy intended to use the LCS as a smaller, multimission vessel that could take advantage of "plug and play" modules to perform a variety of different missions: ASW, mine countermeasures (MCM), and surface warfare against smaller vessels. Other relevant missions included maritime-security and maritime-partnering operations, surveillance and reconnaissance, and support to special operations forces. By mid-2018, thirty-five vessels had been procured from a program that initially was projected to produce over fifty. The program's orders were divided between two contractors (Lockheed Martin and General Dynamics) that provided different hull designs.[36]

Virtually every aspect of the LCS has drawn the ire of critics, from both inside and outside government: costs grew (from initial estimates of $220 million per vessel to $478 million); early versions of the ships suffered from construction problems; and development of the modules to support the three mission areas (ASW, MCM, and surface warfare) has been plagued by repeated and costly delays. In July 2018, the Pentagon's inspector general stated that the Navy had declared the MCM module to be operational without demonstrating that it had fixed the known problems with it.[37] The Navy subsequently abandoned the idea of swapping out the mission modules and instead will equip each vessel with just one of the modules. Repeatedly the Navy has been forced to delay deployment plans for the vessels because of these technical problems. There also are persistent concerns about whether the ship is adequately armed—many doubt it can survive in combat.

In December 2016, the Pentagon's Director of Operational Test and Evaluation, J. Michael Gilmore, told lawmakers that the LCS had not demonstrated "effective warfighting capability in any of its originally envisioned missions: surface warfare (SUW); mine countermeasures (MCM); anti-submarine warfare (ASW)."[38]

A year earlier, then–Secretary of Defense Ashton B. Carter ordered the Navy to reduce its program from fifty-two to forty vessels and to select a single contractor to construct future vessels. Carter acerbically noted in his missive to the Navy: "For the last several years, the Department of the Navy has overemphasized resources used to incrementally increase total ship numbers at the expense of critically-needed investments in areas where our adversaries are not standing still, such as strike, ship survivability, electronic warfare, and other capabilities."[39] Carter's criticisms followed a similar brouhaha in 2014 in which then–Secretary of Defense Charles T. Hagel ordered the Navy to add armament to the LCS. The then Senate Armed Services Committee chairman (and former naval aviator) John S. McCain III (R-AZ) also was a frequent and scathing critic of the LCS from its earliest stages, repeatedly citing "fundamental shortcomings" in the whole program.[40] The program displayed a number of embarrassing technical problems, including hull cracks in the ship's aluminum superstructure and a faulty propulsion system. Various vessels had to be towed back to port and, in one case, driven all the way across the Pacific Ocean for repairs.[41]

In FY19, the Navy decided to stop procurement of the LCS and instead shift to procurement of a new frigate in FY20. In December 2019, the Navy announced that it proposed to retire the first four ships in the LCS class from service more than a decade early to save money.[42] Current plans call for the Navy to build twenty of the new frigates.[43]

The DDG-1000* Zumwalt*-Class Destroyer. The story of the DDG-1000 program bears some similarity to that of the LCS—except that in some ways it is worse. The Navy initially conceived of the ship as the most technologically advanced ever to be built, one that would substitute for several ship classes, including destroyers and guided-missile cruisers. It originally was designed to support troops ashore with long-range, accurate fires, although since then the Navy has shifted the ship's mission to one focusing on surface-fire support at sea. The first two ships were procured in FY06 and FY07.

But less than three years after launching the program the Navy terminated the DDG-1000 program at three ships, proposing instead to purchase more Cold War–era DDG-51 *Arleigh Burke*–class destroyers. The Navy intended the DDG-1000 to be a stealth ship, with a small-to-nonexistent radar cross section—the Navy's version of the Air Force's F-117 stealth fighter. However, instead of becoming the basis (along with the LCS) for the twenty-first-century fleet, the DDG-1000 effectively became an expensive technology demonstrator platform. The Navy underestimated the costs of the program by 47 percent, seeing its initial $8.9 billion per-ship estimate in FY09 grow to $13.1 billion in FY20.[44]

The stealth ship was to run as quietly as a submarine; provide greatly improved battlespace awareness through new sensors; and deliver precise, long-range fires, via advanced, ship-based guns, to support troops ashore. The promise seemed substantial, boasting a first-of-its-kind integrated power system that would be powered by a new electric-drive propulsion system that would feed new, power-dependent, directed-energy and laser weapons. The ship's modular Linux-based computing system, with six million lines of software code, was the first onboard computing environment with its own Internet system. The advanced gun system was to deliver precision, accurate fires with 155 mm long-range, land-attack projectiles at shore-based targets over a hundred miles away, drawing on an advanced, integrated combat system. The DDG-1000 was to have been supported by a crew of just under a hundred, as opposed to the 275 required to operate a *Burke*-class destroyer; the Navy subsequently walked back that initial claim to a crew size of 175.[45]

The DDG-1000 reportedly does in fact have the radar cross section of a fishing boat. However, almost none of the other promised capabilities has yet been realized, and, like the LCS, the ship has suffered persistent technical problems.

The* Ford*-Class Carrier. Perhaps the centerpiece of the twenty-first-century fleet developed during the 1990s was a new generation of aircraft carriers, known as the *Ford* class, to replace the aging *Nimitz*-class fleet that began entering service in 1975. While it was based on the *Nimitz*-class hull, the *Ford* class sought to incorporate a number of important improvements that would enable the ships to launch more aircraft sorties (a bigger flight deck, additional electrical power for the ship's systems) while lowering the number of sailors required to operate the ship by several hundred, which promised to reduce operating costs. The first ship, *Gerald R. Ford* (CVN 78), was commissioned in July 2017 after procurement costs of approximately $13 billion. At least four carriers are to be procured; the Navy has estimated that the last ship in the class, CVN 81, will cost in excess of $15 billion. The first three ships in the class have seen their costs grow by an average of 21 percent over initial estimates. The Navy has exceeded Congress's cost caps on every ship in the program.[46]

Three major new systems are being integrated into the *Ford* class: a new aircraft-catapult system called the Electromagnetic Aircraft Launch System, a new aircraft-arresting system called the Advanced Arresting Gear, and a new radar known as dual-band radar. According to the Pentagon's Office of the Director for Operational Test and Evaluation, all three systems have been plagued by schedule delays, cost growth, and reliability problems—which calls into question the ship's ability to perform as advertised in combat.[47] The office noted the following:

> Poor or unknown reliability of the newly designed catapults, arresting gear, weapons elevators, and radar, which are all critical for flight operations, could affect the ability of CVN 78 to generate sorties, make the ship more vulnerable to attack, or create limitations during routine operations. The poor or unknown reliability of these critical subsystems is the most significant risk to CVN 78. Based on current reliability estimates, CVN 78 is unlikely to be able to conduct the type of high-intensity flight operations expected during wartime.[48]

Frequent *Ford*-class critic and then–Senate Armed Services Committee chairman John McCain characterized the program as "one of the most spectacular acquisition debacles in recent memory."[49]

As McCain noted (and the Government Accountability Office echoed), the entire twenty-first-century Navy shipbuilding program, as highlighted in the case of the *Ford* class, suffered from a number of easily identifiable maladies:[50]

- unrealistic business cases that invariably understated costs and underestimated the difficulties of production that relied on unproven technologies, resulting in schedule delays
- concurrent design and construction, without adequate testing
- lack of testing (and a reluctance to test) to demonstrate advertised capabilities
- new systems that were rushed into production despite the fact that they did not work
- a bewildering mix of different organizations that were responsible for different parts of the program, which made overall management accountability all but impossible[51]

Teething pains are to be expected with any new platform or weapon system, particularly in the case of complex systems such as surface ships. Each of these three programs, however, fell prey to the same maladies that McCain noted.

In short, the innovation process meant to operationalize these systems came unglued. The Navy actually recognized this; it curtailed the DDG-1000 program at three ships and canceled the LCS program halfway through its planned production run, and the *Ford* class still faces significant hurdles to deliver on its promise.

Explaining the Perfect Storm

The innovation cycle of the 1990s produced these three flawed platforms, which represented the Navy's initial attempt to conceptualize its twenty-first-century fleet. In the cases of the DDG-1000 and the LCS in particular, nothing quite like these platforms had been attempted ever before. Both represented aggressive efforts at innovation that could have led to new generations of platforms that might have started the Navy down the path to its sought-after redesigned twenty-first-century fleet. The *Ford* class represented more of an adaptation than an innovation (although several brand-new systems, such as the electric catapult, were introduced). Suffice it to say, if the Navy had succeeded in generalizing these platforms as initially envisioned, Admiral Richardson might not have felt compelled to call for a redesigned twenty-first-century fleet. Identifying what went wrong with these programs in this innovation cycle is important if the Navy is to avoid repeating the mistakes of this first attempt to reconceptualize its fleet.

Importantly, a lack of neither money nor political support doomed the programs; in fact, the situation was quite the opposite. Management within the Navy and the Pentagon, supported by their providers in Congress, kept hoping for success and threw ever-increasing amounts of money at the problematic systems. While it is true that the country and the Defense Department budget increasingly became focused on commitments associated with the post-9/11 irregular wars in Afghanistan and Iraq, the Navy's requests for funding for its twenty-first-century fleet were met, even as costs ballooned and production delays mounted.[52]

Choices made after the 1990s represent only part of the story. Just as important were choices *not* made that could have produced different innovation pathways. Perhaps not surprisingly, the Navy's choices were shaped by institutional identity, institutional preferences, and intrabureaucratic communities (aviators, surface warfare officers, and submariners) that drove investment priorities in the innovation cycle. For example, the attempt to build an invisible ship was not simply a matter of coincidence but instead reflected the preferences of the Navy's powerful surface warfare community, which reside at the heart of the Navy's strategic essence. The idea of an invisible/radar-deflecting ship represented an important attempt at innovation and appeared attractive for lots of obvious reasons. Such a capability certainly would give the United States an edge on the high seas over its adversaries, much as the Air Force's development of its stealth fighter and bomber gave it similar advantages. The point here is that this choice of developing a stealth ship also was influenced by powerful institutional preferences.

The preference for a manned aircraft may provide an even better example of innovation pathways not chosen.[53] The 1990s delivered the era of unmanned systems now on display on a daily basis over America's global battlefields—an innovation choice that the U.S. Air Force has embraced. In contrast, commitment to the F-35 represented the naval aviation community's preference for a manned platform—which preserved the career track and influence of the community within the wider institution.

Instead of developing a stealth ship, the Navy instead could have chosen to develop a stealth drone carrying multiple munitions launched off differently designed ships. Such an investment almost certainly would have posed an engineering problem that was easier and cheaper to solve than building the stealth ship, the

Ford-class carrier, and the F-35. Instead, the Navy's strike culture and commitment to carrier aviation clearly drove its investment strategy in favor of the F-35 aircraft and the *Ford*-class carrier.

As institutional preferences drove the investment strategy, no outside countervailing force emerged across the civil-military divide to force a different set of choices on the Navy. Just as important, no intraorganizational advocates emerged in the period to challenge accepted institutional orthodoxies with a different theory of victory that might have changed the organization's investment priorities.[54] The point here is not to make a normative argument regarding the relative merits of manned versus unmanned systems; it is simply to observe that institutional preferences limited debate encompassing alternative theories of victory that could have produced different innovation pathways.

When comparing the post-1990s cycle with those that preceded it, the obvious conclusion is that, in the cases of these three systems, the bureaucracy proved itself unable to generalize the innovations into executable programs. Bureaucracy could not fix the shared programmatic flaw that resulted from the disparity between the speed of technological change and that of the Navy's plodding acquisition system. It was clear that systems that in some cases took a decade or more to develop and field would find themselves out of date when they arrived in the fleet.[55] Program managers and their supervisors understandably were reluctant to nail down system requirements definitively, preferring instead to develop and build systems simultaneously so that, theoretically, the latest technological advances could be integrated into their platforms. But at least with regard to these three platforms, that approach proved disastrous.

For its part, industry obliged customer preferences, then demanded ever-increasing amounts of money to fix the flawed systems. A shrinking shipbuilding industrial base contributed to the debacles by limiting competition and alternatives as program schedules slipped and costs mounted.[56] For example, Huntington Ingalls Industries, headquartered in Newport News, Virginia, is today the only shipyard in the United States capable of building aircraft carriers such as the *Ford* class.

In its quest to generalize the innovation, bureaucracy did adapt successfully to the ever-increasing complexity of the envisioned systems. Bureaucracy invariably brought about the task specialization within myriad organizations that was necessary to build technical and management expertise in particular programmatic areas.[57] However, that adaptation did not produce generalizable innovation but instead ever-more-complex organizations that complicated program oversight and execution. As the ship classes became more complicated technically, program responsibilities became diffused across myriad organizations. The creation of different task-specialized organizations created span-of-control problems that made it difficult to synchronize and coordinate different program elements. In each of the three shipbuilding programs, vitally important systems grew disconnected from production schedules. Instead of one coherent program, ship construction became a process in which multiple specialized offices each managed different project elements. Senator McCain complained repeatedly about the many organizations that routinely appeared before the Senate Armed Services Committee for hearings about the Navy's shipbuilding program. As he noted, it meant that no single organization or person had overall responsibility for the program, and hence no accountability could be assigned. An exasperated McCain often complained that nobody lost his job because nobody was held accountable.[58] The bureaucratic enterprise meant to generalize the innovation had become too vast and complicated as a result of the demands the Navy placed on it. It provided only what the customer actually asked for.

The bureaucracy's struggles to generalize the innovation were known widely, by all the organizations in the chain of command. Management and oversight within the Navy, the Office of the Secretary of Defense, the White House, and Congress all failed to correct the sideward spiral of each program; instead these entities spent even more money, in the belief that the Navy would fix the problems. Principal-agent relations can explain part of the behavior of the various oversight layers and entities, but at the end of the day, as McCain emphasized, the entire management and oversight system—stretching from the Navy all the way to the halls of Congress—bore responsibility for the expensive acquisition disasters.[59]

Another feature of the 1990s innovation cycle is that the platforms were conceived initially during the 1990s—a period of conceptual drift in U.S. strategy following the Cold War. It is not that the Navy was not busy during the 1990s; far from it. It spent the decade chasing after pirates in various places, conducting humanitarian relief operations, enforcing the trade embargo against Saddam Hussein in the Persian Gulf, and helping to police the skies over Iraq in Operation SOUTHERN WATCH. The Navy promulgated a bevy of new documents designed to convince stakeholders of its continued relevance—and need for money—pointing to its support of land forces and a host of other global constabulary missions.[60] Importantly, over the decade, the Navy saw its fleet shrink by 40 percent, from 526 to 318 ships, and its personnel end strength decline from 570,000 to 370,000.[61]

While the Defense Department successfully beat back attempts at generalized disarmament, which had occurred in Europe, there was no way to gloss over the lack of strategic consensus driving the arm-train-equip enterprise for the military departments over the decade. Scenarios involving much weaker, so-called rogue states eventually were substituted for the threat from the Soviet Union as a reason to preserve programs and budgets. After the 1990–91 Gulf War and its swift and purportedly decisive victory, the RMA offered obvious advantages, and the military departments understandably seized on its promise to guarantee their superiority over potential rivals. The RMA framed war as an engineering problem that could be solved through clever targeting with better, more-accurate, and longer-range weapons supported by an ever-improving sensor suite that cleared away the fog of war as if by magic. The RMA offered the prospect of victory through target destruction via a new generation of digital sensors and long-range, accurate munitions—a mind-set that implicitly encouraged the Navy and the other services to bet on the next technological leap before definitively nailing down their system requirements. Weapon-system requirements gradually became divorced from specific enemy threats and instead migrated to anodyne portfolios of capabilities.[62]

The conceptual drift in national strategy fell squarely into the Navy's lap. The 1990s saw questions implicitly raised about the strategic value of sea power that challenged foundational assumptions that navies were an instrumental component of national power. In World War II, navies enabled land forces by shipping men and their equipment to the fight. In the post-1990s era, however, America's land forces, instead of storming ashore, mostly flew in chartered commercial airliners to airports in countries near the combat areas. While carrier aviation indeed supported troops and operations ashore in Iraq and Afghanistan, the reality was (and remains) that most combat-related air missions could be launched more efficiently from land-based airfields in or near the war zones.[63] The Navy insisted on supporting troops ashore and went to absurd lengths to deliver, such as launching planes off the coast of Pakistan and sending them, via multiple aerial refuelings, to linger in lengthy orbits over Afghanistan to support ground troops (making for missions that Navy pilots described as "eight hours of boredom and twenty seconds of terror").[64]

The institutional preference for—even insistence on—conducting manned strike operations ashore also profoundly shaped the decision to proceed with the new generation of *Ford*-class carriers, which in certain respects were meant to be the "supercarriers" of the twenty-first century. The Navy never considered viable alternatives to the *Ford*-class platform. Congress forced the Navy to study the idea of building more, smaller, cheaper carriers, as potential platforms for strike missions—an idea in which the Navy appears uninterested for the present.[65] There is little doubt that the Navy remains slow off the mark to adopt unmanned systems, having missed a golden opportunity during the post-1990s innovation cycle to get ahead of its competitors. This constituted an enormous opportunity cost of a road not taken. As strategy scholar James J. Wirtz pointedly observed, "One wonders exactly what, if anything, will be flying from those *Ford*-class carriers in 2063 or whether or not they will be at sea at all. One also wonders why the Navy plans to maintain and grow its fleet of aircraft carriers even though piloted combat aircraft are headed for obsolescence. After all, in 2063 aviators may not be allowed to drive themselves to an airport. Would humans really still be at the controls of a combat aircraft?"[66]

The reluctance to embrace unmanned systems represents a critical missed opportunity of the post-1990s innovation cycle, but it is unsurprising in an institution whose identity is grounded strongly in its carrier aviation community. One can only hope that the *Ford*-class carriers and their F-35 aircraft do not turn into versions of the *Iowa*-class battleships of the last century, which were obsolete even as they arrived.

Perhaps more basically, the Navy and its benefactors were unwilling to confront the uncomfortable reality of the post-1990s era: that unthreatened international trade routes did not need navies to protect them; and that, in any case, they were growing so full of twenty-foot equivalent unit (TEU) traffic that no single actor could disrupt those routes significantly.[67] Seaborne support for U.S. military operations in Iraq and Afghanistan represented a mere trickle added to existing traffic on the vast global seaborne highways. The net effect of this undeniable feature of a globalizing world undermined traditional twentieth-century notions of the direct linkage between America's economic strength through trade and the Navy's protection of trade routes.

As in the Cold War era before it, in the 1990s the strategic backdrop framed the innovation cycle of the era. Yet given that the Navy of the 1990s lacked a near-peer competitor and faced pressure to shrink, it is not surprising that the innovation cycle took on a different character than had been the case during the Cold War. The service realized it had to do more with less, and understandably it viewed RMA-era technology as a way to square the circle. Absent the requirement to establish sea control to protect trade routes or to do battle on the high seas, the Navy gradually migrated to the idea that a central purpose of the fleet was to support operations ashore through strikes, in addition to close-to-shore maritime operations conducted to preserve freedom of maneuver. An original purpose of the DDG-1000 was to fire at targets ashore in support of troops, with the idea that the ships would have to sail relatively close to shore to do so. In 2017, the Navy shifted the emphasis to shooting at other surface ships. The LCS focused on support operations close to shore to deal with enemy vessel swarms and mines, among other things.

Unfortunately, even as the Navy struggled to operationalize these two innovative new platforms, the strategic environment changed. The irony is that, while the United States focused on the inconclusive, irregular land wars in the Middle East and Afghanistan—in which indirect fire from Navy ships frankly was not relevant—competitors emerged (or returned) with new capabilities to challenge the

Navy both at sea and in operations close to shore, via development of land-based antiship missiles that could overwhelm the fleet's antimissile defenses.

It is clear that the post-1990s innovation effort was shaped and disrupted by many different factors:

- Bureaucratic and programmatic difficulties in bringing ideas from the drawing board into being as actual systems that could be delivered to the fleet
- An ever-widening chasm between ponderous ship-development and acquisition cycles and the pace of change in technologies
- Management failures within the Navy that prevented the innovation cycle from moving at a predictable, affordable pace to deliver systems that worked as advertised
- Failure of oversight bodies in the Office of the Secretary of Defense, the White House, and Congress to force the Navy into corrective actions that might have kept the innovation cycle on track
- A lack of strategic consensus on the role of America's armed forces, which left the Navy to its own devices in connecting its systems to a clearly defined maritime strategy or a compelling rationale for its existence; in the absence of a clearly defined strategy, the Navy gravitated to strike operations, including direct support of ground forces, missing the opportunity to explore whether cheaper unmanned systems could perform the same missions for less money
- The shaping of the cycle by excessive cost growth at every step, which ensured (and still ensures) that budgets simply will not support the purchase of the proposed numbers of new ships, representing a disconnect of monumental proportions and a failure to ground the innovation cycle in a coherent linkage of ends, ways, and means

Action-reaction cycles remain a timeless feature within militaries—at least for those intent on staying ahead of their adversaries. The Navy faces significant hurdles to ensuring that the conceptual and systemic flaws that produced these three platforms during the 1990s are not repeated. In addition to these flaws, hanging over Richardson's call for a redesigned fleet is the critical issue of money. Naval innovation cycles need money, and lots of it, and it is not clear that there is enough of it to go around, even in the United States.[68]

All is not lost, however. Out of the ashes of the 1990s cycle can spring innovative ideas, technologies, and concepts of operations that can be generalized for a redesigned fleet. Perhaps the technologies of the DDG-1000 can be adapted usefully and applied in different and more-workable ways on new platforms. The same holds true for the LCS. The Navy must sift through these ashes carefully to glean the ideas and practices it should use as the basis for a redesigned fleet. This must start as an inherently intellectual exercise, which in itself requires the institution to be capable of conducting critical self-evaluation before it takes corrective action.

Moreover, political and military leaders need to articulate clearly a set of strategic priorities that the bureaucracy and other stakeholders in the process can operationalize into weapon systems. Admiral Richardson's call to arms that focused the Navy on overcoming its enemies in war on the high seas indeed may have a galvanizing effect, producing a shortened, more sensible innovation cycle that the bureaucracy can generalize, leading to the sought-after, redesigned, twenty-first-century fleet.

NOTES

1. John M. Richardson [Adm., USN, CNO], *A Design for Maintaining Maritime Superiority, Version 2.0,* Navy.mil, December 2018; John M. Richardson [Adm., USN, CNO], *The Future Navy,* Navy.mil, 17 May 2017.
2. U.S. Defense Dept., *National Defense Strategy of the United States of America* (Washington, DC: 2018).
3. For three proposals on how to modify or add to the Navy's force structure, see executive summary to 2016 Navy Force Structure Assessment, 14 December 2016, available at news.usni.org/; MITRE, *Navy Future Fleet Platform Architecture Study* (McLean, VA: 1 July 2016); and Bryan Clark et al., *Restoring American Seapower: A New Fleet; A New Fleet Architecture for the United States Navy* (Washington, DC: Center for Strategic and Budgetary Assessments, 2017), available at csbaonline.org/.
4. Arguments summarized in Steve Wills, "A New Administration, a New Maritime Strategy?," *Center for International Maritime Security,* 29 November 2016, cimsec.org/.
5. As of early 2020, the Navy's shipbuilding plans and its aspirational goals—eventually to achieve a fleet of 355 ships—appeared to be on somewhat uncertain footing. The Navy's fiscal year (FY) 2021 budget submission cut its shipbuilding budget request by $4.1 billion, representing four fewer ships than requested in the FY20 budget. While in February 2020 Secretary of Defense Mark Esper indicated his support for growing the size of the Navy's fleet to 355 ships, he declined to release the Navy's thirty-year shipbuilding plan to the House Armed Services Committee. For a summary of these developments, see Mackenzie Eaglen, "435 Ship Fleet Is the New 355 for the U.S. Navy," *RealClearDefense,* 10 March 2020, realcleardefense.com/.
6. Actual fleet size targets remain in flux. Paul McLeary, "Navy Backing Off 355 Ships, but Closer on Refueling Drone," *Breaking Defense,* 10 April 2018, breakingdefense.com/.
7. A case study focusing on the growth of the People's Liberation Army Navy also certainly would be germane to this line of analysis.
8. Victor A. Thompson, "Bureaucracy and Innovation," *Administrative Science Quarterly* 10, no. 1 (June 1965), pp. 1–20; Stephen Peter Rosen, *Winning the Next War: Innovation and the Modern Military* (Ithaca, NY: Cornell Univ. Press, 1991). For an illustrative Navy case, see Thomas C. Hone, Douglas V. Smith [Cdr., USN], and Roger C. Easton Jr. [Cdr., USN], "Aegis—Evolutionary or Revolutionary Technology?," in *The Politics of Naval Innovation,* ed. Bradd Hayes [Capt., USN] and Douglas V. Smith [Cdr., USN], Strategic Research Department Research Report 4-94 (Newport, RI: U.S. Naval War College, 1994).
9. Emblematic examples in the literature are Thomas C. Hone, Norman Friedman, and Mark D. Mandeles, *Innovation in Carrier Aviation,* Newport Paper 37 (Newport, RI:

Naval War College Press, 2011), and Thomas C. Hone and Mark D. Mandeles, "Interwar Innovation in Three Navies: U.S. Navy, Royal Navy, Imperial Japanese Navy," *Naval War College Review* 40, no. 2 (Spring 1987), pp. 63–83.

10. As noted, while this article refers to these time spans as *cycles,* they just as easily could be defined as *periods.* Referring to periods as discrete elements is a common practice among researchers, used to illustrate generalizable trends. For two examples of the practice, see Bernard Brodie and Fawn M. Brodie, *From Crossbow to H-bomb: The Evolution of the Weapons and Tactics of Warfare* (Bloomington: Indiana Univ. Press, 1973), and Michael Howard, *War in European History* (Oxford, U.K.: Oxford Univ. Press, 2009). The idea of an innovation cycle within distinctive periods also is illustrated in these works. This raises a definitional issue: What does the term *innovation cycle* mean? For the purposes of this article's analysis, an innovation cycle generally mirrors the process identified in Thomas S. Kuhn, *The Structure of Scientific Revolutions* (Chicago: Univ. of Chicago Press, 1962), which describes a cycle leading to paradigm change. An *innovation cycle* thus is a process through which commonly accepted assumptions are challenged successfully, resulting in new understandings of observable phenomena that are then operationalized. This article particularly focuses on the outputs of these cycles that are operationalized as equipment that is designed to improve organizational capabilities and performance. For an illustrative unpacking of the phenomenon of innovation cycles, see Henry Mintzberg and Frances Westley, "Cycles of Organizational Change," *Strategic Management Journal* 13, no. 52 (Winter 1992), pp. 39–59.

11. Stephen Biddle and Ivan Oelrich, "Future Warfare in the Western Pacific: Chinese Antiaccess/Area Denial, U.S. AirSea Battle, and Command of the Commons in East Asia," *International Security* 41, no. 1 (Summer 2016), pp. 7–48.

12. Drawing from figures compiled by the Stockholm International Peace Research Institute, the Peterson Foundation estimated that the United States spent $610 billion on defense in 2017, $32 billion more than the combined totals of China, Russia, Saudi Arabia, India, France, the United Kingdom, and Japan. "The United States Spends More on Defense Than the Next Seven Countries Combined," *Peter G. Peterson Foundation,* 3 May 2019, pgpf.org/.

13. Anthony Capaccio, "Lockheed F-35 Cost Stabilizes at $406 Billion, Pentagon Says," *Bloomberg,* 13 March 2018, bloomberg.com/.

14. Mark Thompson, "The Navy's $1 Billion Frigate," *POGO,* 22 January 2018, www.pogo.org/. See later discussion of how the DDX morphed into the DDG-1000 *Zumwalt* class.

15. Dollar figures are in 2017 dollars. See Congressional Budget Office, *Costs of Building a 355-Ship Navy* (Washington, DC: April 2017), available at www.cbo.gov/.

16. The Chinese naval buildup is detailed in Steven Lee Myers, "With Ships and Missiles, China Is Ready to Challenge the U.S. Navy in the Pacific," *New York Times,* 29 August 2018, nytimes.com/.

17. Foundational works of realism and its variants are Hans J. Morgenthau, *Politics among Nations: The Struggle for Power and Peace* (New York: Knopf, 1948); E. H. Carr, *The Twenty Years' Crisis 1919–1939* (London: Macmillan, 1940); Kenneth N. Waltz, *Theory of International Politics* (Reading, MA: Addison-Wesley, 1979); and John J. Mearsheimer, *The Tragedy of Great Power Politics* (New York: W. W. Norton, 2001).

18. Representative works in the literature are Harold Sprout and Margaret Sprout, *The Rise of American Naval Power 1776–1918* (Princeton, NJ: Princeton Univ. Press, 1946), and Paul M. Kennedy, *The Rise and Fall of British Naval Mastery,* 2nd ed. (New York: Humanity Books, 2006).

19. Charles L. Glaser, "The Causes and Consequences of Arms Races," *Annual Review of Political Science* 3 (June 2000), pp. 251–76.

20. Some foundational works covering military innovation studies are Barry R. Posen, *The Sources of Military Doctrine: France, Britain, and Germany between the World Wars* (Ithaca, NY: Cornell Univ. Press, 1986); Rosen, *Winning the Next War;* and Theo Farrell and Terry Terriff, eds., *The Sources of Military Change: Culture, Politics, Technology* (Boulder, CO: Lynne Rienner, 2001).

21. Richard Fieldhouse and Shunji Taoka, *Superpowers at Sea: An Assessment of the Naval Arms Race* (Stockholm: Stockholm International Peace Research Institute, 1989).
22. Julian S. Corbett, *Some Principles of Maritime Strategy* (London: Longman, 1918).
23. Alfred Thayer Mahan, *The Influence of Sea Power upon History, 1660–1783* (Boston: Little, Brown, 1919).
24. Samuel Eliot Morison, *History of United States Naval Operations in World War II* (Boston: Little, Brown, 1947–62).
25. As detailed in Owen R. Cote Jr., *The Third Battle: Innovation in the U.S. Navy's Silent Cold War Struggle with Soviet Submarines,* Newport Paper 16 (Newport, RI: Naval War College Press, 2003).
26. Developments summarized in Hayes and Smith, *The Politics of Naval Innovation.*
27. This is not to argue that the Navy did not envision a role for nuclear weapons in the 1950s, just that the Navy was on the losing end of the argument with the Air Force over how to share responsibility for the strategic nuclear deterrent. In the 1950s, the Navy fielded the nuclear-capable A-2 Savage medium bomber aboard its aircraft carriers. For additional details, see Jeffrey G. Barlow, *From Hot War to Cold: The U.S. Navy and National Security Affairs, 1945–1955* (Stanford, CA: Stanford Univ. Press, 2009). For additional details on the bureaucratic politics of the strategic bomber program, see Michael K. Brown, *Flying Blind: The Politics of the U.S. Strategic Bomber Program* (Ithaca, NY: Cornell Univ. Press, 1991). Also, preceding the Polaris program, the Navy fielded small numbers of nuclear-capable Regulus cruise missiles, with a range of three hundred miles, deployed on four submarines in 1963–64. The system was phased out as Polaris came on line.
28. James D. Watkins [Adm., USN, CNO], "The Maritime Strategy," U.S. Naval Institute *Proceedings,* 112/1/995 (January 1986). A negative review of the strategy is discussed in John J. Mearsheimer, "A Strategic Misstep: The Maritime Strategy and Deterrence in Europe," *International Security* 11, no. 2 (Fall 1986), pp. 3–57.
29. Detailed in Karl Lautenschlager, "Technology and the Evolution of Naval Warfare," *International Security* 8, no. 2 (Fall 1983), pp. 3–51. Also see George W. Baer, *One Hundred Years of Sea Power: The U.S. Navy, 1890–1990* (Stanford, CA: Stanford Univ. Press, 1996).
30. Paul K. Davis, *Analytic Architecture for Capabilities-Based Planning, Mission-System Analysis, and Transformation* (Santa Monica, CA: RAND, 2002).
31. This approach was a direct descendant of Robert McNamara and Alain Enthoven's Planning, Programming, and Budgeting System, which was introduced in the 1960s to give the civilians in the Office of the Secretary of Defense a way to choose between competing systems being offered by the services. See Alain C. Enthoven and K. Wayne Smith, *How Much Is Enough? Shaping the Defense Program 1961–1969* (Santa Monica, CA: RAND, 1971), and Charles J. Hitch and Roland N. McKean, *The Economics of Defense in the Nuclear Age* (Santa Monica, CA: RAND, 1960).
32. Identified by Adam Grissom as the central feature of military innovation. See Adam Grissom, "The Future of Military Innovation Studies," *Journal of Strategic Studies* 29, no. 5 (October 2006), p. 907.
33. Ibid.; Hayes and Smith, *The Politics of Naval Innovation;* Vincent Davis, *The Politics of Innovation: Patterns in Navy Cases,* Monograph Series in World Affairs, vol. 4, no. 3 (Denver, CO: Univ. of Denver, 1966–67); Harvey M. Sapolsky, *The Polaris System Development: Bureaucratic and Programmatic Success in Government* (Cambridge, MA: Harvard Univ. Press, 1972); Owen R. Cote, "The Politics of Innovative Military Doctrine: The U.S. Navy and Fleet Ballistic Missiles" (PhD dissertation, Massachusetts Institute of Technology, 1996).
34. History summarized from Norman Friedman, *U.S. Destroyers: An Illustrated Design History,* rev. ed. (Annapolis, MD: Naval Institute Press, 2004).
35. For a summary of the Navy's plans for LCS deployment, see Megan Eckstein, "Navy May Not Deploy Any Littoral Combat Ships This Year," *USNI News,* 11 April 2018, news.usni .org/.
36. Ronald O'Rourke, *Navy Littoral Combat Ship Program: Background and Issues for Congress,* CRS Report RL33741 (Washington, DC:

Congressional Research Service, 17 December 2019).

37. U.S. Defense Dept., *Acquisition of the Navy's Mine Countermeasures Mission Package,* DODIG-2018-140 (Washington, DC: Office of the Inspector General, July 2018).

38. *The Oversight, Acquisition, Testing, and Employment of the Littoral Combat Ship (LCS) and LCS Mission Module Programs: Hearing before the S. Comm. on Armed Services,* 114th Cong. (2016) (statement of J. Michael Gilmore, Director, Operational Test and Evaluation, Office of the Secretary of Defense), available at www.armed-services.senate.gov/.

39. Quoted in Sam LaGrone, "SECDEF Carter Directs Navy to Cut Littoral Combat Ship Program to 40 Hulls, Single Shipbuilder," *USNI News,* 16 December 2015, news.usni.org/.

40. A compendium of the late Senator McCain's statements is available at John McCain, "McCain Demands Accountability for Troubled Navy LCS," 1 December 2016, YouTube video, 2:52, www.youtube.com/.

41. The litany of problems is detailed in Hope Hodge Seck, "New Details Emerge on Littoral Combat Ship Breakdowns," Military.com, 9 December 2016.

42. David B. Larter, "Navy Proposes Decommissioning First 4 LCS More Than a Decade Early," *DefenseNews,* 24 December 2019, defensenews.com/.

43. Ronald O'Rourke, *Navy Littoral Combat Ship (LCS) Program: Background and Issues for Congress,* CRS Report RL 33741 (Washington, DC: Congressional Research Service, April 2019).

44. Program summarized in Ronald O'Rourke, *Navy DDG-51 and DDG-1000 Destroyer Programs: Background and Issues for Congress,* CRS Report RL32109 (Washington, DC: Congressional Research Service, 17 April 2019).

45. For the history of the program, see Ronald O'Rourke, *Navy DDG-51 and DDG-1000 Destroyer Programs: Background and Issues for Congress,* CRS Report RL32109, updated ver. (Washington, DC: Congressional Research Service, 2 March 2020). Also see Mark Thompson, "The U.S. Navy's Titanium Tin Can," *POGO,* 10 January 2019, www.pogo.org/.

46. Details drawn from Ronald O'Rourke, *Navy* Ford *(CVN-78) Class Aircraft Carrier Program: Background and Issues for Congress,* CRS Report RS20643 (Washington, DC: Congressional Research Service, 22 October 2018).

47. U.S. Defense Dept., "CVN 78 *Gerald R. Ford*–Class Nuclear Aircraft Carrier," in *FY 2017 Annual Report* (Washington, DC: Director, Operational Test and Evaluation, January 2018), available at dote.osd.mil/.

48. Ibid.

49. *Procurement, Acquisition, Testing, and Oversight of the Navy's* Gerald R. Ford*–Class Aircraft Carrier Program: Hearing before the S. Comm. on Armed Services (2015)* (opening statement of Sen. John McCain, Chairman, S. Comm. on Armed Services) [hereafter McCain statement], available at www.armed-services.senate.gov/.

50. U.S. Government Accountability Office, *Navy Shipbuilding: Past Performance Provides Valuable Lessons for Future Investments,* GAO-18-238SP (Washington, DC: June 2018), available at gao.gov/. Also see U.S. Government Accountability Office, Ford*-Class Aircraft Carrier: Follow-On Ships Need More Frequent and Accurate Cost Estimates to Avoid Pitfalls of Lead Ship,* GAO-17-575 (Washington, DC: June 2017), available at gao.gov/.

51. McCain statement.

52. Certainly federal budget sequestration introduced in 2013 did not help in the execution of programs across the board for the military departments. For example, Navy readiness suffered from sequestration. Details provided in Michael Bayer and Gary Roughead [Adm., USN (Ret.)], *Strategic Readiness Review 2017* (Washington, DC: U.S. Navy Dept., 3 December 2017).

53. Part of the story is told in Andrew J. Bacevich, *The Pentomic Era: The US Army between Korea and Vietnam* (Washington, DC: National Defense Univ. Press, 1986). Also see Alfred Goldberg, ed., *History of the United States Air Force 1907–1957* (Manchester, NH: Ayer, 1978), and Lawrence S. Kaplan, Ronald D. Landa, and Edward J. Drea, *History of the Office of the Secretary of Defense,* vol. 5, *The*

McNamara Ascendancy 1961–1965 (Washington, DC: Office of the Secretary of Defense Historical Office, 2006). This episode recalled the fight between proponents of manned bombers and the pioneers of long-range missiles in the 1950s, which represents another significant case in the record of the U.S. armed forces of innovation and its opponents.

54. Both Rosen, *Winning the Next War,* and Posen, *Sources of Military Doctrine,* emphasize the important role played by internal organizational advocates in the process of military innovation. Bureaucratic politics literature remains relevant to explaining organizational behavior. See Graham T. Allison and Morton H. Halperin, "Bureaucratic Politics: A Paradigm and Some Policy Implications," in "Theory and Policy in International Relations," ed. Raymond Tanter and Richard H. Ullman, supplement, *World Politics* 24 (Spring 1972), pp. 40–79; Graham Allison and Philip Zelikow, *Essence of Decision: Explaining the Cuban Missile Crisis,* 2nd ed. (New York: Longman, 1999); Morton H. Halperin and Priscilla Clapp, *Bureaucratic Politics and Foreign Policy* (Washington, DC: Brookings Institution, 1974); and David A. Welch, "The Organizational Process and Bureaucratic Politics Paradigms: Retrospect and Prospect," *International Security* 17, no. 2 (Fall 1992), pp. 112–46.

55. To be sure, there is a systemic lag in embedding technologies in weapon systems; it can take seven to ten years or more before these systems move through research, development, testing, and evaluation. Technologies envisioned at the beginning of these programs are sure to have advanced by the time fielding occurs. The phenomenon has worsened, however, as the pace of global, societal, and technological change has increased. This argument is perhaps best summarized in Thomas L. Friedman, *Thank You for Being Late: An Optimist's Guide to Thriving in the Age of Accelerations* (New York: Farrar, Straus, Giroux, 2016). Friedman draws on the exponential increase in computing power encapsulated in Moore's Law to illustrate the accelerating pace of change and the difficulties humans and their organizations face in adapting quickly enough to keep pace. The relevance to the Navy is that the pace of change that Brodie discussed in Bernard Brodie, *Sea Power in the Machine Age* (Princeton, NJ: Princeton Univ. Press, 1943) is relevant no longer; advances in technologies and their associated systems have overtaken the pattern of evolution in naval systems that Brodie illustrated.

56. Fifteen shipyards have gone out of business since the end of the Vietnam War, leaving the Navy with seven shipyards from which to source its shipbuilding needs. Details of the decline in the shipbuilding industrial base are in Chief of Naval Operations, *Report to Congress on the Annual Long-Range Plan for Construction of Naval Vessels for Fiscal Year 2019* (Washington, DC: February 2018), app. 4, pp. 16–18, available at secnav.navy.mil/.

57. This is a common characteristic in complex weapon systems. See Chris C. Demchak, *Military Organizations, Complex Machines: Modernization in the U.S. Armed Services* (Ithaca, NY: Cornell Univ. Press, 1991).

58. McCain statement.

59. Ibid

60. Best represented in U.S. Navy Dept., . . . *From the Sea: Preparing the Naval Service for the 21st Century* (Washington, DC: 1992). A compendium of 1990s-era documents is in John B. Hattendorf, ed., *U.S. Naval Strategy in the 1990s: Selected Documents,* Newport Paper 27 (Newport, RI: Naval War College Press, 2006).

61. Bayer and Roughead, *Strategic Readiness Review 2017,* p. 12. For trends in end strength and force structure, see Mark F. Cancian, *U.S. Military Forces in FY 2020: Navy* (Washington, DC: Center for Strategic and International Studies, 3 October 2019).

62. Best represented in U.S. Defense Dept., *Quadrennial Defense Review Report* (Washington, DC: 30 September 2001).

63. As emphasized in U.S. Defense Dept., *Gulf War Air Power Survey* (Washington, DC: U.S. Air Force Dept., 1993).

64. Naval aviators have made such observations to the author on numerous occasions. The lengthy strike missions of America's war in Afghanistan were by no means new. In 1944, as part of Operation MATTERHORN, B-29 bombers under the command of the Twentieth Air Force staged from India and China to conduct bombing raids on Japan—a thousand miles away.

65. Bradley Martin and Michael McMahon, *Future Aircraft Carrier Options* (Santa Monica,

CA: RAND, 2017). The study did not assess the prospect of launching unmanned systems off carriers.

66. James J. Wirtz, "Innovation and Navy Time," in *Maritime Strategy and Naval Innovation in the Age of Competition,* ed. James A. Russell and Alessio Patalano (Annapolis, MD: Naval Institute Press, forthcoming).

67. For example, according to the World Bank, global TEU traffic increased from 224 million units in 2001 to over 750 million units by 2017. "Container Port Traffic," *World Bank,* data.worldbank.org/.

68. Daniel Goure, "Can Trump Rebuild the Military as Deficits Balloon?," *Breaking Defense,* 18 October 2018, breakingdefense.com/.