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PERSPECTIVE ON A TIMELY POLICY ISSUE

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Could the U.S. Navy Fleet of the Mid-21st Century Include Large Uncrewed Vehicles?

The maturation of uncrewed-vehicle technologies across multiple domains creates an opportunity to potentially revise the U.S. Navy's force structure in the coming decades. The goal would be to use these technologies to increase the fleet's capabilities, capacity, survivability, and resilience in the face of near-peer competitors employing large numbers of precision weapons. In this paper, we briefly analyze ways in which the U.S. Navy's fleet could gradually be reshaped through the incorporation of uncrewed vehicles, thereby enhancing its ability to achieve its operational and strategic goals at acceptable risks and costs.

Other recent sources have considered or recommended substantial modifications to the U.S. Navy's fleet structure and plans. For example, the book *Questioning the Carrier* has made the case for radical changes to the U.S. Navy's current force structure, which is centered on aircraft carriers.[1] Here, we focus on how the growing capabilities of uncrewed vehicles can potentially contribute to the gradual reshaping of the fleet from the 2030s through the 2070s.

Abbreviations

AAW	anti-air warfare
ASW	anti-submarine warfare
AI	artificial intelligence
ASW	anti-submarine warfare
CONOPS	concept of operations
IOC	initial operating capability
ISR	intelligence, surveillance, and reconnaissance
UAV	uncrewed aerial vehicle
USV	uncrewed surface vehicle
UUV	uncrewed undersea vehicle

RAND has funded a small exploratory effort to conduct an introductory analysis of some of these issues. This paper is the result of those efforts and was intended to provide some ideas for further analysis as part of much larger studies. We begin by considering what missions the U.S. Navy may need to achieve in the middle of the 21st century and beyond. Next, we analyze how the capabilities of uncrewed vehicles might help to gradually reshape the fleet structure to address those threats, taking into account the various advantages and disadvantages associated with uncrewed vehicles. Finally, we observe lessons from past naval technological transitions, notably the need for gradualism, to help inform potential adjustments as the U.S. Navy's force structure incorporates the capabilities of uncrewed vehicles.

Naval Strategy and Operations: Missions of the Midcentury Fleet

It is axiomatic that the U.S. Navy of the mid-21st century be designed around the missions that it will be called on to perform. To aid our thinking about this, we reviewed several works by classic authors regarding naval strategy, operations, and tactics. These included Bernard Brodie, Raoul Castex, Julian Corbett, Wayne Hughes, and Alfred Thayer Mahan.[2] We do not attempt to comprehensively describe their many volumes of insights here but provide a very brief distillation of some of their collective ideas about the purpose of naval forces, summarized in the following three broad categories:

- Secure civilian and military use of the sea and the airspace above it, while denying adversaries the ability to do the same. Navies need to protect commercial traffic and resource extraction from the seas that are essential to their economies while also enabling the movement of military forces to where they are needed.
  - Classic examples of such struggles are the two Battles of the Atlantic during the world wars. Germany used submarines to try to starve Britain of food and other civilian essentials while also preventing the inflow of military supplies and additional forces from the United States and elsewhere. The Allied navies aimed to counter this campaign to enable safe transit of the Atlantic.
  - A more recent example of commerce protection involved U.S. and allied naval vessels escorting oil tankers in the Persian Gulf to protect them

from Iranian attacks during the 1980s. Conversely, during much of the 1990s, the U.S. Navy and its allies aimed to prevent unauthorized shipping into Iraq in contravention of United Nations sanctions.
  - At the time of this writing in 2024, a coalition led by the U.S. Navy was countering attacks on commercial shipping in the Red Sea by Yemen's Houthi rebels, perfectly illustrating the naval mission of commerce protection.
  - Examples of relevant missions to enable or deny maritime access include surface warfare, anti-submarine warfare (ASW), anti-air warfare (AAW), missile defense, seabed warfare, protection of civilian traffic, blockade, naval mine warfare, intelligence collection, and electronic warfare.

- Conduct operations against land targets and the airspace above land while countering adversaries' ability to do so. As Corbett noted, human beings are land animals, echoing a point (sometimes attributed to Vice Admiral Horatio Nelson) that "the seat of power is on the land."[3] Some of the missions mentioned in the previous bullet are also relevant over land, such as intelligence collection and electronic warfare. Others are specific to the land environment.
  - One important mission set entails striking land targets, such as air bases, missile launch sites, ground vehicles, infantry formations, infrastructure, or military headquarters. Over the last few decades, the U.S. Navy has done this in many locations, from Afghanistan to Panama.
  - Another mission set involves landing forces, on scales ranging from small raids by special forces to full-scale amphibious invasions. U.S. naval forces have done this in locations ranging from Korea to Grenada.
  - A third naval mission set on land involves operating on inland waters, as U.S. Navy forces have done from Vietnam to Iraq. This aligns with the missions described previously regarding securing the sea and denying use of it to others—but with all the complexity of confined waterways where operations are inextricably linked to the surrounding land environment.
  - Sea power may also be used to oppose adversaries conducting any of these missions. For example, this may entail preventing adversaries from approaching a coastline, defending against incoming missiles and aircraft, or launching attacks against amphibious forces.

- Deter conflict by demonstrating the ability and will to perform the first two items. This can be achieved through presence, international engagement, and overt exercises that demonstrate capabilities, as well as by public or private communication. Effective performance in conflict may itself be viewed as a form of communication in addition to its direct benefits. For example, the demonstrated ability of the United States and allied navies to shoot down large numbers of weapons launched by Iran and its Houthi proxies during 2023–2024 can help to deter military adventurism by other powers by making them realize that they are unlikely to defeat the U.S. Navy by targeting its ships with missile barrages.

The Unpredictability of Future Operations

Obviously, each of the three categories mentioned above includes numerous missions, some of which were explicitly mentioned. It would be desirable to know which of these missions the U.S. Navy will most need to focus on in the coming decades so that it can focus on developing the capabilities it needs and large enough capacities (quantities of those capabilities) without wasting resources on excess capabilities or capacities in specific areas. However, the demand for future missions is unpredictable even in the short term, let alone over decades.

The following bullets provide a quick look back at recent history that underscores the extent to which unpredicted challenges can result in substantial demands on naval forces:

- In 1981, the United Kingdom issued a defense white paper in which it assessed that it was unlikely to conduct amphibious landings beyond Europe; the United Kingdom, therefore, would phase out both amphibious assault ships and trim the size of the Royal Navy. The next year, Argentina invaded the Falkland Islands, causing Britain's forces to fight a naval-centric war in the South Atlantic that included an amphibious landing.[4]
- From 1980 to 1988, the United States and other Western powers supported Iraq during the Iran-Iraq War, seeing Saddam Hussein's forces as a bulwark against Iran's Islamic revolutionary government.[5] When Iraq invaded Kuwait in 1990, a U.S.-led coalition—including copious naval forces—moved to block Iraq's further advances and pushed it out of Kuwait the next year. The U.S. Navy's many missions included targeting Iraqi forces, collecting intelligence, conducting air and missile defense, conducting mine countermeasures, supporting marines and special forces, and creating a massive amphibious feint that diverted Iraqi forces to Kuwait's coast, facilitating a U.S. Army flanking maneuver.[6] Naval maritime interdiction and air operations against Iraq continued for over a decade, then naval forces contributed to the 2003 invasion of Iraq and protracted stabilization operations.
- During the 1980s, many U.S. observers anticipated that the Cold War would endure indefinitely. Instead, communism collapsed in Soviet-dominated satellite states in Europe in 1989, and the Soviet Union itself collapsed in 1991, radically changing the nature of demand for the U.S. Navy.
- In 1984, the world celebrated the Sarajevo Olympics in a peaceful, multiethnic Yugoslavia that had largely buried the historical and current tensions among its constituent ethnic groups. Seven years later, a series of wars and massacres began among those groups. The result was that during the series of post-Yugoslav wars of the 1990s, the U.S. Navy, U.S. Air Force, and forces from many North Atlantic Treaty Organization allies targeted ground forces conducting ethnic cleansing.
- In 2000, presidential candidate George W. Bush declared that the United States should not be conducting nation-building operations.[7] The next year, in an operation that would have seemed inconceivable until the 9/11 terrorist attacks, the United States used carrier-based and land-based aircraft to invade and attempt to stabilize deeply landlocked

Afghanistan in what was unequivocally an exercise in nation-building.
- In October 2023, National Security Advisor Jacob Sullivan commented publicly, "The Middle East region is quieter today than it has been in two decades."[8] Less than a week later, after Hamas launched a horrific attack against Israel, the Israelis began a counterattack against Gaza. During this crisis, ongoing as of late 2024, the U.S. Navy has deployed and operated assets to reassure Israel, to deter Hezbollah and Iran, to counter attacks by the Houthis against shipping in the Red Sea, to defeat a massive missile and uncrewed aircraft barrage by Iran, and to closely monitor the situation.

Historical Mission Demands Have Been Diverse

The U.S. Navy, and naval forces globally, has been called on to conduct an incredibly diverse array of missions since World War II. Many of these have been enduring and continual. For example, the U.S. Navy has spent the last 80 years performing intelligence, surveillance, and reconnaissance (ISR) operations; conducting electronic warfare; maintaining presence to reassure allies and deter prospective foes; tracking submarines from rival nations; and ensuring credible nuclear deterrence. Some support functions, such as logistics, are also integral parts of all operations. Other missions have been more episodic, such as striking land targets, conducting amphibious landings, evacuating noncombatants, and providing humanitarian assistance and disaster relief. The last two represent examples of missions that are routinely conducted in peacetime and war.

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In Table 1, we list key missions associated with naval forces conducting combat operations since 1945. These operations have been aggregated for simplicity; for example, all of the Arab-Israeli wars with a naval component are represented by a single row. We also included one noncombat case, the Cuban Missile Crisis, in which the two sides confronted one another so closely and intensely that large-scale naval combat was narrowly averted. These missions have been described in broad terms: For example, *striking land targets and offshore infrastructure* includes suppression of enemy air defenses, which we do not enumerate separately. In this table, we have excluded continual missions and support functions, such as ISR and logistics.

TABLE 1

Conflicts with Substantial Naval Components Since World War II and the Naval Missions Associated with Them

Conflict	Dates	Amphibious Raids and Landings	Striking Land Targets and Offshore Infrastructure	Sea-Based AAW and Missile Defense	Mine Warfare	Surface Warfare	ASW	Riverine Operations	Blockade/ MIO	Escort Operations
PRC attacks against ROC-held islands	1949–1958	X	X						X	X
Korean War	1950–1953	X	X	X	X		X		X	
Cuban Missile Crisis	1962						X		X	
Vietnam War	1964–1973	X	X	X	X			X	X	
Arab-Israeli wars[a]	1956, 1967, 1967–1970, 1973, 1982–1985, 2006, 2022–present	X	X			X			X	X
Indian-Pakistani wars	1947, 1965, 1971	X	X	X		X	X	X	X	X
Sino-Vietnamese battles	1974, 1979, 1988	X	X			X				
Falklands War	1982	X	X		X	X	X		X	
U.S.-led interventions in the greater Middle East (Lebanon, Iran/Persian Gulf, Somalia, Libya, eastern Mediterranean, Red Sea)[b]	1958, 1982–1988, 1992–1995, 2011, 2023–present	X	X	X	X	X			X	X
Iran-Iraq War	1981–1988	X	X		X			X	X	
Grenada	1983	X	X							

Table 1—Continued

Conflict	Dates	Amphibious Raids and Landings	Striking Land Targets and Offshore Infrastructure	Sea-Based AAW and Missile Defense	Mine Warfare	Surface Warfare	ASW	Riverine Operations	Blockade/ MIO	Escort Operations
Sri Lankan civil war	1984–2009	X	X		X	X	X		X	
Desert Storm and postwar Iraq actions	1991–2003	X (feint)	X	X	X				X	
Balkan Wars	1991–1999		X							
Enduring Freedom (Afghanistan)	2001–2021		X							
Iraqi Freedom	2003–2011		X		X			X		
Russian invasion of Georgia	2008		X							
Syrian civil war	2011–2017		X							
Russian full-scale invasion of Ukraine	2022–present	X	X	X	X			X	X	
Total involving U.S. Navy (out of 9)		6	9	4	5	1	2	2	5	1
Overall total (out of 19)		13	18	5	9	6	5	5	12	4

NOTE: Conflicts in which the United States played a central role are shaded gray. This table does not include routine or continuous missions, such as ISR, presence, and nuclear deterrence. ASW = anti-submarine warfare; MIO = maritime interdiction operations; PRC = People's Republic of China; ROC = Republic of China (Taiwan).

[a] We left out the first Arab-Israeli war in 1947–1949, which had near-negligible naval aspects. We included the War of Attrition of 1967–1970 (following the 1967 Six-Day War), in which the two sides engaged in frequent naval attacks and raids.

[b] We excluded Desert Shield/Storm, Operation Enduring Freedom, and Operation Iraqi Freedom, which are listed separately.

Situations in which the United States played a central role are shaded.

Table 1 illustrates the following key points:

- Conflicts over the past 80 years have entailed a highly diverse array of naval missions. This, together with the inherent unpredictability of human affairs described above, suggests that the future U.S. Navy must be prepared for all of these missions and more.
- Power projection from the sea has been highly frequent, reflecting the previously cited dictum that the seat of power is on the land. Nearly all these conflicts have involved bombardment of land targets from the sea, and most have involved amphibious raids and landings.
- The majority of these cases involved attempts to stymie maritime movements. These include both maritime interdiction operations and the use of naval mines.

The Impact of Uncrewed Vehicles and Related Technologies

Having assessed that mission demands for the future U.S. Navy will be diverse and somewhat unpredictable, we next turn to how uncrewed vehicles can help to meet those demands over the next half century and how this could reshape the U.S. Navy. We begin by exploring some of the broad advantages and disadvantages associated with the use of uncrewed vehicles and supporting technologies, such as advanced autonomy. Next, we discuss two proposals for reshaping the midcentury fleet based on the greater employment of uncrewed vehicles. The first entails the advent of aircraft carriers that exclusively host uncrewed aerial vehicles (UAVs), and the second involves the use of uncrewed surface vehicles (USVs) the size of corvettes, frigates, or larger as part of the fleet.

Advantages and Disadvantages of Uncrewed Vehicles

One key advantage is that uncrewed vehicles can be designed differently from their crewed counterparts because they do not need space or resources to accommodate personnel. (This assumes that uncrewed vehicles are designed exclusively for uncrewed use; optionally crewed vehicles would sacrifice many of these design benefits.) On an uncrewed ship, spaces for berthing, storing food and cooking, generating potable water, and meeting other human needs can contain weapons or fuel instead. Likewise, aircraft can eliminate the spaces designed to sustain a pilot. More fundamentally, uncrewed vehicles can also be designed differently. For example, ships and aircraft are now designed with spaces enabling humans to directly view what is happening, as well as to view various screens and to control the vehicle's actions. Building on an idea observed by Vice Admiral (retired) Joseph Metcalf in a 1988 article regarding crewed warship redesign, a wholly uncrewed vehicle could not only eliminate most of that space but could also displace its control devices to interior locations that were less vulnerable to superficial damage.[9] Moreover, uncrewed aircraft can be redesigned to be capable of maneuvers that would otherwise inflict dangerous G-forces (acceleration) on pilots. This can also enable them to use shorter runways for takeoff and landing.

Another key consideration is endurance. Human pilots' physical limitations do not constrain the endurance of uncrewed aircraft, and uncrewed ships do not need to be resupplied with food or to generate substantial quantities of potable water. The extra space available to both types of vehicles could increase fuel storage for longer endurance without resupply. Not having to use energy to keep personnel healthy and comfortable also reduces fuel consumption. Although these systems will have to be refueled, both increased fuel storage capacity and decreased power demand would enhance their endurance relative to crewed assets.

To the extent that uncrewed vehicles require fewer resources aboard, they can potentially be more cost effective, enabling more of them to be built and used. For example, the Congressional Budget Office found substantial lifecycle cost savings per flying hour for uncrewed ISR aircraft relative to their crewed counterparts in a 2021 study.[10] The UAVs had both lower acquisition costs and lower recurring costs per flying hour, more than offsetting their shorter anticipated lifespans. Although such savings are not guaranteed (any new program can turn out to cost more than expected), it makes intuitive sense. Reduced costs per platform and per flight hour can enable more-distributed lethality, the dispersion of combat power onto more platforms. As other writers have described, this diminishes the risks associated with losing any one of them.[11] The proliferation of platforms also enables them to be in more places at once. This effective growth in capacity can be valuable in the event of near-simultaneous crises in different parts of the world or the need to sustain presence as a deterrent in one area while conducting combat operations in another. Increased capacity can also enable the U.S. Navy to better fulfill its missions even in the absence of a conflict.

A central component of uncrewed vehicles' value proposition is their higher risk tolerance. Although large aircraft or vessels are too valuable to throw away recklessly, even without personnel aboard, they can be subjected to greater risks than would be acceptable for humans when the situation demands it.

If the rise of uncrewed vehicles enables the U.S. Navy to achieve its goals with fewer sailors, this would both save money and mitigate the U.S. Navy's recruitment challenges. Those challenges are likely to grow in the coming decades as a result of ever-shrinking cohorts of young U.S. citizens. For example, the 2020 U.S. Census reported 18.4 million children in the 0–4 age range, compared with 22.2 million people in the range of 20–24, corresponding to a 17-percent decline in a generation.[12] Other factors are also reducing recruitment, including declining health among adolescents, high levels of recreational drug use, a tight employment market, and diminishing levels of public trust in government and in the military.[13]

Despite the advantages enumerated above, there are several challenges associated with the use of uncrewed ships and aircraft. First, there is a need for some combination of assured, secure communications with humans or substantial or near-total autonomy. The reliability and bandwidth needed for those communication channels, or the level of autonomy required, increases with the complexity of both the mission and the operational environment.[14] Creating wholly autonomous vehicles is harder than is often anticipated, as has been well demonstrated by the more than $100 billion that the private sector has spent on developing driverless cars over more than a decade. The fundamental problem is that algorithms make mistakes in perception and motor control that humans find inconceivable, a phenomenon termed *Moravec's paradox*.[15] Detecting and addressing the numerous ways in which autonomous systems can err requires vast amounts of virtual and live testing. Moreover, the reduced predictability of autonomous systems can expand the controlled, sensor-studded space needed to test them relative to less autonomous systems because they may stray in unexpected ways and cause safety hazards at great distances. Moreover, although the autonomous capabilities of self-driving cars are designed for an environment that is primarily collaborative (nearly all drivers collectively want to efficiently and safely move through the environment according to an established set of rules), military vehicles need to have autonomy that can withstand relentless interference and attacks by thinking adversaries in more-complex environments. Similarly, ensuring reliable, secure communications—with enough bandwidth and low enough data latency for humans to correct machine errors—can be difficult in an increasingly crowded and contested electromagnetic environment.

In addition, even uncrewed systems require various personnel to maintain these systems, provide logistical support, analyze any datasets that they provide, and, often, control them while they are operating. The proliferation of offboard uncrewed systems has created additional capabilities and capacity, but it has also increased demand for personnel. Increasing automation and the use of artificial intelligence (AI) may someday alleviate the need for so much human involvement, enabling automated data interpretation, fully autonomous control, and possibly even machines that can autonomously maintain and refuel other machines. How rapidly AI improves in that regard is uncertain: Since the 1960s, predictions of AI's trajectory over subsequent decades have often been wildly wrong. Experiments with existing AI have demonstrated that it can easily misperceive objects, particularly when false information is introduced; a famous example involves AI identifying a photo of a panda as a gibbon and doing so with 99.3 percent confidence.[16] Even if AI overcomes technological hurdles and the ability of adversaries to manipulate it, widespread military use of AI requires a high degree of institutional trust in it and the modification of procedures to accommodate its use. Both may take some years to achieve; organizational cultures generally change slowly. Trust issues may be exacerbated by AI that incorporates machine learning. A system whose characteristics are continually changing is one that humans may find less trustworthy, particularly if they do not fully understand what it is learning from its environment and how that may shape its behavior. If AI is increasingly relied on at the same time that maintenance is conducted less frequently because of longer-endurance platforms, AI's limited ability to handle unexpected events could exacerbate the effects of minor breakdowns.

Beyond the challenges of acquisition, large shifts in terms of uncrewed-vehicle usage could also require substantial changes in the U.S. Navy's management of its personnel. The numbers of people going into particular U.S. Navy ratings (specialties), and perhaps the ratings themselves, would need to be adjusted. Recruitment and retention efforts might increasingly reflect the growing importance of technological skills and a willingness to build them. Training curricula and schedules would need to be revamped, while training equipment and facilities might need to be increased to enable personnel to gain requisite experience with sophisticated systems. All these changes would have effects on recruitment and retention goals, in terms of both the numbers and skills of individuals. As in any institutional transition, particularly one in which much of the prior U.S. Navy was still extant, there would be coordination issues and friction as these changes were implemented.

A final consideration is how rival nations may behave with respect to uncrewed vehicles. During confrontations that fall short of outright war—i.e., the *gray zone*—rivals may be more aggressive in attacking or seeking to capture uncrewed vehicles than they would a crewed vehicle because they would not be taking the highly escalatory step of killing or capturing personnel. The People's Liberation Army demonstrated its comfort level with capturing small uncrewed vehicles when it seized a U.S. Navy oceanographic ship's uncrewed undersea vehicle (UUV) in 2016 (though it was returned a few days later).[17] In addition, unexpected escalation could occur if one side thought that the other was employing an uncrewed vehicle that was actually crewed. Vehicles on either side may be ordered to engage the other more aggressively than would have been permitted with crewed vehicles, creating risks of escalation that would have been circumscribed otherwise. Given the absence of data on the dynamics of gray-zone interactions among uncrewed vehicles, there are many unknowns regarding how future incidents could play out.

Taken collectively, the advantages of uncrewed vehicles include increased capacity, endurance, performance, and risk tolerance (at least in some cases). These are offset chiefly by the challenges of autonomy and communications, as well as the fact that uncrewed vehicles have not yet resulted in personnel or cost savings. Below, we will explore a couple of ideas for reshaping the fleet based on some of the advantages mentioned while also taking into account various reasons to be cautious.

Potential Development of All-UAV Aircraft Carriers

Looking back at Table 1, the frequency of demand for striking land targets and for support of amphibious operations would suggest that naval airpower is going to be in high demand. Airpower, of course, also contributes to AAW and missile defense, ASW, ISR, electronic warfare, mine warfare, logistics, and other missions and functions. Although some naval airpower can be land based, there will be a continuing need to launch aircraft from ships, both to maximize the range of power projection and to make aircraft operationally responsive within short timelines. Basing aircraft at sea also conveys other advantages: It is not dependent on host-nation permissions, and the mobil-

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ity of ships makes them more difficult to hit than the array of fixed targets (runways, parked aircraft, fuel, munitions, and personnel housing) embodied in an air base on land.

Although ship-based aircraft will still be required, those aircraft do not necessarily need to have personnel aboard them. Over the last quarter of a century, UAVs have evolved from niche platforms into central contributors to combat capabilities. A pioneering effort in this regard has been the development of the carrier-based MQ-25A Stingray UAV, which is primarily for air-to-air refueling. As of 2024, the U.S. Navy planned to achieve initial operational capability (IOC) by 2026.[18] Over the next several decades, fighters and other carrier-launched aircraft may be designed to be fully uncrewed. Even as the aircraft carrier itself remains a crewed platform, this development could be combined with other technological developments to enable the carrier to be reshaped. For example, today's aircraft carriers need to be long enough to launch and recover aircraft while subjecting pilots to tolerable G-forces. That critical length constraint could be relaxed if UAVs were launched and recovered over shorter distances, using advanced materials with greater tensile strengths than those used to launch and recover today's aircraft. Put another way, some existing amphibious ships could serve as all-UAV carriers when they are not hosting marines. Those ships could also use their well decks to launch substantial USVs or UUVs whose actions could complement those of the UAVs being launched from above.

Parallel technological developments could further enable the redesign of aircraft carriers or bolster the use of smaller amphibious ships as de facto UAV carriers. Advanced UAV autonomy could enable one pilot to supervise multiple UAVs, reducing personnel numbers. AI could also reduce the number of humans needed to analyze and respond to incoming sensor data (again, given sufficient trust of AI). UAVs that no longer have systems to support pilots, and are designed for increased reliability, may require fewer maintenance personnel. The UAVs could be designed to simplify maintenance procedures and refueling to further reduce the number of personnel needed.

Alongside the emergence of UAVs that can supplant crewed aircraft, emerging technologies could contribute to improvements in the ship itself that would further diminish demand for personnel. In some cases, the number of humans scrutinizing either screens or the horizon could be reduced, if well-honed AI were able to cue humans when anomalies were detected. In addition, some aspects of routine tasking could potentially be automated—for example, robots could clean spaces, lubricate machines, or inspect equipment to detect emerging faults. The ship could also incorporate more-automated damage control capabilities to improve capabilities and reduce the number of people needed for that mission. Such automation could include the use of crawling or swimming robots that can be sent into confined, dangerous spaces both to gain situational awareness and to actively respond to floods or fires. Collectively, these changes could have a multiplicative effect: Every operator whose presence was eliminated would enable a large fraction of another person to be subtracted from the crew, given diminished demand for roles from cooks to military police. That would further reduce the space and resource needs associated with humans. Adoption of similar capabilities throughout the fleet could reduce crew requirements on other vessels, enabling space to be repurposed while potentially reducing costs. Some of these changes, such as AI cueing to diminish the number of personnel needed to stand watch, might be achievable in the relatively near term. Although some of the space being vacated by personnel and their needs would likely be occupied by additional information technology hardware and cooling systems, increasingly compact and efficient hardware would help to limit space requirements; galleys do not shrink while maintaining the same capacity but computers do.

Advances in three-dimensional (3D) printing, also called *additive manufacturing*, could further reduce space requirements on an all-UAV carrier. Ships currently need rooms full of spare parts to replace those that break, in quantities that allow for every part to potentially break multiple times. If many of those parts can be 3D printed when they are needed, those rooms full of parts could be replaced by powder and printers occupying a small fraction of that volume. Such 3D printing will need to be able to withstand conditions at sea, such as the ship's motion, continual vibrations, and a limited ability to maintain clean conditions. However, if this can be achieved in the next decade or two, it could create additional space or enable a smaller ship to host copious UAVs. Developments in materials science might also contribute to personnel and space reductions. More-durable parts, or advanced coatings that inhibit corrosion, could diminish both the frequency of breakdowns and demand for personnel to fix items.

Whether future all-UAV aircraft carriers are developed or amphibious ships are used for that purpose the ability to eliminate or repurpose space would be beneficial. Although today's 100,000-ton aircraft carriers are not heavily space-constrained, an all-UAV carrier with more space could potentially accommodate more UAVs than there are aircraft on a carrier today. Alternatively, an all-UAV carrier could store more fuel for its aircraft or even for itself if it were not nuclear-powered. Shrinking the carrier itself would be an option. If smaller all-UAV carriers are less costly than existing aircraft carriers, and require fewer personnel, the U.S. Navy can acquire more of them. The result could be strike groups involving two or more carriers, increasing redundancy and distributing lethality. As was noted in the book *Questioning the Carrier*, the current concentration of naval power into relatively few ships can make each of those assets so valuable as to induce risk aversion, particularly because each aircraft carrier contains roughly 5,000 personnel.[19] More-numerous all-UAV carriers, some of which might resemble today's amphibious ships and which could be used as amphibious ships under alternative circumstances, would reduce the hazards associated with losing any single ship. Alternatively, ships the size of today's aircraft carriers could support more aircraft or go longer before requiring replenishment at sea.

Potential Incorporation of Ship-Sized USVs into Strike Groups

Although all-UAV carriers will likely continue to be crewed, they may be complemented by large USVs, perhaps the size of a corvette, frigate, or larger. Such USVs could be fully integrated into carrier or amphibious strike groups. Some could host sensors, such as radar and sonar, while others would serve as oilers that would effectively constitute offsite storage for other ships. Some could host missiles, torpedoes, or lasers and other electromagnetic weapons and be directed to use them by personnel aboard crewed ships within the strike group. Perhaps each weapon-firing vessel would host only one type of weapon, enabling its design to be optimized for that purpose. For example, a frigate-sized USV might launch barrages of missiles, while a corvette could be used exclusively to drop torpedoes in the vicinity of any intruding submarines detected by the sonar of other USVs. This builds on the idea of an *arsenal ship*—a concept dating back to the 1990s, with prior antecedents—in which a lightly crewed or remotely controlled ship would be bristling with weapons and little else.[20] Because all of the communications involved would be over relatively short ranges in an area where the strike group had electromagnetic dominance, ensuring sufficient reliability and bandwidth would be far easier than doing so for UAVs, which would be going into contested or hostile airspace.

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As was noted above, a key advantage of uncrewed vehicles is the elimination of space and resources to support human beings, although this will be offset by the need for additional information technology hardware for data analysis and storage, as well as cooling capacity for that hardware. Despite this offset, which will presumably diminish as hardware becomes more efficient, a ship designed solely to contain sensors, weapons, or fuel can potentially have a larger payload relative to its size. Distributing such capabilities across several USVs dispersed throughout the strike group aligns well with the idea of distributed lethality, in which combat power is deployed on more assets than at present.[21] Such redundancy could also help to offset the operational impact of losing any one USV, making the fleet more robust and enabling it to undertake calculated risks. For example, corvette-sized USVs with sensing capabilities could be deployed well forward of the fleet to provide additional warning, tracking, and electronic warfare capabilities, enabling crewed ships and missile-shooting USVs to more effectively counter incoming threats. Although they would be valuable enough not to thoughtlessly put them in excessive danger, they could be subjected to greater jeopardy than a ship with a human crew would in the same circumstances. Redundancy across the strike group, and the lack of personnel, could also reduce costs by eliminating the need for USVs to have as much internal redundancy and protection as a crewed ship. The assumption would be that any substantial hit would effectively destroy that asset. Rather than expending resources to make USVs durable and resilient in the face of missile hits, those resources could be used to make USVs more numerous.

Moreover, a strike group containing multiple USVs ranging in size from a corvette to a frigate—perhaps several or more each for sensing, shooting, and refueling—would also have enough redundancy that at any given moment, one of each category could be going back to port for replenishment and light maintenance. For example, each weapon-firing USV could be rearmed and briefly inspected and maintained in port while the others remained on station. Refueling and sensing USVs could likewise have staggered timelines for periodic returns to port. Given support from allies and partners, homeports and maintenance sites for these ships around the globe could enable them help to maximize their peacetime presence.

There are several challenges and risks associated with the use of ship-sized USVs, the foremost of which is reliability. If these USVs are to endure for long periods without personnel conducting maintenance, all systems need to be highly reliable despite the harsh maritime environment. However, commercial ships are already lightly crewed for transoceanic voyages, with fewer than 20 personnel in charge of a behemoth. Admittedly, the U.S. Navy has high standards for vessel reliability and safe handling—a warship running aground in the Suez Canal or crashing into a bridge is beyond intolerable—but technological advances may enable it to transition to fewer or no crew members. It is possible that USVs that are designed for reliability and specific types of redundancy, to the exclusion of habitability, could evince more-consistent reliability than their commercial counterparts. A key question is what the cost of such reliability might be. In addition, self-diagnosis of minor faults would likely be easy: Systems ranging from cars to printers can already detect their own issues. Conceivably, the most-common maintenance issues could be addressed by remotely controlled robots providing continuous data to their human operators on crewed ships, although this will require substantial technological development over the next several decades.

Another key issue regarding ship-sized USVs is uncertainty regarding their costs and the numbers of personnel needed to support them. Although the elimination of systems and space to support personnel can reduce costs, as can reductions in durability, this will be offset by the need for every system to have enhanced reliability and self-diagnostic capabilities.

Finally, the technological and procedural challenges associated with acquiring a fleet of USVs should not be underestimated. Regardless of the level of investment, developing the autonomy these USVs need to reduce their dependence on communications will be difficult, as was described above. Changing the fleet's concept of operations (CONOPS), tactics, techniques, and procedures to reflect the presence of ship-sized USVs will require gradual transitions, copious training, and the slow accretion of trust.

Crewed Ships Will Still Be Required

We have described two ways in which the fleet could potentially include more uncrewed vehicles: through the emergence of all-UAV carriers and ship-sized USVs that are integral parts of the fleet. However, crewed ships will still be required for many decades to come. Despite developments in AI, some activities will still require human intelligence, adaptability, and decisionmaking skills. Humans will likely be needed to analyze operational situations and outthink human adversaries and conduct certain types of maintenance and support. Although it is possible that AI will be able to comprehensively outperform humans by the 2050s or 2070s, many past projections of AI have overstated the pace at which it will advance: considerable uncertainty must be acknowledged.[22] Personnel will still be needed to help direct, operate, and support uncrewed vehicles across multiple domains, including smaller ones than are described above. Authorization may be required before weapons are launched.

Moreover, many types of naval operations require human beings. For example, visit, boarding, search, and seizure of other vessels need to be done by humans as part of maritime interdiction operations, counterpiracy, and other missions. Similarly, credible naval presence to deter adversaries and reassure allies likely requires crewed ships in most cases. A hostile actor can dismiss the presence of even a large, missile-launching USV as an indication of limited will to put sailors in the line of fire. Allies may be similarly unimpressed by the deployment of uncrewed ships while they are being menaced in a crisis. Part of the value of U.S. Navy presence is the fact that having U.S. sailors in the way of potential aggression commits the United States to war if they are attacked; they are a tripwire, like U.S. forces in West Berlin during the Cold War. An uncrewed vessel, even if sunk, may not be seen as having the same impact.

One type of warship is particularly likely to require humans aboard for the indefinite future, given its limited communication links with the rest of the world. Submarines have shown themselves to be invaluable assets from the World War I to the present, for missions ranging from launching weapons to conducting ISR and deploying special forces. Given the limited transmission of electromagnetic energy underwater and the limited bandwidth of acoustic communications, any attempts to remotely control submarines while they are submerged are futile. As a result, they must either have personnel aboard or have phenomenally exquisite autonomy that is trusted by the rest of the fleet. Maintaining crews aboard these assets, which are often used for sensitive missions, such as nuclear deterrence, is the likely outcome for at least the bulk of the 21st century. However, these valuable, scarce assets can be complemented by uncrewed vehicles that will reduce their workload. For example, large UUVs that frequently surface to exchange information and receive orders—though always at the risk of detection—may be able to clandestinely approach targets to conduct ISR or to launch weapons, obviating the need for a crewed submarine. It is also possible that the CONOPS for large UUVs will differ from those for today's submarines or that they will undertake different missions altogether. The same is also true for air and surface assets, which may complement and reduce demand for their crewed counterparts (crewed-uncrewed teaming) or be associated with novel CONOPS and missions.

Potential Changes to the Fleet Will Require a Gradual Transition

Given the prospective opportunities that all-UAV carriers and ship-sized USVs might provide, it would be desirable to pursue ways to make them a reality. To the extent that these approaches may reduce demand for personnel, they could help to alleviate some of the U.S. Navy's recruitment shortfalls. However, the caveats and risks described above should also influence decisions about how quickly to introduce these capabilities into the fleet. Moreover, the fleet is relatively immutable over the short term, unless the U.S. Navy has enough resources to quickly introduce large numbers of new assets, with or without early decommissioning of existing ones. Ships routinely last several decades to half a century; for example, the USS *Missouri* bombarded Japan with its guns in 1944–1945 but also launched missiles against Iraq in 1991 as part of Desert Storm.[23] The aircraft carrier USS *Enterprise,* commissioned in 1961, was deployed during the Cuban Missile Crisis of 1962 and was in service until 2012.[24] Similarly, the aircraft carrier USS *Nimitz*, commissioned in 1975, will be decommissioned in 2026.[25] Ships that are already under construction during the mid-2020s or have joined the fleet relatively recently may last into the 2070s or even beyond.

Earlier, we mentioned the importance of personnel and training considerations in any transition. Introducing all-UAV carriers and ship-sized USVs would likely affect the number of people who are recruited, their training, and their distributions across ratings (some of which may be added, revised, or eliminated). Although fewer people may be needed overall, they would need additional skills to oversee more-complex systems, so skill-based incentives for recruitment and retention would also need to be altered. Overall, the pace of these changes must be aligned with that of the evolution of the fleet itself, so that personnel numbers and skills are balanced to reflect short-term and long-term needs.

In thinking through how all-UAV carriers and ship-sized USVs could be incorporated into the fleet, it is valuable to review past naval transitions, notably the many changes that occurred from the mid-19th century to the mid-20th century. In the 1830s, the U.S. Navy consisted of wooden sailing ships that fired solid cannonballs, monitored the situation with telescopes, and communicated via signal flags. By the 1950s, the U.S. Navy's metal ships were powered by oil, with nuclear power rapidly emerging for select vessels. Aviation and the use of submarines expanded naval warfare into three dimensions. The U.S. Navy's platforms used radar and sonar, as well as electronic communications, to gain situational awareness and coordinate their actions as they fired explosive weapons.

Given the rapidity of technological change, there were advantages in acquiring ships gradually over this extended period. Buying multiple ships at an early stage risked

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acquisition of a large fleet that would rapidly become obsolete. On the other hand, because the timing of future wars was unknown, delaying acquisition until key technology matured carried its own risks of going to war with an outdated fleet. In his book *Sea Power in the Machine Age*, Bernard Brodie described how the Royal Navy responded to several war scares in the mid-19th century by rushing to buy steam-powered vessels to replace sailing ones, although the technology had not yet matured.[26] The result was that the Royal Navy soon found itself with a steam-powered fleet that was at the cutting edge initially but soon lapsed into relative obsolescence. Rapidly building that fleet also resulted in high costs relative to capabilities. More recently, during World War II, the United States was able to build thousands of new ships and aircraft incorporating the latest technology. However, this was possible only because roughly half of the nation's output went to the military during that war, and most of those assets were rapidly decommissioned after the war, given an inability to permanently maintain or crew them.

The emergence of steam power also illustrates how delaying mass acquisition is prudent because compatibility issues arise during the initial integration of new technology, and incongruencies need to be ironed out: It is difficult to predict the consequences of new designs and avoid major revisions. When steam power was first being adopted, both converted sailing ships and purpose-built steamships rode too low in the water, requiring further modifications.[27] Steam power also imposed additional demands that took many years to address. Training, maintenance, and logistics had to be revamped, and a network of coaling stations developed. Decades later, similar service changes were needed for the transition to oil as a fuel source.

Another factor shaping ship design is the capabilities of adversaries armed with similar emerging technologies. At the turn of the 20th century, increasing firepower rendered unarmored ships obsolete, and navies sought to defend their fleets by adding armor. However, thick topside armor affected ships' balance, necessitating further design changes.[28]

The development of aircraft carriers during the 1920s and 1930s also provides corroborating insights. Some aspects of the ultimate design of aircraft carriers were not anticipated at the beginning of the process, as is described in a book called *American and British Aircraft Carrier Development, 1919–1941*.[29] Increasingly powerful, long-range, fuel-intensive aircraft imposed growing fuel demands on carriers over the period. In addition, before the advent of radar that could warn of imminent attack, the urgency of launching numerous planes within a short period was not recognized. Instead, decks were heavily armored for protection, imposing top-heavy weight and thereby constraining other aspects of design. The United Kingdom's rapid development of carriers early during the interwar years made its fleet the most advanced in the world once more, but it also rapidly became obsolete. In addition to the issues mentioned above, the Royal Navy found that the size of its aircraft was limited by the dimensions of its carrier elevators and that its fuel storage was inadequate.

By waiting for technologies to mature, a fleet can expand its refined assets and avoid overstocking on premature versions. The U.S. Navy was slower to procure aircraft carriers than its British counterpart, which was at the vanguard of carrier development in the early 1920s.[30] Meanwhile, the United States experimented with different systems early on and only later found that carriers of any size would have extensive requirements—such as robust flight decks, elevators, and ample fuel storage—to support the increasingly heavy and powerful aircraft. The U.S. Navy also observed the nonlinear relationship between aircraft carrier size and capacity, so it focused on developing larger, more cost-effective ships.[31] Although the U.S. Navy later successfully implemented new technologies in short periods—notably through the introduction of nuclear-powered submarines in the 1950s—that was a product of a unique level of institutional focus and of military and civilian nuclear technological development over the preceding decade.

Moving toward the modern era, 21st-century issues with *Zumwalt*-class destroyers and the littoral combat ship (LCS) also remind us of the need for limiting the number of technological innovations introduced in any given platform. Both the *Zumwalt* class and the LCS programs were widely presented as providing lightly crewed ships that would host emerging technologies, with the LCS described as having the ability to rapidly shift among missions and to serve as a low-cost platform.[32] There were many contributing factors to the failures of these programs, but a key assumption was that the simultaneous addition of numerous untested technologies would smoothly supplant existing capabilities. Various issues in the development of these nascent technologies protracted acquisition timelines, further increasing costs. The experience of these programs represents a reminder of the need to introduce new technologies gradually rather than attempting to compress many of them into a new platform.

The development of the previously mentioned MQ-25A Stingray, a carrier-based UAV for air-to-air refueling, also provides ideas for how future large uncrewed vehicles can be integrated into the fleet. To help prepare both sailors and the U.S. Navy for the Stingray's arrival, the U.S. Navy created the Unmanned Carrier-Launched Multi-Role Squadron 10 (VUQ-10) as the Fleet Replacement Squadron in 2022. VUQ-10's mission is to train and equip personnel to handle the Stingray while also developing testing, maintenance, and operational procedures for it. Developing similar squadrons for other carrier-launched UAVs and large USVs could help to achieve the same for them.[33]

The Stingray also serves as a reminder of the slow pace of U.S. Department of Defense acquisition for all systems, not just uncrewed ones, and the difficulty of hastening the acquisition process in its later stages. The U.S. Navy began developing a carrier-based UAV in 2006; that program was transformed into the Stingray a decade later.[34] The service issued a contract for such vehicles in 2018, with IOC planned for 2024. This timeline was not met, and the U.S. Navy has since indicated that IOC will occur in 2026.[35] However, the U.S. Department of Defense's Office of Inspector General reported in November 2023 that efforts to rush the Stingray program have resulted in U.S. Navy plans to begin initial production before adequate testing and evaluation have been conducted. Its report stated that this "increases risk that the MQ-25 program will not meet operational capability requirements, delay deployment of the MQ-25A to the CVNs [nuclear-powered aircraft carriers], and increase program costs."[36] Trying to accelerate acquisition and overcome earlier delays by skipping key steps can lead to highly negative outcomes, for this and for other carrier-based UAVs or for ship-sized USVs.[37]

In this context, introducing all-UAV carriers and ship-sized USVs could begin with some limited-scale experimentation. For example, one or two amphibious ships might be employed as all-UAV carriers on a trial basis. Subsequently, on the basis of lessons from that experience, an all-UAV carrier might be designed to supplement existing aircraft carriers. For example, a carrier strike group could include an auxiliary all-UAV carrier alongside a traditional carrier, resulting in increased overall sortie rates. As the U.S. Navy comes to better understand how to design and use all-UAV carriers, they could someday operate alongside other ships without a traditional carrier. In time, one or more all-UAV carriers might be used as the centerpiece of a carrier strike group.

Along similar lines, the development of USVs hosting weapons, sensors, or fuel could also be a gradual process. Ships of increasing scale could be designed for that purpose and, after some experimentation, could be employed as part of a carrier or amphibious strike group. At least initially, the purpose would be to bolster the capabilities of that strike group rather than to supplant any of its existing ships. Over a series of decades, given advances in the use of technologies and confidence in them both advanced, multiple USVs could potentially replace individual ships within a given strike group.

Key Findings

Several key points emerge from the preceding analysis:

- Over the next half century, specific naval conflicts are unpredictable, but three broad missions will endure. The U.S. Navy may be confronted with a variety of inherently unpredictable threats and conflicts. However, it should be prepared and flexible enough to continue fulfilling the U.S. Navy's three fundamental missions: secure civilian and military use of the sea and the airspace above, conduct operations against land targets and the airspace above while countering adversaries' ability to do so, and deter conflict by demonstrating the ability and will to perform the first two items.
- The U.S. Navy can consider the long-term use of all-UAV carriers and ship-sized USVs to help reshape the fleet. UAVs and USVs can have greater payloads per unit size than their crewed counterparts and can be designed without the constraints that human occupants impose. UAVs and USVs can also be used in ways that embrace greater risk tolerance and without endurance limitations imposed by their crews. Crewed all-UAV carriers can be redesigned in multiple ways, including reductions in runway length (if novel materials with strong tensile strengths are employed for launch and recovery); they might have features in common with today's amphibious ships. USVs similar in size to corvettes or frigates—and perhaps larger—could host weapons, sensors, or fuel supplies while serving as integral parts of strike groups. If cost and personnel savings can be achieved using crewed all-UAV carriers and ship-sized USVs (relative to existing systems), they can potentially be numerous, with multiple such vessels per strike group.
- A gradual transition is needed. Introduction of all-UAV carriers and ship-sized USVs needs to be a gradual process whereby these systems are introduced and experimented with, allowing time for

both their design and usage to be refined. Unless the U.S. Navy has sufficient resources to quickly acquire these new ships (with or without decommissioning older ones early), the long lifespans of ships will slow any transition. However, a long-term, iterative process can enable efficient acquisition as the U.S. Navy learns how best to use these systems or decides to pursue alternative approaches that better align emerging technological capabilities with its needs.

Notes

1 Vandenengel, *Questioning the Carrier*.

2 Brodie, *Sea Power in the Machine Age*; Castex, *Strategic Theories*; Corbett, *Some Principles of Maritime Strategy*; Hughes and Girrier, *Fleet Tactics and Naval Operations*; Mahan, *The Influence of Sea Power upon History*; Mahan, *Mahan on Naval Strategy*; Armstrong, *21st Century Sims*.

3 Corbett, *Some Principles of Maritime Strategy*.

4 Nott, *The United Kingdom Defence Programme*.

5 Dobbs, "U.S. Had Key Role in Iraq Buildup."

6 Chief of Naval Operations, *The United States Navy in "Desert Shield"/"Desert Storm."*

7 Miller, "Bush on Nation Building and Afghanistan."

8 Beckerman, "The Middle East Region Is Quieter Today Than It Has Been in Two Decades."

9 Metcalf, "Revolution at Sea."

10 Congressional Budget Office, *Usage Patterns and Costs of Unmanned Aerial Systems*. We were unable to find comparable comparisons for USVs and crewed vessels, reflecting the fact that USVs are a much less mature technology than UAVs.

11 Rowden, Gumataotao, and Fanta, "'Distributed Lethality.'"

12 See Blakeslee et al., *Age and Sex Composition*. The U.S. Department of Defense is one of many military forces facing such a challenge; U.S. allies in Europe and East Asia have still lower birth rates. Similarly, China has managed to build the world's largest navy but does not have adequate numbers of sailors to serve in it; China's official military newspaper describes new ships as "equipment awaiting talent." See "China Is Struggling to Recruit Enough Highly Skilled Troops."

13 See Sisk, "The Military Recruiting Outlook Is Grim Indeed."

14 Savitz et al., *U.S. Navy Employment Options for Unmanned Surface Vehicles (USVs)*.

15 Moravec, *Mind Children*.

16 Hao, "How We Might Protect Ourselves from Malicious AI."

17 Lagrone, "Updated: Chinese Seize U.S. Navy Unmanned Vehicle."

18 Office of Inspector General, *Audit of the Navy's Management of the MQ-25 Stingray Program*; Tegler, "Despite Delays, Navy to Accelerate Delivery of Unmanned Tanker"; Naval Air Systems Command, "Unmanned Carrier Aviation"; Lagrone, "Navy Picks Boeing to Build MQ-25A Stingray Carrier-Based Drone."

19 Vandenengel, *Questioning the Carrier*.

20 "US Navy Could Control Arsenal Ship by AWACS."

21 Rowden, Gumataotao, and Fanta, "'Distributed Lethality.'"

22 Armstrong, Sotala, and Ó hÉigeartaigh, "The Errors, Insights, and Lessons of Famous AI Predictions—and What They Mean for the Future; Armstrong and Solata, "How We're Predicting AI—or Failing To."

23 Naval History and Heritage Command, "Missouri III (BB-63)."

24 Naval History and Heritage Command, "Enterprise (CVN-65)"; Naval History and Heritage Command, "Enterprise VIII (CVAN-65)."

25 Doehring, "USS Enterprise (CVN 65)"; McNeil, "US Navy Steps Towards Deactivating Oldest Active Aircraft Carrier."

26 Brodie, *Sea Power in the Machine Age*, pp. 43, 57.

27 Schank et al., *Designing Adaptable Ships*.

28 Brodie, *Sea Power in the Machine Age*, pp. 213–215, 223, 235, 252.

[29] Hone, Friedman, and Mandeles, *American and British Aircraft Carrier Development, 1919–1941*, pp. 82, 89–90, 93–94, 110, 153, 163, 167, 179, 194–195, 199.

[30] Hone, Friedman, and Mandeles, *American and British Aircraft Carrier Development, 1919–1941.*

[31] Hone, Friedman, and Mandeles, *American and British Aircraft Carrier Development, 1919–1941*, pp. 80, 82, 136, 194–195.

[32] Kass, "Zumwalt-Class"; Ong, "U.S. Navy's Zumwalt-Class Destroyers Enter the 2020s"; Polmar, "U.S. Navy—The LCS Games Continue"; Hamilton and Loren, "It's All in the Family."

[33] U.S. Navy, "Unmanned Carrier-Launched Multi-Role Squadron 10."

[34] Lagrone, "Pentagon to Navy."

[35] Lagrone, "MQ-25A Stingray IOC Pushed to 2026 Following Manufacturing Delays."

[36] Office of Inspector General, *Audit of the Navy's Management of the MQ-25 Stingray Program*, p. 28.

[37] Office of Inspector General, *Audit of the Navy's Management of the MQ-25 Stingray Program*; Tegler, "Despite Delays, Navy to Accelerate Delivery of Unmanned Tanker"; Naval Air Systems Command, "Unmanned Carrier Aviation"; Lagrone, "Navy Picks Boeing to Build MQ-25A Stingray Carrier-Based Drone."

References

Armstrong, Benjamin F., *21st Century Sims: Innovation, Education, and Leadership for the Modern Era*, Naval Institute Press, 2015.

Armstrong, Stuart, and Kaj Sotala, "How We're Predicting AI—or Failing To," in Jan Romportl, Eva Zackova, and Jozef Kelemen, eds., *Beyond Artificial Intelligence: The Disappearing Human-Machine Divide*, 2015.

Armstrong, Stuart, Kaj Sotala, and Seán S. Ó hÉigeartaigh, "The Errors, Insights, and Lessons of Famous AI Predictions—and What They Mean for the Future," *Journal of Experimental and Theoretical Artificial Intelligence*, Vol. 26, No. 3, 2014.

Beckerman, Gal, "'The Middle East Region Is Quieter Today Than It Has Been in Two Decades,'" *The Atlantic*, October 7, 2023.

Blakeslee, Laura, Zoe Caplan, Julia A. Meyer, Megan A. Rabe, and Andrew W. Roberts, *Age and Sex Composition: 2020*, U.S. Department of Commerce, C2020BR-06, 2020.

Brodie, Bernard, *Sea Power in the Machine Age: Major Naval Inventions and Their Consequences on International Politics, 1814–1940*, Princeton University Press, 1941.

Castex, Raoul, *Strategic Theories*, Naval Institute Press, 2017.

Chief of Naval Operations, *The United States Navy in "Desert Shield"/"Desert Storm,"* Naval History and Heritage Command, Ser OO/lU500179, May 15, 1991.

"China Is Struggling to Recruit Enough Highly Skilled Troops: The PLA Needs Them to Operate All Its New Weapons," *The Economist*, November 6, 2023.

Congressional Budget Office, *Usage Patterns and Costs of Unmanned Aerial Systems*, June 2021.

Corbett, Julian S., *Some Principles of Maritime Strategy*, Naval Institute Press, 1988.

Dobbs, Michael, "U.S. Had Key Role in Iraq Buildup: Trade in Chemical Arms Allowed Despite Their Use on Iranians, Kurds," *Washington Post*, December 30, 2002.

Doehring, Thoralf, "USS Enterprise (CVN 65)," webpage, last updated July 19, 2024. As of August 27, 2024: https://www.navsource.org/archives/02/65b.htm

Hamilton, Charles, and Donald Loren, "It's All in the Family," *Proceedings*, U.S. Naval Institute, Vol. 128/8/1,194, August 2002.

Hao, Karen, "How We Might Protect Ourselves from Malicious AI," *MIT Technology Review*, May 19, 2019.

Hone, Thomas C., Norman Friedman, and Mark A. Mandeles, *American and British Aircraft Carrier Development, 1919–1941*, Naval Institute Press, 1999.

Hughes, Wayne P., Jr., and Robert P. Girrier, *Fleet Tactics and Naval Operations*, 3rd ed., Naval Institute Press, 2018.

Kass, Harrison, "Zumwalt-Class: Don't You Dare Call These Stealth Destroyers a 'Battleship,'" *National Interest* blog, September 27, 2024.

Lagrone, Sam, "Pentagon to Navy: Convert UCLASS Program Into Unmanned Aerial Tanker, Accelerate F-35 Development, Buy More Super Hornets," USNI News, February 9, 2016.

Lagrone, Sam, "Updated: Chinese Seize U.S. Navy Unmanned Vehicle," *USNI News*, December 16, 2016.

Lagrone, Sam, “Navy Picks Boeing to Build MQ-25A Stingray Carrier-Based Drone,” *USNI News*, August 30, 2018.

Lagrone, Sam, “MQ-25A Stingray IOC Pushed to 2026 Following Manufacturing Delays,” *USNI News*, Aril 4, 2023.

Mahan, Alfred Thayer, *The Influence of Sea Power upon History*, 12th ed., Little, Brown and Company, 1918.

Mahan, Alfred Thayer, *Mahan on Naval Strategy: Selections from the Writings of Rear Admiral Alfred Thayer Mahan*, Naval Institute Press, 2015.

McNeil, Harry, “US Navy Steps Towards Deactivating Oldest Active Aircraft Carrier,” Naval Technology, August 1, 2024.

Metcalf, Joseph, III, “Revolution at Sea,” *Proceedings*, U.S. Naval Institute, Vol. 114/1/1,019, January 1988. As of August 27, 2024: https://www.usni.org/magazines/proceedings/1988/january/revolution-sea

Miller, Paul D., “Bush on Nation Building and Afghanistan,” *Foreign Policy*, November 17, 2010.

Moravec, Hans, *Mind Children: The Future of Robot and Human Intelligence*, Harvard University Press, 1990.

Naval Air Systems Command, “Unmanned Carrier Aviation,” webpage, U.S. Department of Defense, undated. As of September 9, 2024: https://www.navair.navy.mil/product/Unmanned-Carrier-Aviation

Naval History and Heritage Command, “Enterprise VIII (CVAN-65),” webpage, July 8, 2015.

Naval History and Heritage Command, “Missouri III (BB-63): 1944–1995,” webpage, U.S. Navy, June 24, 2019. As of August 27, 2024: https://www.history.navy.mil/research/histories/ship-histories/danfs/m/missouri-iii.html

Naval History and Heritage Command, “Enterprise (CVN-65),” webpage, June 20, 2024. As of November 11, 2024: https://www.history.navy.mil/browse-by-topic/ships/aircraft-carriers/enterprise.html

Nott, John, *The United Kingdom Defence Programme: The Way Forward*, Her Majesty’s Stationery Office, 1981.

Office of Inspector General, *Audit of the Navy’s Management of the MQ-25 Stingray Program*, U.S. Department of Defense, DODIG-2024-026, 2023.

Ong, Peter, “U.S. Navy’s Zumwalt-Class Destroyers Enter the 2020s,” *Naval News*, August 17, 2020.

Polmar, Norman, “U.S. Navy—The LCS Games Continue,” *Proceedings*, U.S. Naval Institute, Vol. 139/8/1,326, August 2013.

Rowden, Thomas, Peter Gumataotao, and Peter Fanta, “‘Distributed Lethality,’” *Proceedings*, U.S. Naval Institute, Vol. 141/1/1,343, January 2015. As of August 27, 2024: https://www.usni.org/magazines/proceedings/2015/january/distributed-lethality

Savitz, Scott, Irv Blickstein, Peter Buryk, Robert W. Button, Paul DeLuca, James Dryden, Jason Mastbaum, Jan Osburg, Phillip Padilla, Amy Potter, Carter C. Price, Lloyd Thrall, Susan K. Woodward, Roland J. Yardley, and John Yurchak, *U.S. Navy Employment Options for Unmanned Surface Vehicles (USVs)*, RAND Corporation, RR-348-NAVY, 2013. As of September 20, 2024: https://www.rand.org/pubs/research_reports/RR384.html

Schank, John F., Scott Savitz, Ken Munson, Brian Perkinson, James McGee, and Jerry M. Sollinger, *Designing Adaptable Ships: Modularity and Flexibility in Future Ship Designs*, RAND Corporation, RR-696-NAVY, 2016. As of September 20, 2024: https://www.rand.org/pubs/research_reports/RR696.html

Sisk, Richard, “The Military Recruiting Outlook Is Grim Indeed. Loss of Public Confidence, Political Attacks and the Economy Are All Taking a Toll,” Military.com, January 22, 2024.

Tegler, Jan, “Despite Delays, Navy to Accelerate Delivery of Unmanned Tanker,” *Navy News*, January 26, 2024.

U.S. Navy, “Unmanned Carrier-Launched Multi-Role Squadron 10: About Us,” webpage, undated. As of September 9, 2024: https://www.airpac.navy.mil/Organization/Unmanned-Carrier-Launched-Multi-Role-Squadron-10/About-Us/

“US Navy Could Control Arsenal Ship by AWACS,” *Jane’s Defence Weekly*, June 12, 1996.

Vandenengel, Jeff, *Questioning the Carrier: Opportunities in Fleet Design for the U.S. Navy*, Naval Institute Press, 2023.

About This Paper

This paper explores how emerging uncrewed vehicle capabilities could gradually shape the structure of the U.S. Navy's fleet from the 2020s through the 2070s. Our intent was to provide Navy personnel and external stakeholders with insights into how the U.S. Navy can evolve in ways that enhance its capabilities, capacity, and survivability.

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For more information on the RAND Navy and Marine Forces Program, see www.rand.org/nsrd/nmf or contact the director (contact information is provided on the webpage).

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