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Sharpening the Spear: The Carrier, the Joint Force, and High-End Conflict

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Policy Study

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I. ACKNOWLEDGEMENTS

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The views of this report are the authors' alone, along with any potential errors.

II. PREFACE

This study grew out of a January 2015 debate on the future of the large, nuclear-powered aircraft carrier. Sponsored by the Naval Academy Museum, two debaters took to the stage for ninety minutes before an audience of several hundred curious onlookers gathered at the U.S. Naval Academy's stately Mahan Hall, where they debated the topic and took questions from the audience.[1]

This unique forum raised interesting arguments on both sides of the issue, and there was a good deal of post-event consensus that the debate represented a healthy public airing of important positions worthy of deeper consideration. This study is an attempt at that deeper consideration.

In the pages that follow, this study addresses the question of whether it is worthwhile to continue to build large, nuclear-powered aircraft carriers (CVN), given their considerable cost and mounting Anti-Access/Area Denial (A2/AD) threats to sea-based operations. Our conclusion is that the emerging threat environment actually increases the need for aircraft carriers, and that none of the alternatives to the CVN offer an equal or better capability and capacity across the range of military options from peacetime presence through major power war.

We arrive at these conclusions first, by surveying the history of the carrier and its embarked air wing, a history marked by wide swings in public and defense elite opinions as to the utility of the carrier. We note the consistency of the criticisms against the carrier over time, and the operational imperatives that consistently overcame them. Next, we move to a discussion of the role of the Carrier Strike Group (CSG) in the Joint Force, which evaluates how CSGs support U.S. strategy and assesses how CSGs might be employed in key scenarios. To close this section, we perform a detailed effects chain analysis designed to examine the capabilities and vulnerabilities of the CSG.

These vulnerabilities track closely with many of the criticisms levied against the CVN, and serve as the basis for a series of recommendations on how to improve the CSG as a system to mitigate the mounting risks while ensuring CSG support for future warfighting needs.

The study concludes with an analysis of some of the alternatives to the CVN and an assessment of the number of carriers necessary to support national strategy.

[1] Study co-author Bryan McGrath took the pro-carrier position, and Dr. Jerry Hendrix of the Center for a New American Security argued against. The report's cover image of an artist's concept of CVN 78 is drawn from the U.S. Navy (050708-D-8455H-001).

III. EXECUTIVE SUMMARY

Key Study Conclusions

This study advances three key conclusions:

- The Joint Force requires sea-based air power to conduct strike, air warfare, and surveillance. Sea-based air power provides classic naval functions (sea control and power projection) and serves as a key enabler of other Joint Force components necessary for victory in high-end conflict. This demand is growing.
- The Carrier Strike Group (CSG), with the large, nuclear-powered aircraft carrier (CVN) at its core, remains the most effective and efficient means of providing these capabilities across the range of military options.
- In order to provide these required capabilities, the Navy must pursue a series of conceptual, capability, and capacity improvements to the CVN, the Carrier Air Wing (CVW), and the CSG.

BACKGROUND

The nation continues to require the power and flexibility of highly mobile, sea-based air power. Sea-based air power, provided by the large-deck aircraft carrier, plays a crucial role in establishing superiority over portions of the ocean in order to use that control to execute other operational tasks, or to deny the use of that sea-space to an adversary. The carrier provides critical strike, air warfare, and surveillance capabilities that other elements of the Joint Force would face difficulty providing—especially against a peer or near-peer threat.

The encompassing CSG combat system of mutually supporting carriers, aircraft, surface combatants, submarines, and logistics ships contributes a unique combination of organic mobility, endurance, and versatility to a Combatant Commander and the nation. Modern threats are evolving that jeopardize

the effectiveness of this combat system in the most demanding wartime scenarios, which in turn impacts the effectiveness of the Joint Force. This report details how the Navy and the nation can respond to those threats.

The CSG plays a key role in providing presence, deterrence, and warfighting capabilities where the nation's interests lie. Since the 1930s, the CSG has been an effective mechanism for both power projection and sea control, and the CSG has participated in nearly all types of naval operations. Recently, the CSG's power, flexibility, and utility have been on display in operations in Afghanistan, Iraq, and Syria. This report concludes that the current demand will increase as Anti-Access/Area Denial (A2/AD) threats and sea control threats increase. However, serious concerns regarding the wisdom of procuring additional large, nuclear-powered aircraft carriers have been raised. Many of these concerns mirror similar concerns raised immediately after World War II, before the Vietnam War, and in the 1970s. In general these concerns center on the ship's cost and operational vulnerability.

Even though all of the components of the Joint Force face increased risk in the evolving threat environment, the aircraft carrier is examined especially closely, due largely to its cost and doubts about its effectiveness in high-end conflict. At an acquisition cost of approximately $12.9 billion, including its design cost, USS *Gerald R. Ford* (CVN 78), the first ship of its class, will cost nearly 18% more in constant year dollars than the cost of the final *Nimitz* Class ship, the USS *George H.W. Bush* (CVN 77).[2] However, this unit cost does not capture the capability improvements and significant cost saving aspects of its design. Due to reduced operations, maintenance and personnel costs, the *Ford* Class's total lifecycle cost is projected to be $4 billion less than the *Nimitz* Class per ship. Despite that economic value, the initial acquisition cost leads some to question the ship's return on investment. Such criticism overlooks questionable executive decisions made by the Office of the Secretary of Defense that influenced costs and performance. In particular in 2002, Secretary of Defense Donald Rumsfeld directed the Navy to incorporate all envisioned technologies and ship feature enhancements originally planned for integration over three ships into a single ship (CVN 78), which inserted considerable cost and schedule risk to the program in its infancy.[3] Although the subsequent *John F. Kennedy* (CVN 79) is

[2] "Aircraft Carrier Construction: *John F Kennedy* (CVN 79)," Report to Congress, Department of Defense, March 2013, 17.

[3] A thorough summary of CVN 78 Class cost issues, including authoritative criticisms and Navy and shipbuilder responses thereto, is available in the Congressional Research Service Report RS20643 of 12 June 2015 "Navy Ford (CVN-78) Class Aircraft Carrier Program: Background and Issues for Congress" by Ronald O'Rourke.

expected to cost less than $11.5 billion in constant year dollars, iteratively reducing cost through effective program management must continue to be a priority for the Navy.[4]

Second, critics of the CVN point to the opportunity cost of spending so much money on a single ship, claiming that there are not only more efficient and economical methods of spending that money, but that doing so would be operationally effective across the entire fleet architecture. Although improving the performance of other elements of the Joint Force should be vigorously pursued, this analysis suggests existing and future requirements will demand a significant capacity of survivable naval aviation, and large-deck aircraft carriers provide the most efficient means of supplying it. As the capability of non-carrier components of the Joint Force changes and as threats evolve, periodic examination of the role and number of carriers in U.S. fleet design should take place. Existing analysis suggests an enduring requirement for carrier-provided aviation.

Finally, there are those who believe that the very cost of the CVN (and the number of sailors required to operate it and its air wing) will create in the minds of senior decision-makers the likelihood that such an investment of dollars and people is simply too valuable to risk in combat.[5] Although the loss of a CVN would be a significant blow to the United States in conflict, war against a peer or near-peer threat like China would likely involve the loss of numerous units and thousands of military personnel. Throughout history, the United States has employed military force despite significant risks and military losses to achieve its national interests. Given its significant military history over the past few decades, using capital intensive assets in missions both large and small, there is little reason to think that future decision-makers will become more risk averse.

Independent of cost considerations, concerns regarding the operational vulnerability of the carrier are mounting. As adversaries continue to advance the capability to target and attack the aircraft carrier and other surface forces at greater ranges, the current historically modest range of the carrier's striking force places it well-within the effective range of these modern A2/AD weapons and sensors. If then, the carrier is out-ranged by adversary systems, the risks of employing its air wing may outweigh the benefits conferred by its capabilities, and the wisdom of continuing to acquire them may be dubious.

The CSG faces major constraints and vulnerabilities that reduce its campaign utility

[4] "Aircraft Carrier Construction: *John F Kennedy* (CVN 79)," Report to Congress, Department of Defense, March 2013, 17.
[5] Jerry Hendrix. "The U.S. Navy Needs to Radically Reassess How It Projects Power," *National Review*, April 23, 2015.

to the Joint Force in high-threat scenarios. Although this analysis identifies a number of carrier weaknesses and vulnerabilities, many of these same weaknesses and vulnerabilities apply to other elements of the Joint Force—especially land-based systems. Nonetheless, assessment of current and projected scenarios portend a growing demand for the sea-based aviation that carriers provide.

In order to ensure the Joint Force is prepared to deter and defeat aggression, major changes to the CSG are needed. The Navy must develop new concepts and capabilities for the employment of CSGs in a systemic manner, and this study makes recommendations as to how to improve the elements of that system to face current and future challenges.[6]

EMPLOYMENT CONCEPTS

The Navy needs to examine new operational concepts for the employment of the carrier as part of a system. New operational concepts will allow the Navy and Joint Force to more effectively use existing systems and to develop new capabilities to meet emerging threats.

- **Power Pulse:** The Navy should adopt new operational concepts for CSGs that seek to pulse combat power, instead of providing steady-state support.
- **Integrated Multi-CSG Operations:** The Navy should develop doctrine, and exercise as possible, the capability to conduct fully integrated multiple carrier CSG operations that maximize the full potential of carrier airpower, rather than conducting single or aggregated CSG operations.
- **Renew CSG Emphasis on Sea Control:** Although not an operational concept, the Navy should critically examine the burgeoning future requirements for sea control and adequately adjust its programmatic portfolio to meet those threats.
- **Develop Single Naval Battle:** Consistent with the aims of Single Naval Battle, Navy/Marine Corps integration to achieve operational objectives should improve, especially the employment of Marine Corps aviation and amphibious forces to address sea control requirements.
- **Distributed Basing Dynamics:** The Navy, along with the other services, should develop the capability to operate from fixed and mobile advanced and intermediate staging bases.

[6] Some of these efforts must be to restore proficiencies in capabilities and concepts that have atrophied since the end of the Cold War, while other efforts must be to develop new capabilities and concepts necessary to counter new threats.

- **Air Force-Navy Theater Strike:** The Air Force and the Navy should continue to develop concepts and capabilities for using complementary capabilities (such as pairing Air Force bombers with Navy carrier fighter wings) to conduct integrated operations, including strike, against mature A2/AD threats.

CAPABILITY IMPROVEMENTS

To fully address emerging gaps in high-end conflict, the development of new concepts must be complemented by the development of new capabilities. These capabilities can be categorized as improvements to the carrier itself, carrier air wing, other ships in a CSG, and carrier infrastructure and supplies.

- **The Aircraft Carrier:** As technology (such as friendly and enemy weapons and aircraft planform design changes), concepts, and requirements change, the role of carriers and the appropriate design should be periodically examined. In the near term, the ability of CSGs to operate with extensive Emissions Controls (EMCON) should improve. Additionally, improvements to the carrier's passive and active systems and measures that frustrate detection and provide protection should continue, these include decoys, jammers, the Surface Ship Torpedo Defense (SSTD) program, and potentially lasers and high-powered microwaves. Lastly, improving the recoverability (operating in a degraded condition) of a carrier in spite of damage to its flight decks or damage associated with electronic warfare should improve.
- **Carrier Air Wing:** The Navy should address the existing and projected capability gaps in the carrier air wing. In general, this requires the Navy to increase air wing striking range, develop sea control aircraft, and develop new weapons. Lastly, the Department of Defense (DoD) and Congress should critically evaluate the naval aviation portfolio, including potential portfolio trades between land-based, permissive environment aircraft and sea-based, contested environment aircraft.
- **Other Ships in the CSG:** Significant weaknesses in the combat and logistical capability of cruisers, destroyers, and the Combat Logistics Force (CLF) should be addressed. The organic ISR ability of surface combatants should improve. Additionally, the Navy should rapidly develop, test, and deploy a Vertical Launch System (VLS) reload capability. The current CLF is too small and vulnerable for contested operations in the vast Pacific. The Navy needs additional, more resilient, and potentially differently designed CLF and supporting logistics ships and infrastructure.

- **Industrial Infrastructure and Suppliers:** The Navy should carefully examine the industrial base involved in the construction of carriers, their accompanying ships, and aircraft. Moreover, the Navy should improve efforts to protect key component fabrication and shipyard centers during heightened states of tension or conflict.

In summary, this analysis validates the ongoing Joint Force requirement for naval aviation provided by aircraft carriers, and concludes that the large-deck, nuclear powered carrier is the most combat effective and cost-efficient means of providing it. Implementing the aforementioned recommendations will be necessary to improve the combat potential of CSGs and the entire Joint Force in view of mounting threats designed to undercut the effectiveness of the CSG. Some of these changes will be disruptive to existing plans, programs, and paradigms; however, the alternative is a rapidly weakening force that incurs greater operational risk not only for itself but also for other components of the Joint Force. Only by altering course can the Navy ensure that the CSG's contribution to the Joint Force remains relevant to the nation's needs and future warfighting requirements.

IV. THE EVOLUTION OF THE AIRCRAFT CARRIER: HISTORY AND CONTROVERSY

Naval aviation has dominated maritime military operations since the beginning of World War II. Despite its effectiveness in crises as a combatant and deterrent, a series of similar arguments against the Navy's air arm as a whole and carrier aviation in particular, occur throughout the aircraft carrier's existence.

The debate over the aircraft carrier can be divided into the "pre-carrier operations" and the "carrier operations" periods. The pre-carrier operations period began in 1918, with the deployment of the HMS *Argus*, the world's first full-length flight deck aircraft. This period lasted until 1941, when carriers came into widespread service in the Pacific theater of the World War II. Before 1941, criticisms of the carrier remained theoretical, since naval aviation was a largely unproven weapon.[7]

In 1941, the "carrier operations" period began, with both the United States Navy and Imperial Japanese Navy's reliance on aircraft carriers as capital ships. In the "carrier" period, debates over the platform's utility fall into the "strategic and hydrogen bomb" challenge (1942-1965), "early anti-access" (1965-1980), and "modern" categories. These debates show that challenges to the carrier have largely maintained common fundamental characteristics since 1941.

The United Kingdom produced the first aircraft carrier in 1918 constructing the HMS *Argus'* flight deck atop an ocean liner's hull.[8] Other powers followed suit, creating their own naval aviation platforms. The United States converted the USS *Jupiter*, a collier, into its first flattop, the USS *Langley*, in 1922. The United States commissioned its first two combat aircraft carriers, the USS *Lexington* and USS *Saratoga*, in 1927.

[7] Of note, on November 11, 1940 Royal Navy torpedo bombers launched from an aircraft carrier successfully struck Italian naval forces at harbor in Taranto.
[8] "HMS *Argus* I49," *Military Factory*, http://www.militaryfactory.com/ships/detail.asp?ship_id=HMS-Argus-I49, last updated July 28, 2014.

The first carrier debate, between 1920 and 1941, centered on the theory of air power, and how it applied to sea combat. Although the aircraft had proven itself an effective, multi-role combat platform during World War I, naval aviation played almost no part in this conflict. Strategic planners remained disposed towards land-based aircraft. The Washington Naval Treaty of 1922 limited the number of battlecruisers, battleships, and aircraft carriers that party nations could construct, thus making the debate over carrier efficacy even more theoretical due to restricted experimental platforms.[9]

Most naval theorists and commanders supported naval aviation, but the debate centered on the role of the new instrument. Battleship proponents saw aircraft as primarily scouting and spotting tools. They acknowledged the necessity of aircraft in the contemporary battlespace, but believed that the defensive power of the battleship would protect it against most aerial attacks. The airplane did not render the battleship obsolete, they argued, just as the torpedo boat and submarine did not render it obsolete.[10] In their fleet model, naval aircraft would be mounted on fast, well-armed scout cruisers. Cruiser scout planes would act as spotters for the big guns of the fleet's battleships. Aircraft carriers, due to their slower speed and lack of armament and armor, would never be able to deploy aircraft as effectively as scout cruisers. The short range of aircraft also rendered them useless for striking enemy targets, since the battleship would theoretically be able to close the distance between itself and the carrier and sink the unarmed flat top. Air power proponents in this camp believed that the future of aviation was land-based, since larger aircraft with better strike ranges could only be launched from land installations.

Carrier proponents divided into two groups: offensive strike advocates and air control advocates. The former was limited by the above-mentioned naval treaties of the time and the range limits on naval aviation. Nevertheless, they argued that air power would allow for the most effective projection of offensive naval force. Those who held this opinion included the first advocates for the modern carrier strike group (CSG). The carrier, surrounded with support ships, could close the distance needed to deploy its aircraft, and remain safe from a surface-based response due to its escort forces.[11]

The more widely held, pro-carrier opinion (that of the "air control" advocates) recognized the contemporary limitations of carrier aircraft, the restrictions of the Washington Treaty, and

[9] FW Rockwell. "Developing the Aircraft Carrier," *Proceedings Magazine*, July 1922.
[10] Sidney Ballou. "Seagoing Aircraft," *Proceedings Magazine*, November 1924.
[11] GB Vroom. "Strategic Value of the Aircraft Carrier," *Proceedings Magazine*, January 1925 http://www.usni.org/magazines/proceedings/1925-01/strategic-value-aircraft-carrier

decreased U.S. military spending.[12] The air control proponents argued that, while the carrier was key to winning a naval engagement, it would not serve as the decisive offensive arm. Instead, aircraft would be used to secure the skies against an enemy fleet and to scout for surface combatants.

As the Washington Treaty unraveled, the United States and Japan increased their construction of aircraft carriers. In contrast, the United Kingdom, Germany, and Italy invested a higher proportion of their funding into surface combatants. The littoral nature of the European peninsula ensured that land bases could typically fill power projection needs during naval combat. Conversely, the vastness of the Pacific encouraged the United States and Japan to construct carrier fleets.[13] Nevertheless, most U.S. planners did not yet envision carriers as the striking arm of naval forces.

WORLD WAR II

Following the attack on Pearl Harbor in December 1941 and the United States' subsequent entry into World War II, air power came into its own. The European theater had already demonstrated the usefulness of air control to ground operations as well as the ability of modern aircraft to strike deep into enemy territory. Naval aviation, however, remained largely unexplored. The U.S. Navy relied on carriers even more, since the Japanese surprise attack had decimated the American battleship fleet. In the Pacific, U.S. carriers struck Tokyo in the Doolittle Raid of April 1942, stopped Japanese southward expansion in the Coral Sea in May 1942, and decisively defeated the Japanese Navy near Midway Island in June 1942.[14] Following these major engagements, carriers contributed to a gradual campaign of sea control and power projection across the South and Central Pacific that ejected Japan from its conquests and struck the Japanese homeland.[15] In the European theater, U.S. and British carriers conducted Surface Warfare missions against German and Italian capital ships, contributed to closing the mid-Atlantic air surveillance gap in the campaign against U-Boats, provided air cover for the invasion of North Africa, and defended the Mediterranean bastion of Malta. By the end of the war, the United States Navy had 97 aircraft carriers of various types in commission.[16] In these wartime engage-

[12] Sidney Ballou. "Seagoing Aircraft," *Proceedings Magazine*, November 1924, http://www.usni.org/magazines/proceedings/1924-11/seagoing-aircraft
[13] James E. Fechet. "The Need for Additional Aircraft Carriers," *Proceedings Magazine*, July 1932.
[14] Thomas Hone. "Replacing Battleships with Aircraft Carriers in the Pacific in World War II," *Naval War College Review*, Winter 2013, Vol. 66, No. 1, 56-76.
[15] Army Air Corps bombers provided the grand majority of strikes against the Japanese home islands.
[16] Norman Polmar. *Aircraft Carriers: A History of Carrier Aviation and its Influence on World Events, Volume II-1946-2006*, Washington, DC: Potomac Books, 2008, 2.

ments, power projection from the air, rather than simply air defense became a key aspect of strategic thinking. This paradigm shift signaled the beginning of the "modern" carrier debate. The "modern" debate can be divided into the three previously mentioned categories: "strategic and hydrogen bomb" challenge (1942-1965), "early anti-access" (1965-1980), and "modern" (1995-present).

The "strategic and hydrogen bomb" stage began in 1942, prior to the advent of nuclear arms. Its various iterations from 1942-1965 had the same theme: the debate between naval and ground-based aviation, itself an outgrowth of the forced evolution of airpower doctrine during WW II. The Army Air Corps had played a decisive role in terminating the war with the dropping of two atomic bombs on Japan, and many observers found little role for carriers in a world in which strategic nuclear bombers could swiftly and efficiently terminate conflicts. Additionally, the Army Air Corps, and subsequently the Air Force, viewed carrier strike forces as redundant to long-range, land-based bombers and a source of competition for funding.

The first anti-carrier, pro-land based aviation advocate was Russian emigrant, Major Alexander de Seversky, founder of the Republic Aviation Corporation, and one of the first pre-World War II airpower advocates.[17] His thesis, articulated in *Victory Through Air Power* (which Disney made into a movie in 1943, one year after its publication) was that victory over Germany and Japan required full air superiority, along with the ability to conduct long-range strikes into enemy territory.[18] De Seversky's theories, along with the work of others such as Giulio Douhet and Hugh Trenchard, became the basis for strategic bombing doctrine. He viewed naval aviation as vastly inferior to its ground-based counterpart because of the payload that large bombers like the B-17 and B-29 could carry. Long-range bombers and escorts could deliver large payloads to vulnerable enemy targets.[19] Conversely, carrier-based aircraft would be unable to deliver the same amount of firepower against a target without moving a carrier or fleet into a vulnerable position deep within hostile waters. With the advent of the atomic bomb, de Seversky argued that naval aircraft would never be able to carry a device so heavy and large.[20] De Seversky hypothesized that land-based aircraft would be able to outrange naval interceptors, leaving carriers vulnerable to large payload bombers and comparable pursuit aircraft launched from

[17] Stephen Sherman. "Alexander de Seversky," Acepilots.com, last updated 16 April 2012, http://acepilots.com/wwi/pio_seversky.html
[18] John A. Collet. "Aircraft Carriers, Dive Bomber, and Torpedo Planes," *Proceedings Magazine*, October 1942.
[19] Karl P. Mueller. "Air Power," Santa Monica: RAND Corporation, 2010, http://www.rand.org/content/dam/rand/pubs/reprints/2010/RAND_RP1412.pdf.
[20] TU Sisson. "In Any Operation," *Proceedings Magazine*, March 1955.

secure land bases. Writing in *Victory Through Air Power*, de Seversky's statement, "where a navy still operates essentially as in the past, it is for one of two reasons: one, because the action is in areas safely beyond the range of land-based aviation, or two, because the enemy's aviation is inadequate, inferior, or nonexistent."[21]

Naval aviation proponents identified the flaws in de Seversky's arguments. Fundamentally, de Seversky mischaracterized the nature and composition of the modern battle fleet. Although his points about air power were sound, he was unwilling to accept the innovations occurring in the combination of air and seapower. His primary critique of sea-power was its inability to deliver effective force, and the ability of land-based defenses to deny materially preponderant fleets' access to critical regions. This thesis, however, was constructed assuming the battleship to be the striking arm of the modern fleet.[22]

De Seversky's assumption regarding long-range bomber capabilities was proven fundamentally incorrect by combat experience. Heavy bombers were much more effective than smaller carrier-based bombers at attacking fixed land installations and large army groups.[23] Bombardiers enjoyed a 1,000+ yard bomb target radius, especially when bombing fixed targets. Naval aircraft could not carry the same payloads as these big bombers, and were therefore less effective at conducting large-scale aerial bombardments.

However, traditional bomber tactics were remarkably ineffective against naval forces. Even slow moving ships like escort carriers (carriers built on transformed merchant marine hulls) could evade major bombing runs from larger aircraft. In contrast, carrier aircraft proved an effective anti-ship system, in addition to providing carriers and fleet groups with an effective area defense capability to intercept attacking aircraft and a precise capability to strike land targets.

POST-WORLD WAR II AND KOREA

Strategic bombardment was the next development in the carrier debate. Relying on the same ideas that de Seversky espoused, proponents of this view (including de Seversky himself) argued that jet propulsion allowed land-based aircraft to outrange and outfly sea-launched aircraft. Strategic bombardment advocates argued that land aircraft would outperform naval platforms since weight limitations on World War II-era carriers limited the use of heavy jet aircraft. Jet-propelled aircraft had a longer range than

[21] Alexander de Seversky. "The Twilight of Sea Power," *Victory Through Air Power*, New York: Garden City Pub. Co., 1943, 154-155.
[22] De Seversky, 159-162.
[23] John A. Collet. "Aircraft Carriers, Dive Bomber, and Torpedo Planes," *Proceedings Magazine*, October 1942.

their propeller-driven counterparts, allowing land-based aircraft to threaten enemy carriers. Additionally, Air Force interceptors could fill all carrier aviation roles, making the flattop too vulnerable and costly.

In response, the Navy commenced a dedicated program to modernize existing carriers and develop a new carrier capable of handling current and future heavy aircraft, particularly carrier-launched nuclear bombers and jet-powered interceptors. In 1948 Congress approved funds for construction of the 65,000-ton aircraft carrier CVA 58, the USS *United States*. The subsequent Key West Agreement brokered by Secretary of Defense James Forestall with the Joint Chiefs affirmed the Air Force's lead role in strategic nuclear bombing, while allowing the Navy to execute nuclear attacks against targets of naval interest, such as submarine pens, shipyards, and naval airfields.[24]

However, the following year, the new Secretary of Defense Louis Johnson concluded the *United States* and her aircraft would be duplicative of the Air Force's strategic bombing mission. He cancelled construction of the *United States* and set a Fiscal Year 1951 carrier force level of four ships.[25] A so-called "Revolt of the Admirals" erupted in which Navy leadership questioned the wisdom of these cuts.[26] During this period, a series of House Armed Services Committee hearings analyzed the complementary nature of land and sea-based air power and led to congressional support for carrier aviation.

On 27 June 1950, in response to North Korea's invasion of South Korea, President Truman ordered naval and air forces to both defend South Korea and deter Communist/Nationalist conflict in Formosa. At the time, the Navy's carrier force was being drawn down to the levels proposed by Secretary of Defense Johnson. With only 15 aircraft carriers in service, *Valley Forge* was the only carrier in the Seventh Fleet.[27] *Valley Forge* and the British carrier *Triumph* formed as Allied Task Force 77 and provided the majority of allied airstrikes on the Korean Peninsula for nearly a month, as the U.S. Air Force worked to establish bases in Korea for tactical aircraft. The operational realities of the Korean War, along with misplaced assumptions regarding power projection, reinforced Congressional support for the aircraft carrier. During the Korean War, naval aviators struck deep into the Korean Peninsula, provided close air support, and engaged key targets, such as bridges and

[24] Polmar, 47-48.
[25] Matthew S. Muehlbauer and David J. Ulbrich. *Ways of War: American Military History from the Colonial Era to the 21st Century*, London: Routledge Press, 2013, 423.
[26] Jeffrey G. Barlow, *Revolt of the Admirals*, Washington Navy Yard: Naval Historical Center, 1994.
[27] Jerry Miller, *Nuclear Weapons and Aircraft Carriers*, Washington, DC, Smithsonian Institution Press, 2001, 182.

	Modified ESSEX	FORRESTAL	FORRESTAL Advantage
Ship Fuel (gallons)	1.5 million	2.5 million	67%
Aviation Fuel (gallons)	440,000	1.3 million	195%
Aviation Ordnance (tons)	650 tons	1,650 tons	154%

Figure 1: Improvement of the *Forrestal* Class over the Modified *Essex* Class [30]

mobile units, that high altitude bombers had difficulty attacking.[28]

Combat experience again disproved arguments against the aircraft carrier, and with the introduction of a new Secretary of Defense, George C. Marshall, a new class of large carriers similar to the cancelled *United States* was laid down in 1952. The *Forrestal* Class was the first U.S. "super carrier" and was specifically built to operate jet aircraft. Its larger and reinforced deck and faster speed enabled the launch and recovery of heavy jet aircraft with higher stall speeds. Studies demonstrated that as a result of her size and design features, the *Forrestal* could provide a stable base for air operations approximately 96 percent of the year in the challenging sea conditions of the Norwegian Sea and Taiwan Strait, compared to only 60 percent of the year on an *Essex* Class carrier.[29] The *Forrestal* also incorporated three new technologies: an angled flight deck, steam catapult, and an optical landing system. These innovations increased aircraft sortie rates and significantly increased operational safety.[30]

Not all in Congress were placated by the Korean War success of the carrier. In August 1958, six carriers of the Seventh Fleet patrolled the Formosa Strait and escorted Nationalist Chinese supply ships to and from Quemoy and Matsu, dissuading further Communist Chinese aggression in the area.[31] Nonetheless, the same year Representative Clarence Cannon, Chairman of the House Appropriations Committee, declared that the billions of dollars spent by the United States on aircraft carriers were utterly wasted, adding that the carrier-building program is "the most colossal national debacle in all military history."[32]

The advent of the hydrogen bomb presented a challenge not only to naval strategists and carrier supporters, but to all seapower

[28] Polmar, 54.
[29] Ibid, 137.
[30] Figure 1 data drawn from Polmar, 136.
[31] Shu Guang Zhang. *Deterrence and Strategic Culture: Chinese-American Confrontations, 1949-1958*, Ithaca: Cornell University Press, 1993, 249.
[32] Polmar, 153.

proponents. The advent of the H-bomb led to the third resurgence of the strategic bombardment argument against the carrier. H-bombs had a wide enough blast radius to destroy a carrier group—even if the bomb missed directly striking ships or if the carrier group was relatively dispersed.[33] Also, if the carrier could evade one H-bomb attack, a land-based enemy could field more bomber wings than a carrier could defend against.

Carrier advocates responded with several assertions. First, although the carrier was vulnerable to an H-bomb attack, ground targets were more vulnerable to an H-bomb response. No location is invulnerable, and very few targets can survive a direct nuclear hit.[34] Land forces are vulnerable to a wider variety of threats than all naval forces, but remain valuable.[35] Strategic planners must treat naval forces in the same manner.

Second, cost comparisons between long-range bombers and carrier groups are consistently misleading. Combat experience demonstrated that carrier aviators could execute a much wider variety of missions than high-altitude carpet bombers. Additionally, a suitable comparison between the carrier and equivalent land forces would include the cost of ground-based interceptors and attack aircraft, the extra land bases required to extend attack aircraft operational range, and protection for those bases.

Following the conclusion of the "strategic bombing" debate, in the mid-1960s, carrier detractors used arguments based on anti-access weapons and carrier platform limitations to criticize the flattop. Spatial restrictions became more apparent as jet aviation replaced the navy's propeller aircraft.[36] The mainstay of the United States fleet at the time, the *Essex* Class carrier, was designed for propeller aircraft service during the Second World War. Propeller aircraft required less fuel and mechanical assistance than jets, were smaller, and carried smaller weapons.[37] With larger aircraft, such as the F-8 Crusader and A-3 Skywarrior, shipboard space requirements increased further. The *Midway* Class experienced the same spatial problems as the *Essex* Class. Although larger platforms were designed to offer more storage space for U.S. aircraft, critics pointed out that expanding airframes forced the *Forrestal* Class supercarriers to sacrifice storage space for longer catapult launching systems, more fuel, and extra crew space for the growing size of air wings and necessary support

[33] LH Bibbly. "The Future of the Carrier?," *Proceedings Magazine*, August 1959.
[34] Laurence B. Green. "A Case for the Attack Carrier in the Missile Age," *Proceedings Magazine*, July 1958.
[35] Ibid.
[36] "Diminishing Returns in the CVA," *Proceedings Magazine*, August 1964.
[37] Ibid.

personnel.[38]

Concurrently, carrier detractors argued that missiles provided a low-cost alternative to the carrier. Having already made the argument against the carrier in nuclear war, they maintained that in limited war, cheap, anti-access systems could prevent a carrier from entering enemy waters. Fast attack submarines cost significantly less than the carrier, and in great enough numbers could overwhelm a carrier along with its escorts.[39] The closer the carrier approached the shore, the more difficult it would become to project power without being damaged. Critics maintained that for offensive operations, missiles could fill the carrier's role.[40] Missiles could cover greater ground than the carrier, and provided that scouting worked properly, could destroy high value targets like carriers with ease.[41] Thus, the carrier could be denied territory easily, while strategic bombers would carry out offensive strikes in both limited and unlimited conflicts. Combat experience again answered these arguments.

VIETNAM

In August 1963, Secretary of Defense Robert McNamara decided against nuclear propulsion for the already authorized CVA 67, estimating the cost of a nuclear-powered carrier as one-third more than a conventional ship.[42] Criticizing the decision, the Joint Congressional Committee on Atomic Energy countered that the total lifecycle cost of a nuclear-powered carrier was only 3 percent more than a conventional one and recommended the United States adopt nuclear propulsion in all future major surface warships.[43] Laid down 22 October 1964, CVA 67 named *John F. Kennedy* after the assassinated president would be the last conventionally-powered U.S. aircraft carrier.

In addition to a critical analysis of the higher costs of nuclear propulsion, Secretary McNamara's advisors contended that improvements in the range and performance of land-based aircraft made investments in land-based aviation preferable to carrier aviation. They accordingly recommended

[38] Ibid.
[39] Bibbly.
[40] Ibid.
[41] Laurence B. Green. "A Case for the Attack Carrier in the Missile Age," *Proceedings Magazine*, July 1958.
[42] The USS *Enterprise* (CVN 65) was the first nuclear-powered aircraft carrier.
[43] Nuclear Propulsion for Naval Surface Vessels: Hearings Before the Joint Committee on Atomic Energy, 88th Congress, First Session, Hearings from October 30-31 and November 13, 1963, Washington, DC: GPO, 1964, 244.

halting carrier construction, which would shrink the carrier fleet to nine ships by 1979.[44]

As with the Korean War, escalation of the Vietnam War led to a new perspective by the Secretary of Defense. Carrier aviation's availability and effectiveness played a key role during the conflict, especially during the early stages before tactical aviation bases on land were well-established. Carrier aircraft conducted strike, air warfare, and reconnaissance missions. Carrier-based F-4 Phantom's, F-8's, A-6's, and A-4's executed suppression of enemy air defenses (SEAD), strike, and intercept missions, and the F-8 had the best kill ratio of any American aircraft during the Vietnam War, 19:3 against enemy MiG-17 and MiG-21 interceptors. Carrier aircraft could also deliver timely on-target air support. Additionally, carrier EA-1F, EKA-3B, and EA-6A/B jamming aircraft played critical roles detecting and jamming enemy radars to support Navy strikes and assist Air Force B-52 bombers penetrating to their targets.[45]

Additionally, by the mid-1960s, strike and carrier-based fighters had ranges that equaled their land based counterparts, greatly increasing operational flexibility, and the introduction of the A-3 and A-5 allowed the carrier to fulfill strategic strike missions. The subsequent A-6 could deliver any weapon in the U.S. gravity-bomb nuclear arsenal, and gave the Navy its first truly all-weather, all condition attack aircraft.

Developments in aerial tactics allowed smaller, lighter aircraft to deliver large payloads against specific targets. By the end of the Vietnam War, the U.S. Navy had the ability to fulfill any combat mission that the USAF could, from pinpoint precision strikes to nuclear attack, with the Air Force retaining its superiority in carpet-bombing. Increased range and better performance, along with the full development of aerial refueling (first incorporated by the Navy in the 1950s), greatly extended the operational range of naval aviators, allowing them to strike land targets outside the range of shore based defenses. These developments made carriers more responsive to both Vietnam War requirements and high-end requirements for conflict against the Soviet Union.

The carrier also proved itself through its flexibility. In a hybrid conflict such as Vietnam, where the United States was faced with a conventional army and an insurgency, all ground installations were vulnerable to attack. Land forces, including land-based aircraft, needed hardened fire bases to project power. Carrier aviation, however, provided an increased measure of safety from Vietnamese ground attack.[46]

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[44] Polmar, 224.
[45] Rick Morgan. *A-3 Skywarrior Units of the Vietnam War*, Oxford: Osprey Publishing, 2015, 54.
[46] "Carrier Air and Vietnam … An Assessment," *Proceedings Magazine*, October 1967.

Concurrently, the Navy's Sea-Based Air Strike Study succeeded in influencing the Department of Defense of the utility of carrier aviation, despite improvements in land-based aircraft.[47] In response, in 1966 Secretary McNamara announced a new policy supporting the construction of new carriers and air wings, testifying: "although the investment to procure these ships is substantial, our experience in Vietnam and recent study results indicate that total costs to procure, support, and defend overseas land-based tactical air forces are comparable to total costs of carrier task forces of equal capability."[48]

The Vietnam War also featured the beginning of the construction of the nuclear-powered *Nimitz* Class. Equipped with a two-reactor steam plant, the class featured improved endurance and performance. As with the first of its predecessor *Enterprise* Class, the *Nimitz* (CVN 68) laid down in 1968 was the largest and most expensive warship to date. CVN 68 featured improved endurance and performance with a two-reactor steam plant.[49]

THE COLD WAR

Despite the success of the carrier in Korea and Vietnam, advancing submarine and long-range missile technologies posed a threat to the aircraft carrier. Missions that required the carrier to operate in contested waters could threaten the platform's survivability. Carrier operations necessitate activity in contested waters, since the primary advantage of the carrier is its ability to deliver on-point airpower to any point in littoral areas or the ocean itself. Operating the carrier alone would leave it vulnerable to enemy fleets, particularly submarines that could swarm the vessel. Shipboard space, always at a premium, would be an issue in combating undersea threats, since the carrier would require a large and diverse air wing to hunt down and destroy submarines and fill its other roles equally effectively.

In addition to developments in aircraft design, the primary answer to air and submarine threats against the carrier was the carrier strike group CSG. The modern CSG is derived from Japanese and American WW II era carrier groups, wherein both sides quickly discovered that unsupported carriers were vulnerable to aerial, surface, and subsurface attack, and therefore employed the precursors to carrier groups. The U.S. Fast Carrier Task Force, made up of four *Essex* Class carriers and 5-12 light carriers, covered the entire Pacific with its power projection capabilities.

[47] Robert K. Wilcox. *First Blue: The Story of World War II Ace Butch Voris and the Creation of the Blue Angels*, New York: MacMillan Press, 2007, 290.
[48] Polmar, 287.
[49] John Birkler, et al. *The U.S. Aircraft Carrier Industrial Base*, Santa Monica: RAND Corporation, MR-948-NAVY/OSD, 10.

Each *Essex* Class could operate independently, with its own destroyer screen. Combined, these carriers projected an immense amount of power.

The Cold War carrier battle group, an analogue to the CSG, maximized the effect of the supercarrier, screening it with surface combatants, while placing the single carrier at the center of a group's operations. The supercarrier, with its immense air wing, could act as the sole capital ship. Protected by a variety of surface and subsurface vessels, the "carrier group response" allowed the United States Navy to counter shore threats, particularly from more advanced weapons systems such as bomber-launched cruise missiles. This combination of advanced technology and operational doctrine maximized American blue water power during the Cold War. The United States was also able to rely on its allies to shape operations in littoral areas. Technological advancement, improving operational doctrine, and the geostrategic situation ensured that the United States could tailor its defensive capabilities to a specific spectrum of threats.

During the 1970s, two major carrier oriented developments took place. First, in 1973 the USS *Midway* was forward stationed at Yokosuka, Japan.[50] This first-ever peacetime forward stationing of a carrier reduced trans-Pacific transits, thus increasing carrier availability.

Second, during the 1970s complements or alternatives to the *Nimitz* Class carrier were seriously considered. Chief of Naval Operations Elmo Zumwalt examined the merit of a proposed Sea Control Ship (SCS) to fill the ASW role while escorting ships or operating with groups of non-carrier ships. The design analyzed in the 1973-1974 period would "displace 17,000 tons full load, be 670 feet long, with a speed of 25 knots, and could operate 16 ASW helicopters and 5 Harrier-type VSTOL aircraft, with the latter focused on providing a limited air defense capability."[51] In order to minimize the size and cost of this conventional carrier, the SCS would not have arresting gear or catapults. The cost was envisioned at $100 million, one-tenth the cost of a *Nimitz* Class ship. Another small carrier concept, the nuclear strike cruiser Mark II, res embled the Soviet *Kiev* Class and would modify a cruiser design to include a large flight deck for helicopters and VSTOL aircraft.[52]

A further promising design was the Vertical/Short Take-off and Landing (VSTOL) Support Ship (VSS). The VSS would complement the fleet of 12 large carriers with smaller carriers capable of limited AAW, SUW, and ASW. With arresting gear and catapults, the VSS would be capable of

[50] "USS *Midway* CV 41," U.S. Carriers, http://www.uscarriers.net/cv41history.htm
[51] Polmar, 294.
[52] Polmar, 297.

	SCS Design	VSS Design	CVV Design
Displacement (full load in tons)	13,735	29,130	59,800
Length (feet)	610	717	912
Speed (Maximum in knots)	26	30	27.8
Manning (Including Air Wing)	700	1,600	4,025
Aircraft	3 AV-8B, 17 SH-3	4 AV-8B, 6 SH-2, 16 SH-3D	24 F-14A, 10 S-3A, 4 EA-6B, 6 SH-3H, 4 KA-6E, 8 E-2C, 2 RA-7

Figure 2: Alternative Carrier Design Characteristics [55]

launching E-2 Airborne Early Warning (AEW) aircraft. However, the cost of the VSS was estimated at nearly $1.3 billion compared to approximately $2.2 billion for a fourth *Nimitz* Class carrier, while offering significantly less capability.[53]

During the Carter administration, the VSS concept was reborn as a conventionally-powered, even larger design labeled Aircraft Carrier Medium (CVV). With a proposed cost of approximately $1.5 billion, Secretary of Defense Harold Brown extolled the virtue of the CVV, saying, "Construction of this new carrier would mark an essential and important step in reversing the trend of the last decade toward ever larger, more expensive ship. This Administration is fully committed to reversing this trend. […] The CVV will have the capability to operate all of the Navy's current aircraft, including the S-3, F-14, and E-2C. […] The CVV's normal operating air wing is expected to include about 60-65 modern aircraft, compared with about 90 for existing Forrestal/Nimitz CV/CVNs."[54] [55]

Congress, however, deemed the *Nimitz* Class carrier significantly better value and included construction of the *Nimitz* Class CVN 71 in the 1979 Defense Department Authorization Bill, instead of a VSS. Concerned by the cost of the CVN 71, President Jimmy Carter vetoed the Bill; however, Congress overrode the President's veto to successfully build CVN 71.

POST-COLD WAR

During the 1980s, Secretary of the Navy John Lehman sought to increase the size of the fleet to 15 carriers from the 13 then in

[53] Norman Friedman. *U.S. Aircraft Carriers: An Illustrated Design History*, Annapolis: Naval Institute Press, 1983, 350.
[54] John Moore. *Jane's Fighting Ships 1979–1980*, London: Macdonald and Jane's, 1979, 674-675; Polmar, 298.
[55] Figure 2 CVV Operating Air Wing drawn from "The U.S. Sea Control Mission: Forces, Capabilities, and Requirements," Congressional Budget Office, June 1977, 74; other information from Polmar, 299.

commission. An increase in the rate of carrier construction during the Reagan administration sought to counteract the declining size of the force, which stemmed from Secretary of Defense McNamara's hiatus in carrier construction during the 1960s. Nonetheless, with Secretary Lehman's departure from office, the size of the carrier fleet continued to shrink.

The U.S. Navy operated 12 aircraft carriers from the mid-1990s until 2006, when the number dropped to 11. During this time there was a concomitant reduction in the number of escorts assigned to a CSG, in response to the lower sea control threat.[56] In December 2012, the number of U.S. carriers dropped to 10, with the retirement of the USS *Enterprise* (CVN 65), a state that will continue until the commissioning of the lead ship of the newest class of U.S. carrier, the USS *Gerald R. Ford* (CVN 78).

In 1995, the Navy initiated a Mission Area Analysis (MAA) to begin long range planning for eventual replacement of the *Nimitz* Class. The MAA concluded a new carrier must exhibit "increased flexibility and growth potential, lower life-cycle cost, and improvement in critical mission capabilities."[57] Additionally, the new class of carrier must, independent of land bases, conduct sustained surveillance, battle space dominance, and strike combat operations.[58] A subsequent DoD Analysis of Alternatives rigorously examined 75 ship designs of varying air wing compositions (from 40 to 80 Aircraft, Conventional Take-Off and Landing (CTOL) and Short Take-off Vertical Landing (STOVL) flight decks), various types of propulsion (steam, diesel, gas turbine, and nuclear), different maximum speeds, different hull forms and sizes, and various combinations of auxiliary and defensive systems.[59] This process led to the current *Ford* Class design.

Three factors characterized the post-Cold War carrier debate: the rising costs of maintaining a carrier fleet, perceived inefficient overmatch against low-end enemies, and the development of A2/AD threats. First, some observers contended that the cost of the carrier will only increase over time, as carriers and aircraft become larger, eventually pricing carriers out of the Navy's fleet.[60] The Navy, the contended, could replace its air wing with missiles to attack surface, land, and aerial targets. The Aegis

[56] Michael Mullen. "Sea Power 21 Series: Part VI--Global Concept of Operations," *Proceedings*, April 2003, 67.
[57] "Aircraft Carrier Construction from *Nimitz* Class to *Ford* Class," Program Executive Office Aircraft Carriers, Rev 13 (3.6.13), 16.
[58] "Ibid.
[59] Figure 3 (following page) is courtesy of Talbot Manvel. Talbot Manvel, "USNA Museum Storyboard for *Ford* Development Part I," December 15, 2014.
[60] Richard C. Arthur. "Nobody Asekd Me But … the Last Days of Carrier-Based Aviation?" *Proceedings Magazine*, January 1999.

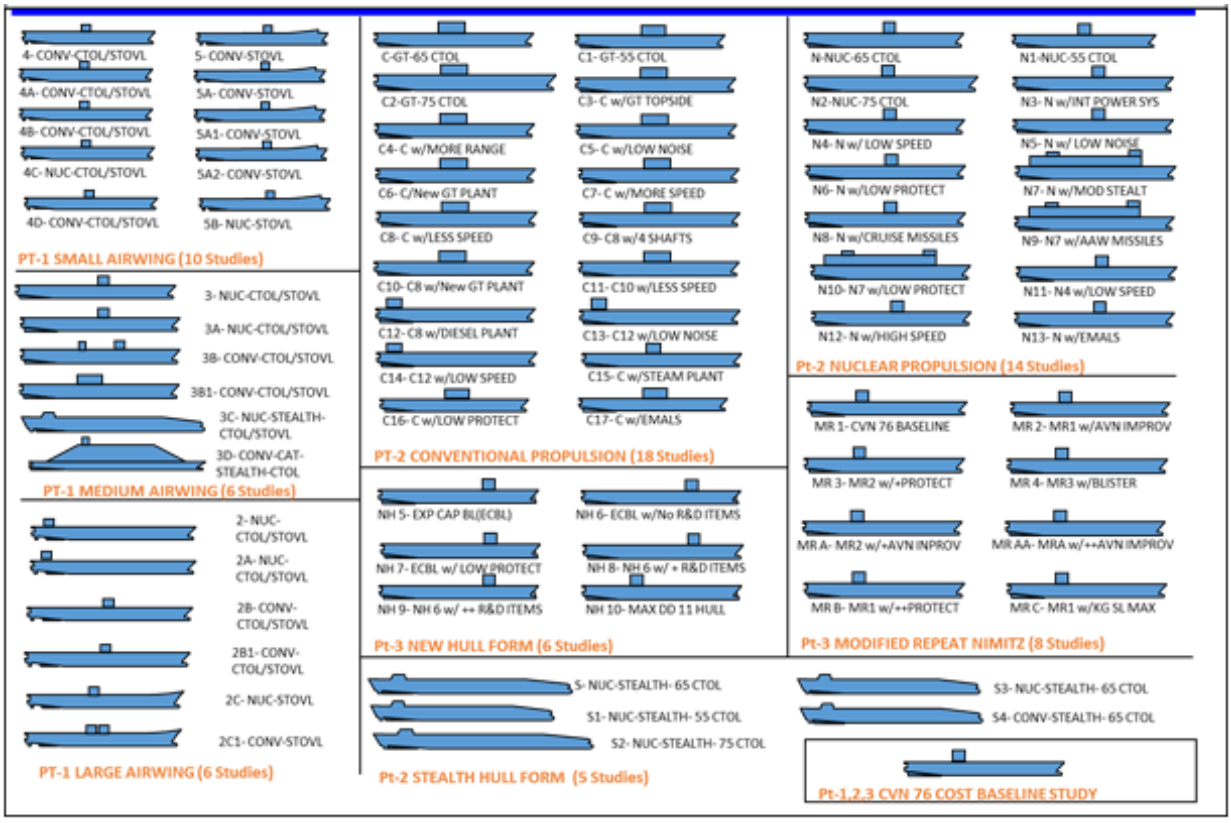

Figure 3: 75 Concept Designs in DoD's CVX Study Analysis of Alternatives (AoA) 1996-2000 [59]

system allowed support ships like cruisers and destroyers to defend a large area and intercept incoming missiles and aircraft. Any remaining carriers could be patterned off amphibious assault ships, with the VTOL/STOL capable jet filling the seldom-necessary role of air control fighter, with Aegis-style systems conducting "aerial combat" missions.[61] The striking arm of the fleet could be the cruise missile, launched from a variety of platforms. The missile, its proponents argued, could fill air superiority, air defense, and naval fire support roles, making a variety of U.S. ships obsolete.

A second argument asserted aircraft carriers were unnecessary for conflict against low-end adversaries and did not envision the rise of potent state adversaries. This viewpoint was particularly popular between 1995 and 2005, as U.S. forces focused on the proliferation of terrorism in the Middle East, especially in the absence of a great power competitor. Since no fleet challenged U.S. sea control, the role of the Navy would be largely (if not exclusively) that of force projection. As a result, a position arose asserting that the diminution in adversary air threats resulted in aircraft carriers being unnecessary. Moreover,

[61] Ibid.

any aerial threats would be minimal, since the complexity and cost of modern air power was extremely high. Therefore, the carrier would be unnecessary in large numbers, since aerial combat in the traditional sense would cease to exist and had become too costly.

The third group of skeptics of the carrier's utility observed the development of A2/AD systems, which could threaten carriers. This position grew in prominence during the late 2000s and early 2010s. Public revelation of the Chinese DF-21D Anti-Ship Ballistic Missile (ASBM) accelerated this concern, with many observers contending there was no effective defense against such a weapon.[62]

CONTEMPORARY OPERATIONS

During the 1990s and 2000s, aircraft carriers played key roles during operations in Southwest Asia, the Taiwan Strait, and the Balkans. During Operation Enduring Freedom, the U.S. retaliation for al Qaeda's September 11 2001 attacks, carrier aircraft from the *Carl Vinson*, *Enterprise*, and *Kitty Hawk* provided 72 percent of combat sorties in the early stages of the campaign when the United States did not have access to Central Asian airbases.[63] The range of operations in the Afghanistan campaign leveraged the carrier's organic aerial refueling capabilities in the S-3B and F-18E in addition to Air Force tanking. Strike missions from the carriers entailed distances ranging from 600 to 750 NM, with sorties lasting from four and a half to ten hours.[64]

During Operation Iraqi Freedom, five carriers were employed in the March 2003 campaign, while two other carriers were in work-ups and two other carriers were on their way to the theater or held in reserve in the Western Pacific.[65]

In 2014 the CSG demonstrated its versatility when the *Bush* CSG relocated from the Arabian Sea where it had been supporting operations in Afghanistan to 750 NM away in the Arabian Gulf in less than 30 hours and immediately began conducting strikes against the Islamic State of Iraq and Syria (ISIS). Due to difficulties obtaining basing access and coalition support, the *Bush* CSG was the only coalition strike force to project air power against ISIS for 54 days.[66]

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[62] "Report: Chinese Develop Special 'Kill Weapon' to Destroy U.S. Aircraft Carriers," U. S. Naval Institute, March 31, 2009.
[63] Polmar, 400.
[64] Benjamin S. Lambeth. "American Carrier Air Power at the Dawn of a New Century," RAND: Santa Monica, 2005, ix-x.
[65] Ibid, iii.
[66] "Senate Armed Services Committee Holds Hearing on the Navy Posture in Review of the Proposed Fiscal 2016 Defense Authorization," U.S. Navy, March 10, 2015.

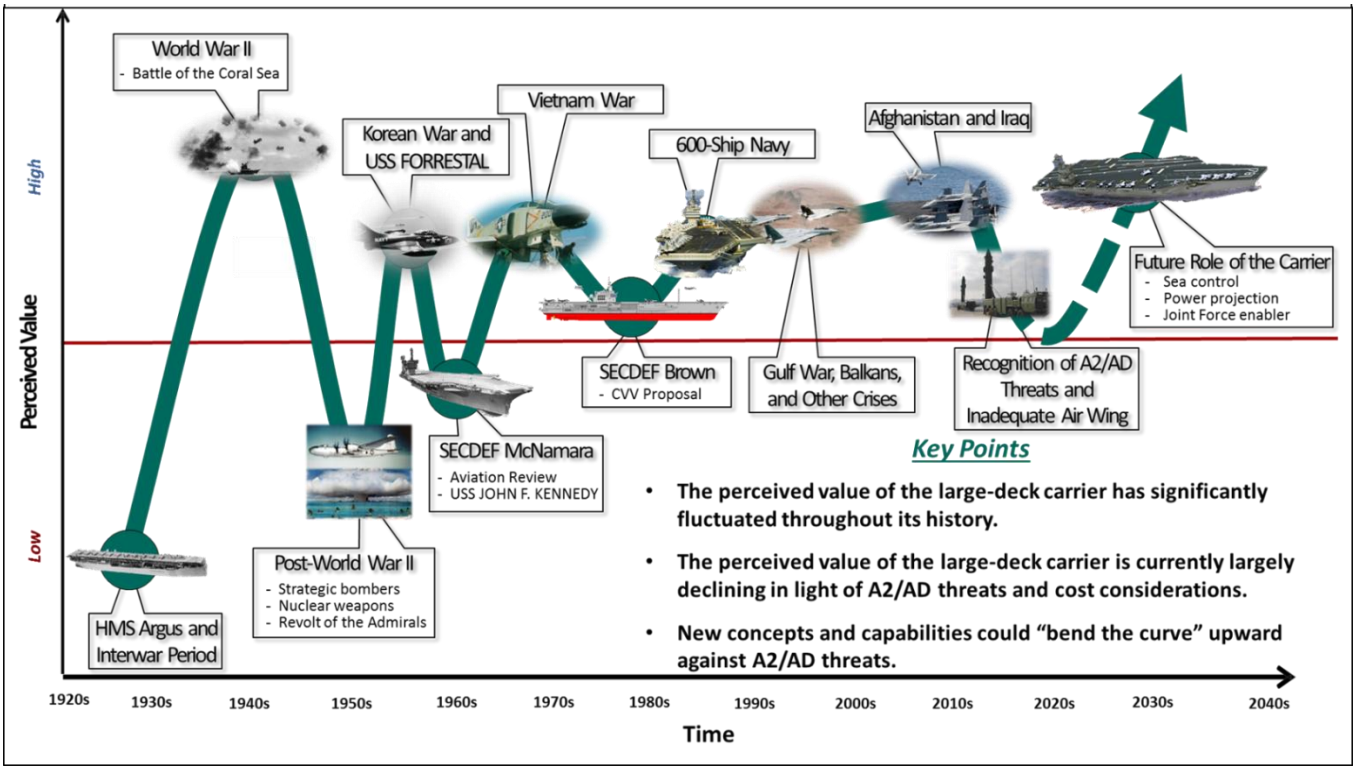

Figure 4: Perception of the Value of the Aircraft Carrier [67]

SUMMARY

Two points arise from the foregoing historical analysis of the role of aircraft carriers. The first is that there have been several wide swings of support among defense planners regarding the value, in terms of cost and utility, of aircraft carriers. These debates have in the past, been temporarily resolved by the performance of aircraft carriers in contingency operations. Secondly, throughout its history, there have been repeated analytical efforts to discern the most efficient and effective means of providing sea-based air power. These efforts consistently concluded that large, nuclear-powered carriers were preferable to smaller and/or conventionally-powered versions.

Despite the successful operational employment of aircraft carriers, concerns regarding carrier cost and utility against advanced threats remain. The potent sea-denial threats fielded by countries such as China, Russia, and Iran lead many observers to question whether large-signature surface ships, such as carriers, are still survivable and valuable. Throughout its history, the aircraft carrier and its accompanying strike group has evolved as a system, adopting new hull designs, shipboard systems, carrier air wings, and employment concepts. During that same history, the perceived value of the large-deck carrier has significantly fluctuated, with major changes in both proposed carrier design and

force size.[67] Currently, the perceived value of the large-deck carrier is declining in light of mounting A2/AD threats and cost considerations.

Many of these concerns echo similar arguments against the carrier since 1940, which criticized the carrier's lack of armament (outside of its aircraft), its at times inadequate air wing, its perceived high cost as improperly compared to stand-alone missiles and shore-launched bombers, and the threats posed by new weapons. It remains to be seen whether new carrier concepts and capabilities can "bend the curve" upward against A2/AD threats, but throughout history the carrier has overcome numerous challenges and demonstrated the value of sea-based airpower in the modern battlespace.

[67] This style of Figure 4 was inspired by Figure 21 in Mark Gunzinger and Bryan Clark. "Sustaining America's Precision Strike Advantage," Center for Strategic and Budgetary Assessments, June 2015.

V. THE ROLE OF THE CARRIER STRIKE GROUP IN THE JOINT FORCE

The CSG system of mutually supporting carriers, aircraft, surface combatants, submarines, and logistics ships provides a unique combination of organic firepower, surveillance, mobility, endurance, and versatility to a Combatant Commander and the nation. Accordingly, carriers play key roles in providing presence, deterrence, and warfighting capabilities to the country.

Throughout history, the CSG's power has provided an efficient means to perform or enable nearly all types of naval operations, including: Strike Warfare, Surface Warfare (SUW), Integrated Air and Missile Defense (IAMD), Anti-Submarine Warfare (ASW), Mine Warfare (MIW), Amphibious Operations, Maritime Interception Operations (MIO), Protection of Shipping, Reconnaissance, and Humanitarian Assistance and Disaster Relief (HA/DR).[68]

The CSG's power, flexibility, and utility have been on frequent display in recent operations in Afghanistan, Iraq, and Syria. However, these applications are not representative of the most appropriate planning scenarios to guide critical review of the role of the CSG in the Joint Force. Instead, the most challenging scenarios for the Joint Force—military operations against the peer or near-peer threat of China—merit examination in evaluating the role of the CSG. The threat posed in these scenarios is the most demanding and represents a significant risk to CSG operations, but the stakes involved in overcoming those threats and the centrality of considerations for victory in such a scenario warrants this approach. Before moving to the specificity of warfighting scenarios, a brief discussion of the broader strategic context in which naval forces operate is required.

U.S. STRATEGY

The 2014 Quadrennial Defense Review called for the Joint Force to "project power and win decisively" in spite of "increasingly sophisticated adversaries who could employ

[68] Joint Publication 3-32: Command and Control for Joint Maritime Operations, Joint Staff, August 7, 2013, xv, http://fas.org/irp/doddir/dod/jp3_32.pdf.

advanced warfighting capabilities."[69] The People's Republic of China (PRC) has developed powerful forces capable of challenging the U.S. ability to project power, deter and defeat aggression, and operate effectively in the various warfighting domains, as called for by the Quadrennial Defense Review. The scale and sophistication of the PRC threat, coupled with an overall Comprehensive National Power capable of rivaling that of the United States in the years ahead, results in a near-peer threat that is rapidly adopting peer characteristics.[70] The ability of the United States to counter Chinese regional aggression and project power is essential to its ability to advance its interests and sustain its global leadership, as called for by the National Security Strategy.[71]

While multiple states, including Russia and Iran, are fielding A2/AD capabilities, and while A2/AD capabilities will continue to proliferate globally, the ability of the United States to deter and defeat PRC aggression serves as a bellwether for U.S. capabilities worldwide. By developing the ability to deter and defeat the pacing threat of the PRC, the United States will ensure it has the fundamental capabilities necessary for countering many types of aggression worldwide.[72]

RELEVANT SCENARIOS

While multiple planning scenarios with maritime and land components involving China merit examination and may reveal distinct operational needs, the defense of Taiwan rises to the top in terms of its utility in force planning. First, even if conflict in Taiwan never takes place, it is perceived as a major conflict potentially involving the United States, and the perceived capability of the United States to deter and defeat aggression underpins U.S. alliance relationships. Additionally, in the defense of Taiwan, the United States has a crucial intersection of interests, objectives, and capabilities that result in a critical planning scenario.

Operationally, to a greater degree than other possible scenarios involving China, the People's Liberation Army (PLA) can leverage short range and interior lines of communication to employ an enormous capacity of forces against Taiwanese, U.S., and other partner and allied forces to achieve their objectives of either invading and occupying Taiwan or wielding force to compel

[69] "Quadrennial Defense Review," Department of Defense, 2014, 14, 19, http://www.defense.gov/Portals/1/Documents/pubs/2014_Quadrennial_Defense_Review.pdf.
[70] Comprehensive National Power is a Chinese quantitative assessment of a state's net military, economic, and cultural power. China Institute of Contemporary International Relations. "Global Strategic Pattern: International Environment of China in the New Century," Beijing, Shishi Press, 2000.
[71] National Security Strategy of the United States, February 2015, 2.
[72] This statement does not address the force-sizing considerations involved in being able to address the threat posed by China and other actors simultaneously.

capitulation. Additionally, the United States may receive little indication and warning of an impending Chinese attack, further complicating the United States' ability to support the defense of Taiwan. In light of this challenging situation, prudence demands the United States employ it as a planning scenario.

Other relevant scenarios that may reveal critical operational needs include those involving conflict in the South China Sea or the Senkaku Islands. Additionally, a focus on Taiwan (or even the South China Sea) is not to say a potential conflict with China would likely remain localized to the Western Pacific. On the contrary, it could involve overt and covert conflict across the globe.

This analysis utilizes a notional 2020-2025 Defense of Taiwan scenario, and seeks to capture at a general-level, expectations regarding how forces might be employed. An overall Concept of Operations (CONOPS) for the defense of Taiwan might seek first to deter PRC aggression via communication of the general costs of conflict, specifically that a disruption to the peace and stability of the region could threaten the entire international order. Other elements of a conventional deterrence campaign might also be employed if time permitted, such as the movement of key enabling forces to readying positions, arraying combat forces in the region in a more resilient posture, and increasing surveillance flights and patrols.

Then, if conventional deterrence fails, U.S. forces would employ geographically distributed units to prevent a PRC invasion of Taiwan, to counter compellent forces, to support Taiwanese survival, and to apply direct pressure against PRC power projection forces and indirect pressure via extended blockade and other elements of U.S. national capability.[73] Specifically, operational lines of effort may include: disrupting, deceiving, and destroying PRC OTH Intelligence, Surveillance, and Reconnaissance (ISR) capabilities; defeating PRC amphibious invasion; constraining and eventually defeating the PRC naval fleet; defending allies and partners as possible with a focus on protecting power projection nodes; dislocating the PRC from the international economy by interdicting trade and reorganizing trading structures; and resupplying Taiwan as possible.

Overall, the scenario would likely feature a U.S. commitment to counter PRC aggression backed by the commitment to conduct a prolonged, global compellent campaign as necessary. It is possible that in a defense of

[73] Compellence is "inducing [an enemy's] withdrawal, or his acquiescence, or his collaboration by an action that threatens to hurt, often one that could not forcibly accomplish its aim but that, nevertheless, can hurt enough to induce compliance." Thomas C. Schelling. *Arms and Influence*, New Haven: Yale University Press, 1966, 2-3. In the case of Taiwan, this could include air and missile bombardment, blockade, and political assassination strikes.

Taiwan scenario, U.S. forces would employ in a manner that to some extent levies lower requirements on power projection forces, while relying more heavily on more indirect approaches such as an extended blockade. However, more directly responsive operational alternatives must be examined, as their inclusion in a menu of response options for national leadership represents the minimum acceptable level of military planning.

ASSESSMENT OF THE FUTURE FORCE

Assessments of the performance of the programmed Joint Force reveal significant challenges as a confluence of three factors that will exacerbate existing deficiencies. First, sophisticated A2/AD systems will likely proliferate to a larger number of countries than currently field them. Second, A2/AD systems will mature and improve in sophistication and coverage, and will feature improved sensors, networks, and weapons, thus producing adversary battle networks with regional and global surveillance capabilities. Third, China will continue to develop capabilities, posture, and forces more suited to global power projection, moving beyond current estimates of mere regional hegemony. This "Anti-Access Enabled Power Projection Force" has the potential of not only posing major challenges for the United States in East Asia, but also in other regions of the world through the extended range of mainland China-based weapons and sensors, the global mobility of other anti-access systems, and the development of global power projection and sea control forces, such as Surface Action Groups, Amphibious and Carrier Battle Groups, nuclear-powered attack and guided missile submarines, and long-range tanking and strike aircraft.[74]

China's 2015 Defense Strategy confirmed this shift to a force capable of enhanced power projection. The document called for China "to develop a modern maritime military force structure commensurate with its national security and development interests, safeguard its national sovereignty and maritime rights and interests, protect the security of strategic SLOCs and overseas interests, and participate in international maritime cooperation, so as to provide strategic support for building itself into a maritime power."[75]

High-end scenarios involving countries such as China or Russia are greatly challenging for U.S. forces and entail the assumption of high levels of risk relative to lesser threats. Both traditional and alternative CONOPS that could be employed are relatively brittle and vulnerable to enemy disruption and deception.

[74] This phrase was developed by Jim Thomas, Center for Strategic and Budgetary Assessments.
[75] "China's Military Strategy," The State Council Information Office of the People's Republic of China, May 2015, http://news.usni.org/2015/05/26/document-chinas-military-strategy.

Additionally, current CONOPS are highly dependent on air forces, which face the dual threats of structured attacks of offensive missiles and aircraft, and advanced IADS. Consequently, with regard to a scenario involving China, threats against U.S. and Allied airpower in the First and Second Island Chains are resulting in a greatly decreased number of forces that could be generated and sustained against targets at extended range.[76] This threat particularly affects land-based airpower based within the First Island Chain, reducing the number of tactical aircraft, tankers, ISR platforms, and ASW aircraft that could be employed.

Additionally, perceived U.S. advantages in military competitions, such as Undersea Warfare, Air Superiority, and Secure C4ISR, are eroding due to symmetric and asymmetric counters adopted by U.S. adversaries. Moreover, the geographic and environmental conditions of the Near Seas facilitate PLA defensive concepts and complicate the ability of the United States to employ certain assets, such as Attack Submarines, in particular concepts of employment.[77] In other areas, such as Surface Warfare (SUW) and IAMD, the United States faces marked deficiencies versus Chinese and Russian threats.[78]

This paper asserts that in order to counter China's growing capability, the Joint Force will require carriers to execute power projection, surveillance, and sea control missions. However, several decades of a low blue-water threat have conditioned U.S. naval forces to a heavy emphasis on power projection, while against an opponent like China, sea control requirements are likely to expand. The development of Chinese and Russian long-range regional and global power projection capabilities will constitute formidable threats that the United States must counter in order to achieve its national security goals. Faced with continuing threats to short-range air and naval capabilities, as well as the mounting long-range sea control threats, the Joint Force will depend on naval forces to protect Sea and Air Lines of Communication and deny sea control to enemy forces, while exercising sea control locally where desired (and necessary). These mounting sea control threats would be coupled by an increase in the range of land-based threats, such as land-launched boost-glide missiles ranging beyond 1,500 NM or hypersonic cruise missiles launched from low observable bombers far from land.

Across the Joint Force, capabilities, concepts, postures and forces must be developed to

[76] The First Island Chain refers to the first chain of major archipelagos out from the East Asian continental mainland coast. The Second Island Chain is the next chain of archipelagos out from the East Asian continental mainland, principally composed of the Bonin Islands, Marianas Islands, and Caroline Islands.
[77] The Near Seas refers to the South China Sea, East China Sea, and Yellow Sea.
[78] James Holmes. "The US Navy's Cruise Missile Nightmare," Real Clear Defense, February 20, 2015, http://www.realcleardefense.com/articles/2015/02/20/the_us_navys_cruise_missile_nightmare__107640.html.

meet these mounting threats. These requirements will stress all of the Armed Forces, not just the Navy and its CSGs. That said, there are a significant number of critical warfighting requirements that would go unmet or at least be dramatically under-resourced without aircraft carriers. There is no other element of the Joint Force that can provide the unique contributions of the CSG to Joint warfighting, to include broad area AAW, SUW, ISR, and ASW capabilities, that other elements of the Joint Force would be challenged to provide given their reliance on fixed land bases that would almost certainly be targeted in the scenarios under consideration.

In a conflict with China, the importance of carrier-based naval air forces would increase. There would be numerous capabilities required from all elements of the Joint Force, yet carrier-based naval air forces would be required not only to perform power projection and sea control missions, but also to assume greater responsibility for missions now largely conducted by land-based air forces—especially early in a conflict.

In the case of a scenario involving China, carrier air would play an important role in AAW. It would conduct independent Offensive Counter-Air (OCA) missions, provide escort support of Air Force units (such as bombers), provide supporting OCA missions to dislocate enemy SUW and ASW operations, and it would provide selective Defensive Counter-Air (DCA) for Second Island Chain bases. In terms of strike, CSGs would play an important role finding enemy fleets, providing air support to SAGs, other naval forces, and supply forces, providing strike to engage enemy naval forces, and providing limited strikes against land-based operational nodes. In terms of ISR, carrier aircraft would play a critical role surveilling enemy forces at sea, in the air, and on land. The likely degradation of U.S. and allied land-based broad-area ISR and ASW capabilities (due to attacks against undersea infrastructure, satellites, air bases, and long-range interceptor aircraft in the air) coupled with PLAN development of larger numbers of quiet nuclear attack submarines (SSN) and diesel-powered submarines (SSK) would contribute to the requirement for carrier-based, organic area ISR and ASW capabilities. Improved surveillance and targeting capabilities would not only facilitate organic CSG strike, but would also allow other elements of the Joint Force the ability to conduct long range strikes.

Joint Force requirements for CSGs to contribute to sea control missions, especially at the earlier stages of a conflict, would likely limit its early contribution to power projection missions. Nonetheless, the ability of CSGs to conduct long-range strike operations against both enemy fleets and land bases provides significant operational flexibility to the commander, especially as gains are made against the adversary ISR complex.

American submarines would play a considerable role in any conflict with China, although the physical limitations of submarines (especially related to speed and sensor range) and their high-priority demand by the Joint Force to conduct other missions (such as ISR, strike, and the monitoring of China's ballistic missile submarines) will limit their full employment as sea control assets.

To summarize, in a high-end conflict with China, the CSG will face a considerably higher demand for its traditional naval duties such as sea control and scouting, as current land-based elements of the Joint and naval force architecture envisioned to contribute to these missions are almost certainly to be under attack by weapons that will have a higher probability of arrival than those available for striking moving targets (such as the carrier). At least as important though, will be the requirement for the CSG to enable other elements of the Joint Force to operate forward within an acceptable level of risk in an environment where First Island Chain land-based air would almost certainly have been targeted. These missions would include air support to forcible entry operations, escort of long range bombers and strikers to their launch positions, and protection of airborne high value units performing crucial missions such as ISR, command and control, refueling, and communications relay. As the campaign matures, the power projection and strike capabilities of the CSG will rise in importance as elements of the Chinese targeting complex are effectively neutralized.

CARRIER STRIKE GROUP EFFECTS CHAIN ANALYSIS

The previous section assesses the envisioned role of the CSG as part of the Joint Force. This section applies an effects chain analysis to current concepts of operation of the CSG, in order to provide a holistic view of its activities, from the construction of the ships and aircraft that comprise it, to the logistics system that sustains it. This analysis reveals numerous opportunities for disruption of U.S. CSG operations, but more importantly, it reveals vulnerabilities that must be mitigated to reduce operational risk against a high-end opponent. Each element of this analysis is worthy of deep study far beyond the scope of this effort, but looking across them holistically is worthwhile for a comprehensive understanding of operational risk. The subsequent section will identify a series of critical improvements the CSG must undergo in order to be capable of meeting Joint Force requirements.

Construction: As with all large U.S. military ships, the construction of carriers, escort ships, and embarked aircraft relies on a capable yet brittle industrial base. Destruction of key long lead-time fabrication centers either at shipyards or at component manufacturers could seriously retard the United States' ability to produce additional platforms during a

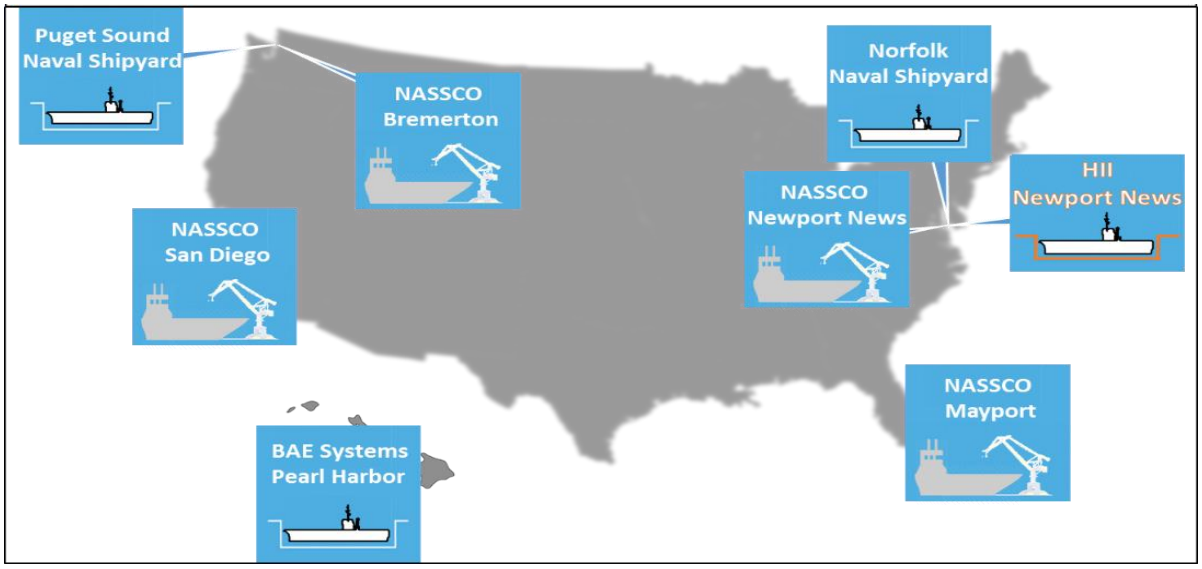

Figure 5: U.S. Dry-docks Capable of Receiving, Constructing, or Repairing, *Nimitz* or *Ford* Class Carriers

conflict. With regard to the *Ford* Class carrier, Huntington Ingalls Industries (HII) Newport News, Virginia Shipyard is the only shipyard in the United States capable of constructing *Ford* Class carriers. With their existing dry-docks and construction equipment, neither HII's Ingalls Shipbuilding yard in Pascagoula, Mississippi, Bath Iron Works in Bath, Maine, or General Dynamics' San Diego, California National Steel and Shipbuilding Company (NASSCO) shipyard are capable of building *Nimitz* or *Ford* Class carriers. Additionally, yards capable of building ships of frigate size or larger are not numerous.

Port Stay: Carriers, as are all ships in port, are vulnerable to a range of threats. These threats can include conventional air, missile, torpedo, or mine attacks. Attacks can also include use of short-range guided rockets, artillery, missiles, and mortars by paramilitary units to destroy key components, such as radars, or the employment of missiles, torpedoes, or mines fired from commercial ships operating in or near the port. Alternatively, paramilitary units could tag a ship with a time-delayed beacon that would transmit the ship's position. Although these threats increase in density in forward operating areas, their possibility (especially by paramilitary units or commercial ships) should be considered within the continental United States.

Communications and Navigation: During navigation, ships normally rely on regular radio communication with aircraft and other ships. As a mobile airbase, without pre-planned procedures that enable ships and aircraft to operate in emissions control (EMCON) or with reduced emissions, these emissions can be detected at extremely long

ranges and threaten to permit unambiguous identification of a carrier to sensitive enemy land, ship, and aerial radio direction finding equipment.[79] Additionally, U.S. Navy ships make extensive use of satellite systems for communication and precision, navigation, and timing. Given existing CSG's extensive reliance on satellite systems, the PLA's demonstrated capability to jam, spoof, and destroy satellites in all orbits (including Global Positioning System satellites in Medium Earth Orbit and Advanced Extremely High Frequency satellites in Geostationary Orbit) can greatly complicate naval operations.

Securing Operating Areas: In order to conduct sustained flight operations, the CSG must temporarily secure an operational area around a carrier. This area may move over the course of a mission or campaign, which complicates enemy efforts to target a CSG. Dislocating enemy activity in this area is a necessity. The ability of the CSG to use active and passive methods to complicate enemy finding, fixing, tracking, targeting, engaging, and assessment efforts is a crucial element of maximizing the survivability of a CSG. To find naval forces, however, the enemy has a range of detection methods. These include: dedicated tattle-tale vessels, civil and/or commercial vessels equipped with two-way Beidou navigation/communication systems and high-frequency radios, radars, electro-optical/infrared, and signals collection satellites, high altitude-long endurance UAS, submarines, surface ships, undersea surveillance infrastructure, maritime patrol aircraft, and radio direction-finding equipment. Each of these systems is dangerous by itself; operated in concert and properly fused, they form a powerful element of an A2/AD reconnaissance-strike complex. Given the carrier's size and planar deck shape, the High Frequency (HF) Radar Cross Section (RCS) of an aircraft carrier is difficult to decrease. The CVN also has a relatively large acoustic signature, generating noise from aircraft take-offs and landings, hard-mounted propulsion and power generating machinery, and low propeller speed onset of cavitation. As stated by the Defense Science Board, "under certain circumstances, CVNs are subject to acoustic detection at ranges of several hundred miles."[80]

Additionally, although the density of the enemy's surveillance capabilities decreases with range, a number of surveillance systems are either global in nature or are difficult to fully suppress or avoid. The resilience of the enemy's reconnaissance-strike complex results in a situation in which even a degraded surveillance reconnaissance-strike network would pose a persistent "fleet in being" threat. For instance, even if enemy Over-the-Horizon (OTH) radars were destroyed, ASBMs could

[79] "Defense Science Board Task Force on the Future of the Aircraft Carrier," Office of the Undersecretary of Defense for Acquisition, Technology, and Logistics, October 2002, 55.
[80] "Ibid, 57-58.

be husbanded for subsequent cueing by other sensors.

If a CSG were positively identified, an enemy could employ a range of powerful weapons from different platforms. These include land, air, surface, or sub-surface launched mines, missiles, bombs, or torpedoes.[81] Among other weapons, the land-based DF-21D and DF-26 ASBMs have an estimated range between approximately 1,000 to 1,500 NM and 1,600 to 2,160 NM, respectively.[82] Other platforms, such as land-based bombers armed with anti-ship cruise missiles or submarines, can operate at similar distances or beyond.

The CSG uses a variety of active and passive methods, kinetic and non-kinetic weapons, to identify threats, deceive adversaries of its position, and interrupt enemy effects chains. These systems include jammers, spoofers, decoys, surface-to-air missiles, point defense guns, and carrier-launched command and control aircraft and fighters.

Independent of the CSG, land-based aircraft, such as P-8s, MQ-4s, and E-3s, land-based radars, and satellites play an important role in detecting enemy submarines, surface ships, missiles, and aircraft. If use of these systems were denied or restricted, through ASAT weapons, degradation of communications links, IADS, OCA, or destruction of land-bases, (or if the systems were tasked to support other higher-priority missions) the CSG's maritime domain awareness would degrade and the relative importance of CSG-based broad-area surveillance capabilities would increase. This persistent ISR and targeting capability would be an organic carrier capability gap that P-8 and MQ-4 aircraft, which can only operate in permissive environments, would face difficulty addressing. Although programs such as the Defense Advanced Research Project Agency's Tactically Exploited Reconnaissance Node program could expand surface combatant ISR capabilities, large, carrier-launched aircraft will likely be necessary for aircraft with a sufficiently large aperture, size, weight, power, and cooling for long-range, high performance airborne early warning systems.[83]

The Navy's post-Cold War elimination of the organic broad-area ASW coverage previously provided by the S-3B has resulted in a significant gap in the face of a mounting PLAN submarine threat. The S-3B provided an ASW combat radius of approximately 460 NM and

[81] Bombs and missiles could employ either conventional high explosive, penetrator, submunition, or high-powered microwave warheads.
[82] "Re-enter the DF-21D ASBM," *U.S. Naval Institute News*, July 18, 2011, http://blog.usni.org/tag/df-21d; Richard Fisher. "DF-26 IRBM may have ASM variant," *IHS 360*, September 2, 2015. http://www.janes.com/article/53994/
[83] "Tern Continues Progress toward Enabling Small Ships to Host Their Own Unmanned Air Systems," DARPA, March 23, 2015, http://www.darpa.mil/news-events/2015-03-23.

endurance of approximately seven hours.[84] In contrast, inner defense zone MH-60R helicopters equipped for ASW missions only provide an approximately 125 NM combat radius and 2.7 hours of endurance.[85]

Strike: During a conflict, the CSG's strike capability would be called upon to target both naval assets and land-based systems. These strikes would seek to dislocate enemy operations and attrite enemy systems to achieve operational-level objectives. The CSG's strike capability would largely stem from missiles carried in the VLS of its surface combatants and the capacity of its carrier aircraft.

Faced with a potent A2/AD threat, CSGs would be forced to exercise restraint, conducting flight operations outside the range envelope of significant systems such as the DF-21D and DF-26 or incur risk by "standing-in" or operating within that range. Additionally, CSGs would likely be tasked with providing air cover for Surface Action Groups conducting Tomahawk strikes further inside the enemy threat envelope. Overall, the increased threats facing CSGs would likely force a decrease in the force gradient available for strike. Or put another way, after 25 years of relatively unmolested capability to strike targets ashore from our ships and aircraft, increased threats to the force will require a greater degree of time, attention, and resources (to include sorties) to create operationally relevant space.

The carrier's current and projected short-to-medium range air wing exacerbates this problem by limiting options available to CSG commanders. The F-35C's approximately 610 NM combat radius improves air wing performance over the Super Hornet's 390 NM combat radius; however, the small size of the planned F-35C procurement (and thus continued reliance on F/A-18E/F aircraft) and the need for strike packages against advanced enemies to employ EA-18G electronic attack support results in a relatively consistent strike radius.[86] Additionally, the F-35C's lack of all-aspect, broadband radar cross section reduction measures results in an aircraft significantly more stealthy than the F/A-18E/F, yet significantly less stealthy than the Air Force F22.[87] The introduction of the F35C does, however, offer additional air warfare opportunities as its increased range, sensor, and network capabilities can enable

[84] "S-3B Viking," Naval Technology, http://www.naval-technology.com/projects/s3-viking-aircraft/.
[85] "MH-60R Seahawk;" BGA Aeroweb, http://www.bga-aeroweb.com/Defense/MH-60R-Seahawk.html.
[86] "F-35 Joint Strike Fighter," Selected Acquisition Report, Department of Defense, FY 2015, 14, http://breakingdefense.com/wp-content/uploads/sites/3/2014/04/F-35-2013-SAR.pdf; N.B., Super Hornet combat radius assumes 1 center-line external fuel tank, 2 MK-84s, and 2 AIM-120s.
[87] The F-22 has an unclassified, estimated frontal RCS of approximately 0.0001~0.0002 sqm, while the F-35 has an unclassified, estimated frontal RCS of about 0.0015 sqm. "RCS Reduction," EC4630 Radar and Laser Cross Section, U.S. Naval Postgraduate School, Fall 2011, http://faculty.nps.edu/jenn/EC4630/RCSredux.pdf.

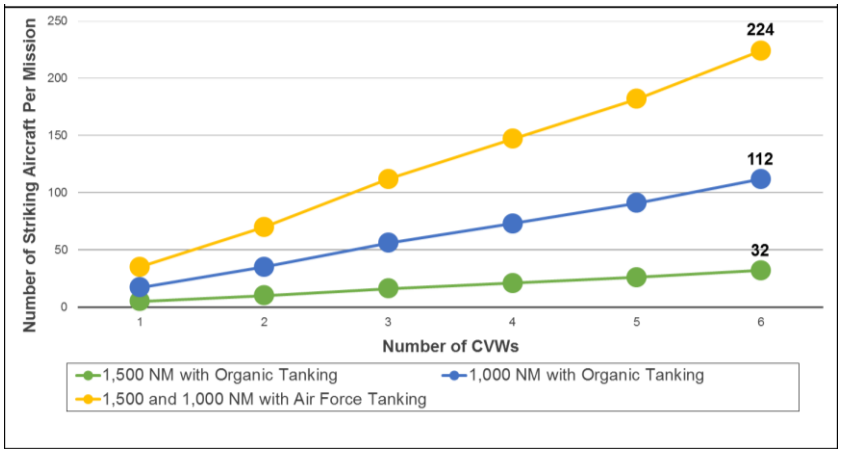

Figure 6: CVW Striking Aircraft Capacity at 1,500 and 1,000 NM [89]

new employment concepts.

Moreover, the Navy's retirement of its dedicated tanking force, the KA-6D in 1996, and the S-3B in 2009, has decreased the proportion of the air wing available for air warfare and strike missions (as strike aircraft must now be assigned limited tanking roles known as "buddy" tanking) and increases the carrier's reliance on land-based Air Force tanking (which may be limited or even unavailable in light of strikes against air bases).[88]

Additionally, a sub-optimal strike weapons mix within carrier air wings forces commanders to either rely on long-range stand-off weapons, such as AGM-158 JASSM (and in the future the JASSM-ER derivative Long Range Anti-Ship Missile, LRASM), or short-range, low probability of arrival standoff weapons, such as AGM-154 Joint Standoff Weapon (JSOW) or guided bombs to strike fixed or mobile targets. Furthermore, enemy development of effective integrated air and missile defenses has enormously complicated strikes. Offensive counter-air sweeps by advanced fourth and fifth generation fighters serve to push back the operational range of key assets, such as Air Force tankers and airborne early warning aircraft. Coupled with threats against air bases, this enemy threat against tanker orbits limits the effectiveness of carrier aviation by requiring a higher proportion of a carrier's air wing to be dedicated to buddy-tanking. Closer-in, effective Defensive Counter-Air sorties threaten to intercept non-stealthy aircraft. Finally, a dense network of land and ship-based, kinetic and non-kinetic, air and missile defense systems can intercept aircraft and munitions.

[88] Brad Elward. *Nimitz Class Aircraft Carriers*, Oxford: Osprey Publishing, 2014, 30.

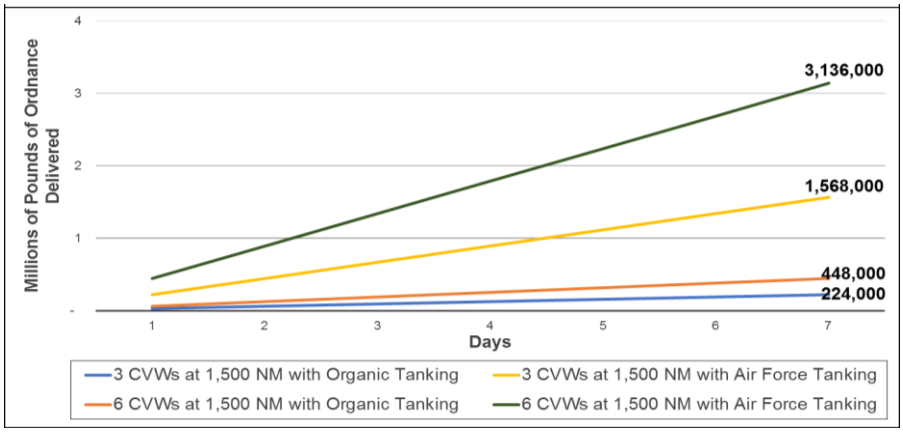

Figure 7: Cumulative CVW Ordnance Delivered by 3 and 6 CVWs at 1,500 NM in Week

In spite of these threats and limitations, current carrier air wing strike capability is significant, even at extended ranges. Operating alone, a single carrier air wing could—using organic tanking alone—generate five F/A-18E/F fighters that could drop two 1,000-pound class weapons (e.g., AGM-154 JSOW) after 1,500 NM of flight in an uncontested environment.[89] If the aircraft must only fly 1,000 NM, the number of striking fighters increases to 17. The support of Air Force tanking increases the number of fighters to approximately 35 at both 1,500 NM and 1,000 NM. Additionally, effective strike range could be extended through the employment of stand-off munitions. For instance, JASSM-ER has a range of over 500 NM, and JSOW-ER has a range of over 250

[89] This basic model assumes 44-aircraft F-18E/F CVWs and straight-line uncontested flight to weapons release points. Nine fighters per CVW are not dedicated to the discussed strike mission but rather to satisfy air and sea defense requirements or are held in reserve. Strike aircraft carry two 1,000-pound class weapons (e.g., AGM-154 JSOW), two AIM-120s, and two AIM-9s. Organic tanking F-18E aircraft carry five external fuel tanks and two AIM-9s. During normal flight operations, only three external fuel tanks are carried to minimize wing stress; however, during a major contingency five could be carried. At 1,500 NM, organic tanking-only strike operations require a tanker-to-striker sortie ratio of 8:1, and six tanker configured aircraft per striker. At 1,500 NM, Air Force tanking-only strike operations could support at least a 2:1 striker to hose ratio, possibly greater depending on tanker type and capacity. This analysis assumes the use of KC-10 or KC-46 aircraft, with 3 hoses per tanker and 6 strikers per tanker. At 1,000 NM, organic tanking-only strike operations require a tanker-to-striker sortie ratio of 1:1. At 1,000 NM, Air Force tanking-only strike operations could support a 2 or 3:1 striker to hose ratio, depending on tanker type and capacity. This model uses a 3:1 striker to hose ratio, for 9 strikers per tanker ratio. Due to air wing size limitations (and the need to employ at least 9 aircraft for battlespace dominance defensive requirements and to hold in reserve), strike capacity for Air Force tanking-enabled missions at 1,500 NM and 1,000 NM is roughly equivalent, albeit with a smaller demand for Air Force tanking assets at 1,000 NM. This cumulative analysis does not take into account the effects of attrition on the air wing (please see Figure 7 for information on the cumulative effects of attrition). Furthermore, the reserve requirement notwithstanding, this analysis does not fully account for either battlespace dominance or strike fighter tanker escort requirements of the air wing. Lastly, this model assumes CSGs of three carriers operating together would require a total of 20 defensive/reserve fighters during the duration of the offensive strike mission.

NM.[90] The use of stand-off munitions would decrease the level of carrier "stand-in" potentially desired for large strikes and increase the proportion of the air wing dedicated to strike or escort, as opposed to buddy-tanking.

Operating as part of multi-carrier operations, the capability of the carrier further increases. The combination of multiple carrier air wings facilitates meeting baseline air and sea defense requirements and allows the allocation of a higher proportion of the air wing to offensive missions. Three carrier air wings could organically deliver 112,000 pounds of ordnance per strike at 1,000 NM, and six carrier air wings could organically deliver 224,000 pounds of ordnance per strike at 1,000 NM. If supported by Air Force tanking, six carrier air wings could organically deliver 448,000 pounds of ordnance per strike. Over the course of a week, the amount of ordnance delivered by an air wing—even at long range—could be significant.

This analysis demonstrates how the combat power generated by multiple CSGs significantly increases in a nonlinear fashion. Accordingly, an operational commander may need to effectively balance contributing to operations that quickly deny compellence aims while carefully husbanding forces in order to create naval groups with multiple carriers.

Air Warfare: The CSG's air warfare capabilities are a crucial contribution to the Joint Force. A major reduction in the number of tactical fighter sorties generated from short-range airbases due to aircraft and missiles attacking airbases would place a premium on the ability of the CSG to conduct OCA and selective DCA missions, or other missions such as escorting long-range Air Force bombers. As always, the contribution of Navy EA-18G electronic attack aircraft would be in high demand, especially in view of Air Force's 1998 retirement of EF-111A Raven electronic warfare aircraft—its last dedicated tactical electronic warfare aircraft.

In conducting its air warfare missions, the carrier air wing would face deadly foes. Many current and projected advanced fourth and fifth generation adversary aircraft exhibit superior aerodynamic characteristics, sensors, avionics, and weapons performance over the Navy's F/A-18E/F Super Hornet fleet.[91] Additionally, several enemy long-range air-to-air missiles with various seekers outrange U.S. air-to-air missiles and not only threaten to destroy figher aircraft, but also

[90] Marina Malenic. "USAF approves JASSM-ER FRP," IHS Jane's, December 15, 2014, http://www.janes.com/article/47000/usaf-approves-jassm-er-frp. / "JSOW," Raytheon, http://www.raytheon.com/capabilities/products/jsow/.
[91] Oriana Skylar Mastro and Mark Stokes. "Air Power Trends in Northeast Asia: Implications for Japan and the U.S. – Japan Alliance," Project 2049 Institute, 29, http://project2049.net/documents/mastro_stokes_japan_airpower_paper.pdf.

threaten to engage at very long range, supporting aircraft such as electronic warfare aircraft, airborne early warning aircraft, and tankers. This potential qualitative inferiority in the air is aggravated by a potential quantitative inferiority. Major reductions in the size of carrier air wings have placed carrier aviation in a double-inferior situation in which it not only has qualitative but quantitative weaknesses. The introduction of the F-35C and continued development of the Navy's Naval Integrated Fire Control – Counter Air (NIFCA) system work to address some of the existing and projected deficiencies in the fleet, but gaps will remain.

The ability of the PLA to surge large numbers of aircraft to conduct offensive and defensive air operations, and the potential for reduced U.S. ability to operate from closer-in, land-based air bases, complicates U.S. air warfare concepts of operation. Assuming a notional, stressing mission case in which carrier fighters were called on to provide Offensive Counter-Air/Escort support for Air Force bombers, the PLA's Air Force and Navy would be credibly capable of employing at least 425 fourth generation fighters to conduct operations out to 400 NM from China's coast and 160 advanced fourth generation fighters that could conduct operations beyond 600 NM from from China's coast, if they were alerted.[92]

In contrast, a group of three CSGs could only generate 56 fighters (using organic tanking) and 112 fighters (using Air Force tanking) to conduct Offensive Counter-Air or Escort missions out to 1,000 NM from the carrier. A group of six CSGs would still be outnumbered in the number of fighters it could generate if it relied on organic tanking, but would slightly outnumber enemy fighters with over 600 NM ranges if it relied on Air Force tanking. As the number of PLA advanced fourth and fifth generation aircraft grows, this deficiency would increase the risk posed to U.S. forces, not only because of the number and sophistication of enemy threats, but also because long-range fourth and fifth genation aircraft could disrupt U.S. aerial refueling operations, making long-range missions by carrier aviation even more challenging.

This analysis demonstrates the crucial role of the carrier air wing in conducting air warfare missions, while at the same time showing its limited size compared to numbers of aircraft that can be generated by a continental enemy.

[92] This analysis assumes that 60% of PLA Air Force and Navy aircraft are dedicated to operations in the theater of operations, that 20% of all PLA aircraft are undergoing maintenance at any point in time, and that 20% of available fighters are dedicated to Defensive Counter-Air missions. Assuming PLA forces selected when to execute a desired campaign and had husbanded their forces in preparation for that campaign, or assuming the PLA dedicated more than the modest 60% of their inventory to this campaign, the number of aircraft capable of countering U.S. aircraft could be significantly higher. Operating the carrier closer to the engagement area would increase the number of aircraft that could be sortied. Analysis of CVW capacity uses a similar methodology to that presented in the Carrier Strike Capability section of this report.

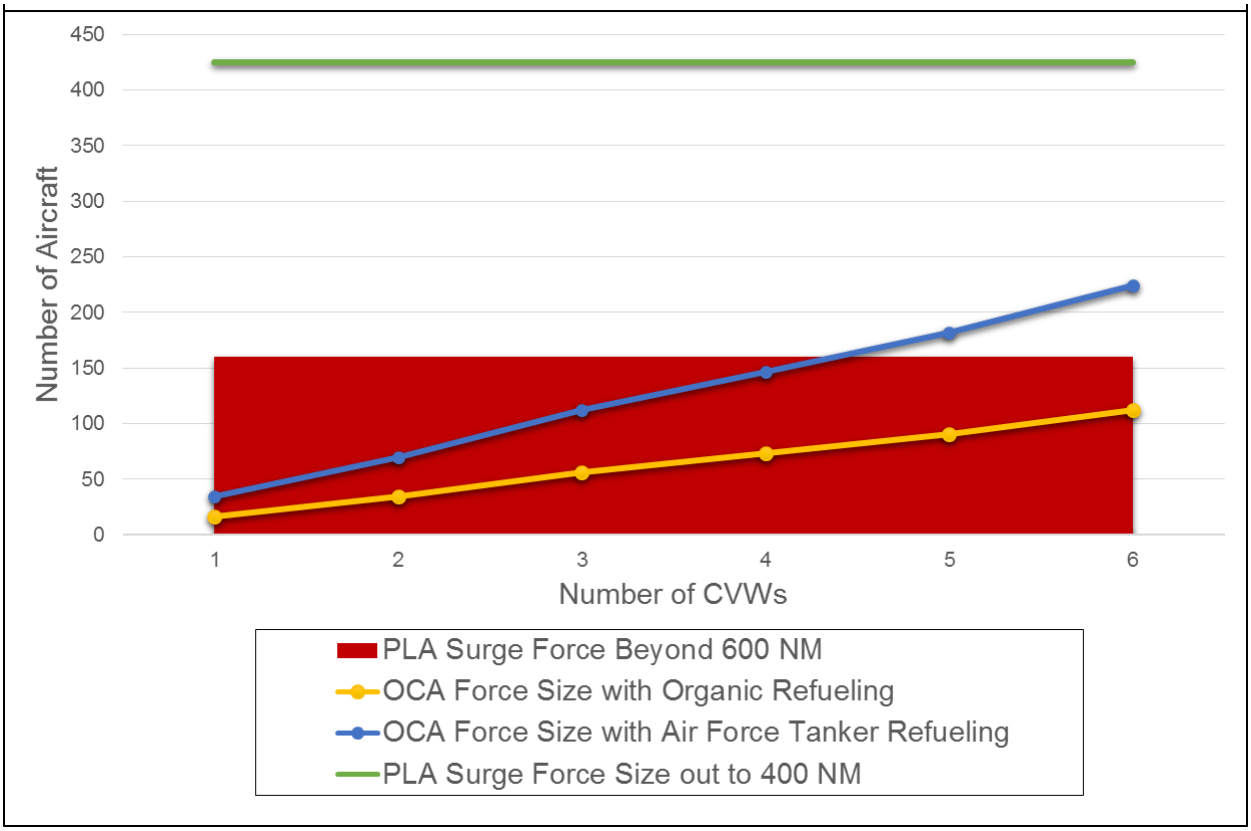

Figure 8: Comparisons of U.S. CVW and PLA Surge Force Generation Capacity

It also suggests a few implications for U.S. forces. First, carrier aircraft should be husbanded for select pulse operations, instead of being allocated piecemeal for smaller steady-state support missions, such as forward DCA patrols. Such an employment of carrier aircraft will increase the likelihood U.S. aircraft can achieve numerical superiority for a desired location and time period. Second, the analysis shows how U.S. aerial refueling concepts of employment are vulnerable to disruption, increasing the importance of future U.S. air superiority fighters with long ranges. Third, this analysis demonstrates the importance of degrading enemy broad-area ISR. Fourth, this analysis demonstrates the importance of maximizing the number of embarked aircraft on carriers, as deploying air wings are significantly smaller (in terms of numbers of aircraft) than can be accommodated. Fifth, this analysis demonstrates the continued importance of integration with the Joint Force for air operations. This argument has several facets.

Given the potential quantitative superiority of enemy fighters in many situations, the ability of the U.S. Air Force to generate fighter sorties from short or medium-range air bases should continue to be prized and should be made more resilient to counter A2/AD threats to air bases. Additionally, Air Force tankers

Ship Class	Number	Fuel Storage (barrels)	Ordnance Storage (tons)	Speed (knots)
T-AO 187	15	180,000	N/A	20
T-AOE 6	3	156,000	1,800	26
T-AKE 1	12	18,000	5,900	20

Figure 9: CLF Ships

significantly increase an air wing's ratio of offensive compared to organic tanking aircraft. Consequently, new concepts that appropriately posture Air Force tankers and their requisite supporting infrastructure should be explored. Furthermore, carrier aviation and other elements of the Joint Force (such as surface or sub-surface launched missiles and electronic warfare assets) should play an important role in degrading an enemy's ISR picture and air base operations, thus complicating enemy efforts to mass air assets to counter attacks.

Underway Replenishment (UNREP): The CSG's ability to replenish fuel, munitions, and supplies at sea provides it with an extraordinary level of endurance to conduct persistent military operations against an enemy. Supplies are moved from CLF ships to combatant ships by several processes for connected replenishment and vertical replenishment (with helicopters) known collectively as UNREP.[93]

Before the end of World War II, over a fifth of the U.S. Navy's 1,000 ships were combat logistics ships capable of UNREP.[94] During the Cold War, the 600-ship Navy plan programmed a CLF of 15 station ships that would form part of a Carrier Battle Group. These 15 station ships would be supplied by 10 Underway Replenishment Groups, which consisted of two oilers, a stores ship, and an ammunition ship.[95] During conventional contingencies, Underway Replenishment Groups would be refueled from a network of nearby Advanced Bases. By 1989, the CLF consisted of 56 ships.

The 2015 CLF force consists of 29 ships of three classes: 15 oilers (T-AO), 2 fast combat support ships (T-AOE), and 12 dry cargo/ammunition ships (T-AKE).[96] Two

[93] "Combat Logistics Force," Military Sealift Command, http://www.msc.navy.mil/pm1/
[94] Williamson Murray and Allan R. Millett. *A War to be Won*, Cambridge: Belknap Press, 2001, 337.
[95] John F. Ince. *Transitioning the Combat Logistics Force into the 21st Century*, Alexandria: Center for Naval Analysis, CRM 98-69/May 1998, 10–16.
[96] The Navy's 30-Year Shipbuilding Plan aims for a CLF inventory total of 29 ships from FY2016 to FY2045. "Report to Congress on the Annual Long-Range Plan for Construction of Naval Vessels for Fiscal Year 2016,"
Office of the Chief of Naval Operations, March 2015, http://news.usni.org/wp-content/uploads/2015/04/FY16-30-Year-Shipbuilding-Plan.pdf#viewer.action=download.

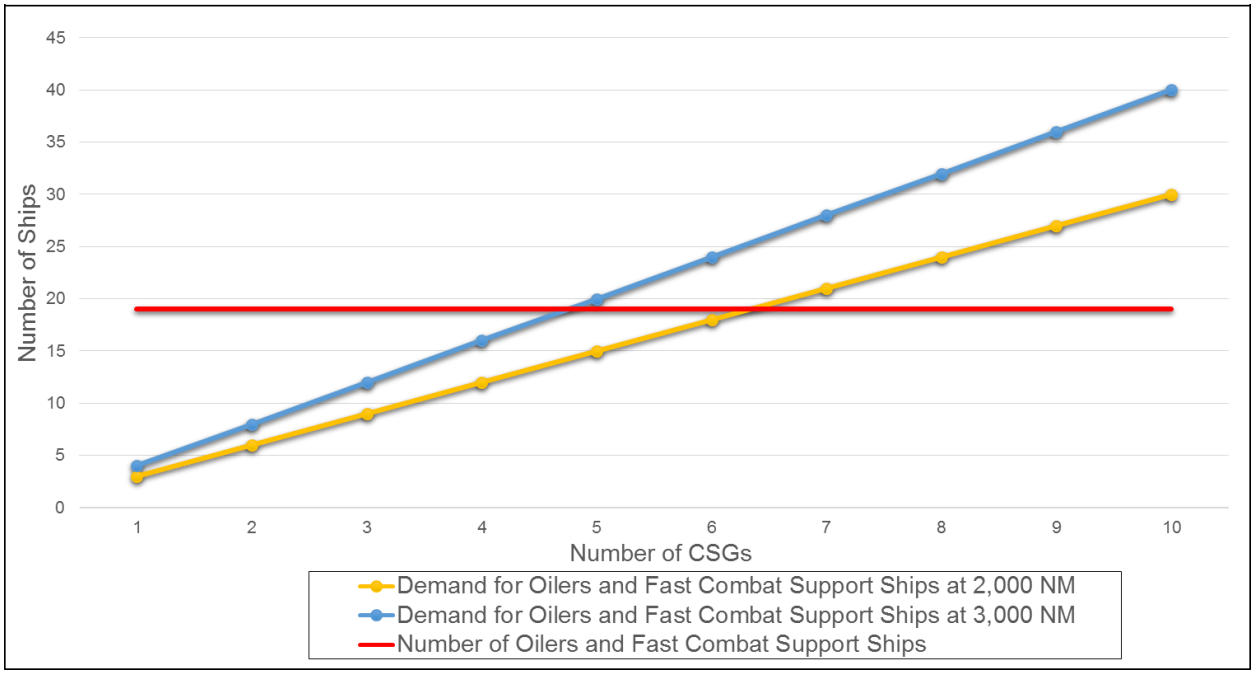

Figure 10: CLF Capacity and Demand for Refueling CSGs 2,000 and 3,000 NM from Advanced Bases

additional T-AOE fast combat support ships have been placed in Mobility Status B - Out of Service In Reserve (OSIR) and could be called up in 6 to 9 months during a major contingency. As of 2002, the CLF was sized according to the two major theater war planning construct (Korea and Southwest Asia), providing planners with access to shuttling oilers and supply ships from nearby bases in Japan, Bahrain, and Oman for contingencies in the respective areas.[97] Current CLF models assume CLF ships will be able to provide a steady supply of fuel, munitions, and stores from a network of nearby Advanced Bases to CSGs. This shuttling model increases the likelihood that many of these critical supply ships will fall outside of a CSG's protective umbrella.

Analysis performed in 2002 validated a requirement for 30 CLF ships, nearly equal to the 2015 fleet size.[98] This analysis went on to state, however, that using more stressful planning factors that do not assume major fleet bases near potential contingencies, and that anticipate the development of a potent Chinese sea control threat, would result in a significantly higher wartime requirement for CLF ships.[99]

Basic analysis demonstrates the Navy's potential capacity shortfall during a major

[97] Robert O. Work. "The Challenge of Maritime Transformation: Is Bigger Better?," Center for Strategic and Budgetary Assessments, 2002, 122.
[98] Ibid.
[99] Ibid.

conflict.[100] For instance, if CSGs were able to operate 2,000 NM from Advanced Bases, CLF oiler and fast combat support ship capacity would begin to be outstripped by demand at approximately six CSGs. If, however, logistics Advanced Bases were pushed back to 3,000 NM from CSGs because of threats, denied political access, or operational bottlenecks at closer bases, the requirement for CLF ships would further increase, causing a gap at less than five CSGs. This capacity gap is observed in CSG operations, yet may be an even greater concern for the operation of other fleet units such as amphibious ready groups and surface action groups, which have smaller fuel and munitions stores. Additionally, if future carrier variants move away from nuclear power, this problem would be significantly exacerbated. Lastly, this analysis does not examine CLF requirements for other, non-CSG U.S. ships operating in the AOR or forces operating outside the AOR, both of which would significantly increase CLF demand.

In addition to the capacity gap, UNREP operations face three other major challenges during conflict with a near-peer enemy such as China. First, unescorted CLF ships or tanker and cargo ships that fuel and supply advance CLF ships and bases are vulnerable to enemy attack by air and missile systems or submarines. People's Liberation Army operational guidance theory explicitly calls for Active Strategic Counter-Attack on Exterior

[100] This analysis makes the following assumptions. First, a CSG normally consists of a carrier, a cruiser, an attack submarine, two destroyers, and a T-AOE fast combat support ship (or a T-AO 187 oiler and a new T-AKE dry cargo/ammo ship that both substitute for the T-AOE). In aggregate, the carrier, cruiser, and destroyers normally carry approximately 150,000 barrels of aviation and ship fuel. (Miller, 13) Using fuel consumption levels equivalent to operations conducted during Operation Desert Storm, a T-AOE could provide enough fuel for approximately 6 to 7 flying and steaming days for the CSG, before the T-AOE would need to consolidate fuel from an oiler shuttling from an Advanced Base. (Miller, 13) Second, this analysis assumes all four T-AOEs are active, instead of the current state in which two are in OSIR. Consequently, if an Advanced Base was within 2,000 NM from the combat zone, it would require two oilers shuttling to and from the T-AOE to meet the 7 day cycle, because the shuttle cycle lasts 12 to 14 days. With the Advanced Base 3,000 NM from the combat zone, it will require three oilers shuttling to meet the 7 day cycle because the shuttle cycle lasts 17-20 days. This conservative analysis does not assume delays at or destruction of advanced bases, or the threatening or destruction of CLF ships (or supporting tankers transiting to Advanced Bases). In addition to intentional threats, constraints in infrastructure could limit operations. For instance, in Guam's Apra Harbor the fuel loading/offloading facility can only accommodate two 180,000 barrel tankers at any one time. Any of those factors could significantly retard this process and increase the number of necessary CLF ships. This analysis also does not capture the operational benefit gained by operating T-AOE ships in a CSG over T-AO ships, or the potential increase in fuel consumption if CSGs operated at higher speeds than during Operation Desert Storm in order to confound enemy targeting. As countervailing factors, at higher numbers of CSGs (above eight for instance), it is unlikely all CSGs would be engaged in flight operations simultaneously, thus decreasing their demand on the CLF force. This analysis also does not take into account the likely effects of attrition on U.S. forces in decreasing CLF demand. Overall, effective operation of a CSG in a high tempo environment would require constant resupply of it and its supporting ships. For a more detailed model of CLF operations, please see: Gerald G. Brown and W. Matthew Carlyle. "Optimizing the US Navy's Combat Logistics Force," DOI 10.1002/nav.20318,October 21, 2008, http://faculty.nps.edu/mcarlyle/docs/browncarlyle2008nrl.pdf.

Lines.[101] These operations would seek to target the soft logistical and command and control network upon which the main force relies. Were CLF, tanker, or cargo ships escorted, this demand would require surface combatant escorts, diverting them from other missions. The loss of critical CLF ships risks starving a CSG of its necessary fuel, munitions, and supplies, forcing it to withdraw from an operational area to resupply.

Second, the Navy lacks a capability to conduct underway replenishment of the MK 41 VLS for surface combatants. Although the original development of VLS included a "requirement to replenish ten VLS canisters per hour, day or night in Sea State 5 conditions", tests demonstrated the crane "did not have the capacity to lift Tomahawk VLS canisters; SM-2 VLS transfer rate was three per hour; and the pendulum action of the crane limited UNREP to Sea State 3 conditions."[102] Consequently, the VLS crane was removed from surface combatants and rearming of VLS is only performed in port. This weakness effectively means that a CSG's combat endurance lasts only as long as the size of the magazines of its surface combatants, which could be rapidly depleted in high-end missile exchanges.[103]

Third, the land-based logistics system would be under threat both from kinetic and non-kinetic attack. The PLA has expended considerable effort penetrating the U.S. Transportation Command and Defense Logistics Agency's (DLA) networks.[104] During conflict, this exploitation would likely attempt to deny use of the logistics network, generate deceptive orders that reduce system efficiency, or use the logistics network to track likely U.S. military operations. Furthermore, land-based warehouses, munitions depots, and fuel infrastructure are vulnerable to air, missile, and paramilitary/special forces attack. The DLA's general trend of reducing the number of fuel Underground Storage Tanks in operation in the Pacific has accentuated this vulnerability. Additionally, while DLA has sought a more distributed fuel storage and distribution architecture in the Western Pacific, it has focused its efforts on developing more storage within the First Island Chain, vice the Second Island Chain or Central

[101] Anton Lee Wishik II. "An Anti-Access Approximation: The PLA's Active Strategic Counterattacks on Exterior Lines," 2011 World Security Institute, China Security, Issue 19, 37-48.
[102] Marvin O. Miller. "Underway Replenishment System Modernization," Unrep System Engineer, Port Hueneme Division, NAVSEA, 15.
[103] N.B. In theory, in a large CSGs with multiple carriers and surface combatants, surface combatants could be cycled through the force as their VLS magazines ran low. In practice, uneven and unpredictable expenditure of VLS weapons on surface combatants during battle would increase the pressure on a CSG commander to withdraw to fully replenish its stores—especially in a high threat environment.
[104] Bill Gertz. "Chinese cyber attacks on Transcom reveal wartime plans to disrupt U.S. military logistics," FLASH Critic, September 21, 2014, http://flashcritic.com/chinese-cyber-attacks-transcom-reveal-wartime-plans-disrupt-u-s-military-logistics/.

Pacific.[105] Were a conflict to take place, many of these locations would be more vulnerable to attack.

Overall, the Navy's current CLF capacity and capability would be stressed in a high-end scenario involving at a minimum six CSGs, and any attrition suffered by that force would rapidly impact force operations. This poses a significant weakness in the effects chain of the CSG and other components of the Navy.

Attrition and Repairs: Although the CSG has robust defenses, it is possible its ships and aircraft will incur damage and losses during the course of a campaign. U.S. Navy ships, in particular carriers, train extensively to control damage to a ship and maintain combat readiness even after hits. However, the scale of potential damage and losses to a CSG during conflict with a near-peer adversary poses significant challenges.

First, as stated by the Defense Science Board, the *Nimitz* and *Ford* Class carriers are the only "surface ship [classes] now in the U.S. Navy designed and built to be survivable. The ship design encompasses many features (such as armored flight deck, double hull, magazine location, and shock-absorbing structures) intended to allow the ship to sustain multiple hits by missiles or torpedoes, yet survive."[106] Nonetheless, significant bomb or missile strikes to the carrier's armored aviation deck could result in a mission kill of the platform. For instance, "although a *Nimitz* Class CVN is designed to survive multiple (three to five) torpedo hits, even a single hit will probably result in mission-terminating damage."[107] This reduction in capability would not only decrease the contribution of the CSG to the Joint Force, but also it would increase the risk to the CSG as necessary sea control aviation sorties during the carrier's retrograde could not be conducted. Given the size and draft of carriers, significant repairs could only be conducted at a limited number of locations, pulling the carrier out of a theater for an extended period of time. During the Cold War, the Navy divested itself of its World War II capability to conduct ship repairs at floating dry docks at advanced staging bases in islands or atolls.

A second major challenge during combat losses would be the search and rescue of downed aviators. Although the CSG can conduct search and rescue of downed aviators using its organic MH-60S helicopters, the MH-60S's combat radius of approximately 150 NM limits rescues to a limited zone near the CSG.[108] Envisioned operations requiring

[105] Terry Shawn. "Pacific Shift," Defense Logistics Agency, June 2, 2015, http://www.energy.dla.mil/Pages/PacificShift.aspx.
[106] "Defense Science Board Task Force on the Future of the Aircraft Carrier," Office of the Undersecretary of Defense for Acquisition, Technology, and Logistics, October 2002, 60.
[107] "Ibid, 57-58.
[108] "MH-60S," Lockheed Martin, http://www.mh-60.com/mh-60s/.

flying hundreds if not over a thousand nautical miles from the carrier leaves a gap where either the CSG must rely on other forward-deployed assets or develop new capabilities or employment concepts. During the Battle of Britain, Great Britain's relative superiority rescuing its downed airman gave it a key advantage over the Luftwaffe. Likewise, although never anticipated, the U.S. submarine fleet in the Pacific rescued 520 downed aviators.[109] Given that high loss rates would likely be an element of air combat against a near-peer threat, addressing this gap must be a high priority.

In summary, CSGs would face major, multifaceted threats in operations against a mature A2/AD threat, such as China. Although many of these threats could affect units other than the CSG, the CSG's important role in power projection operations makes it a valuable target and the carrier's large signature makes it relatively vulnerable to detection. Despite these threats, assessment of the role of CSG's in counter-A2/AD operations demonstrates both their significant utility and significant weaknesses in the near term. Using a combination of novel defensive capabilities and astute tactics, CSGs can play an instrumental role for the Joint Force. Informed by this analysis of the role of the CSG in the Joint Force, the next section of this report provides a number of recommendations to improve the CSG as a system.

[109] Rolfe L. Hillman. "A Focused Narration of the Silent Services' World War II Lifeguard Operations," Undersea Warfare, Summer 2014, Issue No. 55.

VI. IMPROVING THE CARRIER STRIKE GROUP AS A SYSTEM

As a result of the great distances between its landmass and its security interests, the United States requires a large, powerful Navy, capable of projecting power from the sea thousands of miles from the ports from which that power originated. Naval air power provided by the air wing from the large-deck aircraft carrier plays a key role in both sea control and power projection operations and provides critical capabilities for strike, surveillance, and air warfare that many other elements of the Joint Force would face difficulty providing—especially against a peer or near-peer threat. In short, the Joint Force needs and demands sea-based air power provided by the carrier. However, the CSG as a system faces major constraints and vulnerabilities that limit its campaign utility to the Joint Force, and these vulnerabilities must be addressed in order to provide the Joint Force with the capabilities required.

In order to ensure the CSG as a system and the Navy in general is prepared to deter and defeat aggression, major changes are needed. The Navy must develop new concepts and capabilities for the employment of the CSG, some of which will be disruptive of current plans, programs, and paradigms. However, the alternative is a rapidly weakening force that incurs greater operational risk not only for itself but also for other components of the Joint Force. Prudent course changes can ensure that the CSG remains the Navy's most effective method of providing its contribution to national security and prosperity.

CSG CONCEPTS OF EMPLOYMENT

Innovative employment of the CSG that capitalizes on its mobility, flexibility, and sustainability should be developed and exercised. Several options follow.

Power Pulse: In the absence of a robust sea control threat over the past few decades, CSG

operations have sought to establish a sanitized, relatively mobile "seabase" for conducting steady-state support to the Joint Force through strike operations. Under this concept, by cycling carriers on station, CSGs could conduct nearly constant strike operations (including Close Air Support), Air Warfare patrols, and electronic attack coverage. China's maturing A2/AD complex, as well as the networks being developed by other adversaries such as Russia, Iran, and Syria, directly challenges this notion of CSG operations.

In response, important new operational concepts such as the Air-Sea Battle (ASB) Concept seek to leverage improved inter-Service collaboration and integration to counter A2/AD threats. The ASB Concept's operational approach to the A2/AD threat is to "develop networked, integrated forces capable of attack-in-depth to disrupt, destroy and defeat adversary forces (NIA/D3)."[110] Additionally, the ASB Concept recognized the importance of protecting rear echelons of the Joint Force against longer range and more precise weapons.[111]

However, the ASB Concept and subsequent concepts such as the Joint Concept for Entry Operations often sought to describe necessary actions by the Joint Force to enable parallel or series power projection operations.[112] Under this paradigm, new operational concepts (ASB) would create conditions for the return of U.S. naval forces to the execution of traditional CONOPS. In other words, U.S. forces would degrade the A2/AD threat to the extent necessary to establish an environment for conducting steady-state operations from the traditional, protected, mobile seabase.

The nature of near-peer and potentially future peer threats such as China has called into question this shaping approach, and two factors combine to undermine it. First, although a traditional "rollback" campaign that seeks to gradually geographically push back an enemy's effective reconnaissance-strike complex and ASB's NIA/D3 approach that seeks to systematically disrupt, destroy, and defeat the reconnaissance-strike complex have merit and should be pursued as possible, advanced threats such as China may pose effective residual threats even after much of their capability has been either rolled-back or degraded under an NIA/D3 approach. These capabilities could be cued by a number of surveillance systems that are difficult to fully suppress, ranging from commercial satellites to tattle-tale fishing and merchant vessels. Consequently, a "fleet in being" of land or sea-based weapons that are difficult to target

[110] "Air-Sea Battle: Service Collaboration to Address Anti-Access & Area Denial Challenges," Air-Sea Battle Office, May 2013, 4.
[111] Ibid, i.
[112] Ibid, 4.

(such as effectively hidden Transporter Erector Launched missiles or deep-water mines) could continue to threaten naval forces within a large threat envelope, even after much of the enemy's search and strike capability had been degraded.[113] This persistent threat undermines both the "rollback" approach and the shaping approach that ASB appears to suggest.

A second factor that undermines the shaping approach is the likely development trajectory of adversary power projection forces. Air and naval power projection forces could potentially deploy from an enemy's continental landmass and present a challenging, multi-axial threat that endangers close-range, steady-state sea base operations.

Consequently, the Navy should develop a conceptual paradigm for how to employ CSGs without a near term goal of consolidating at a sanctuary point. In response a concept of pulsing combat power—or what has often been called "hit and run" tactics should be explored for use against mature A2/AD threats. Carrier Strike Groups would operate at the periphery of an enemy's A2/AD volume, employing long range weapons against selected targets, before high speed movements in radio silence (emissions control) to the next operating area. By repositioning frequently at range, CSGs would increase an enemy's required search area and consume available ISR resources. Additionally, by operating at greater distances, CSG operations would leverage external lines of communication to dislocate enemy operations ashore and at sea. For example, CSGs could emerge to provide short, intense pulses of strike, air warfare, and sea control firepower to disrupt enemy operations and attrite enemy force structure. These operations contribute to degrading an enemy's reconnaissance and strike capability, while retaining the ability to dynamically operate from range. At the same time, by operating from range, CSGs force an enemy to stretch its own tactical effectiveness. For instance, operating from range improves the effectiveness of defensive tactics such as Silent SAM and concepts such as Outer Air Battle.

CSG Power Pulse operations would have significant implications for necessary capabilities, including changes to the make-up of the air wing, an increase in the demand for fuel and supplies to support higher-tempo, multi-location maneuvering and flight operations, an increase in the demand for CSG-independent ASW forces to conduct multi-location ASW precursor operations, and implications for other components of the Join Force. For instance, it is likely that CSGs would provide significantly fewer steady-state Combat Air Patrols over or near forward land-bases if executing hit and run tactics. This

[113] Julian S. Corbett. *Principles of Maritime Strategy*, Westford: Courier Corporation, 2012, 222.

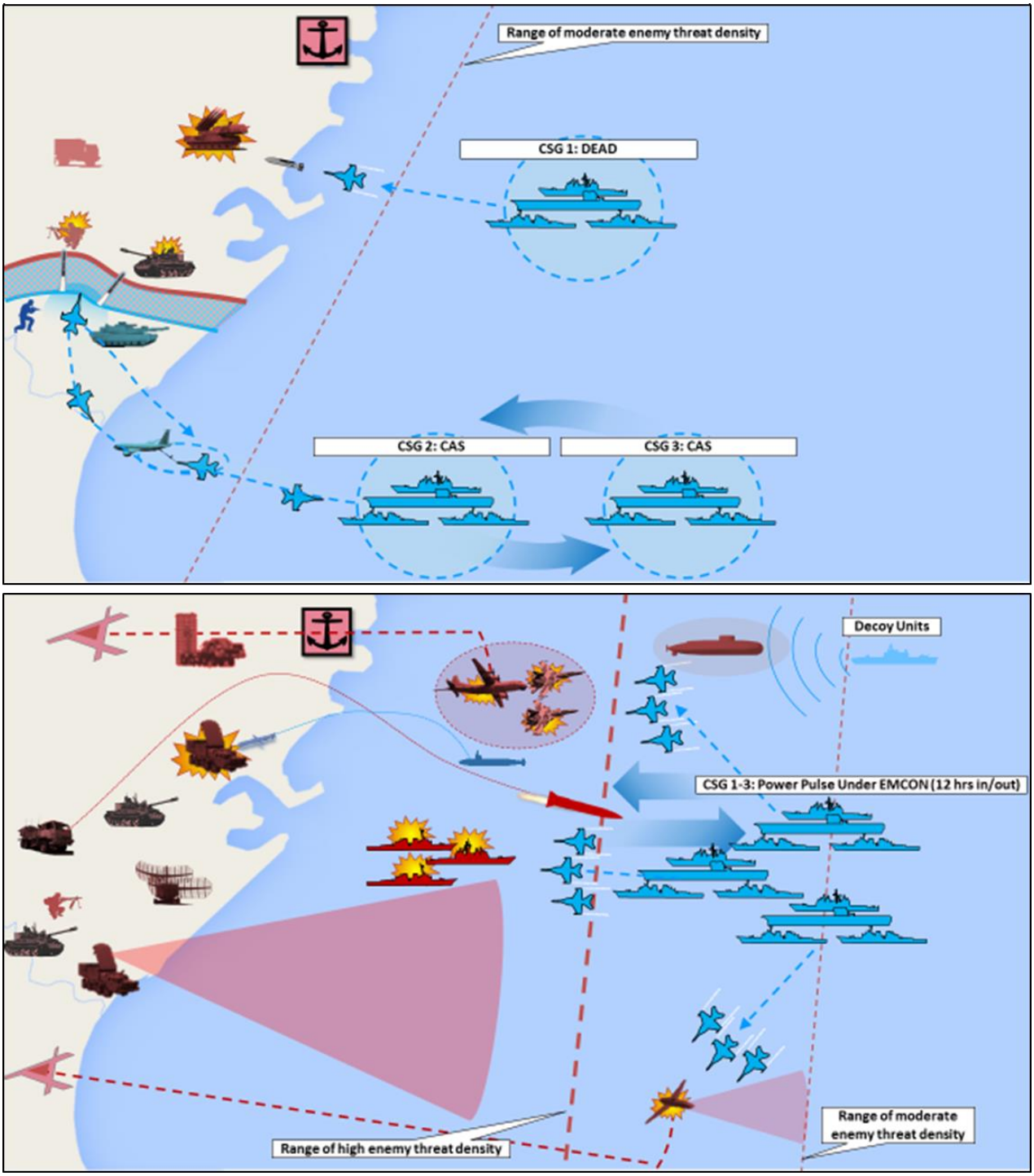

Figure 11: Persistent Support vs Power Pulse

would increase the relative importance of Army Air and Missile Defense units and Air Force tactical fighters protecting forward land-bases. On the other hand, by operating at greater distance from adversary strength, CSGs could play a larger role protecting

distant advanced and intermediate bases by offering an air warfare capability that could be cued to intercept inbound or egressing enemy strikes. In the Pacific, this would entail using CSG air cover to augment Army and Air Force defense of Second and Third Island Chain locations. Finally, the high speeds and distances required by this concept are greatly enabled by nuclear power, as conventionally powered carriers attempting this concept would require frequent refueling from an already thinly stretched logistics force.[114]

Integrated Multi-CSG Operations: A conflict in the Western Pacific will undoubtedly summon forth much of the Navy's carrier force. In order to maximize the combat power generated by numerous CSGs, the Navy should develop more effective doctrine for and regularly exercise the capability (if only at the planning and command and control level) to conduct integrated multiple carrier CSG operations that maximize the full potential of carrier airpower, instead of aggregating multiple CSGs and dividing up fly-days, missions, battlespace, or target lists accordingly.[115]

By operating as groups of mutually-supporting carriers and supporting ships, multiple carrier CSG operations can more effectively meet baseline battlespace dominance requirements and dedicate a higher proportion of the force to offensive power projection and sea control missions. In some respects, the Navy is well-versed in how to conduct multiple carrier operations. Numerous military operations during the 20th and 21st centuries have involved multiple carriers. However, multiple carrier operations frequently involved aggregating individual carriers in order to cycle carriers out of an operating station or coordinating effects, instead of integrating to achieve them together.

Additionally, the rise of Joint Functional Commanders—specifically the Joint Forces Air Component Commander and the Joint Forces Maritime Component Commander—has served to diminish the employment of integrated multi-carrier operations. This resulted from post-Cold War operational habits in which much of the carrier air wing was allocated to the JFACC for overland operations, operations in which the integrated actions of multiple air wings were unnecessary and not a core competency of the JFACC staff. In modern A2/AD conflict, the requirements of the JFMCC will drive an increased need for the kind of large scale integration we suggest.

The proposed approach recommends more effective multiple-carrier coordination over

[114] In Figure 11 (previous page), CAS stands for Close Air Support, and DEAD for Destruction of Enemy Air Defenses. This graphic and others in the CSG Concepts of Employment section are inspired by the style used in Mark Gunzinger and Bryan Clark. "Sustaining America's Precision Strike Advantage," Center for Strategic and Budgetary Assessments, June 25, 2015.
[115] Thank you to Paul Giarra for his insight on this subject.

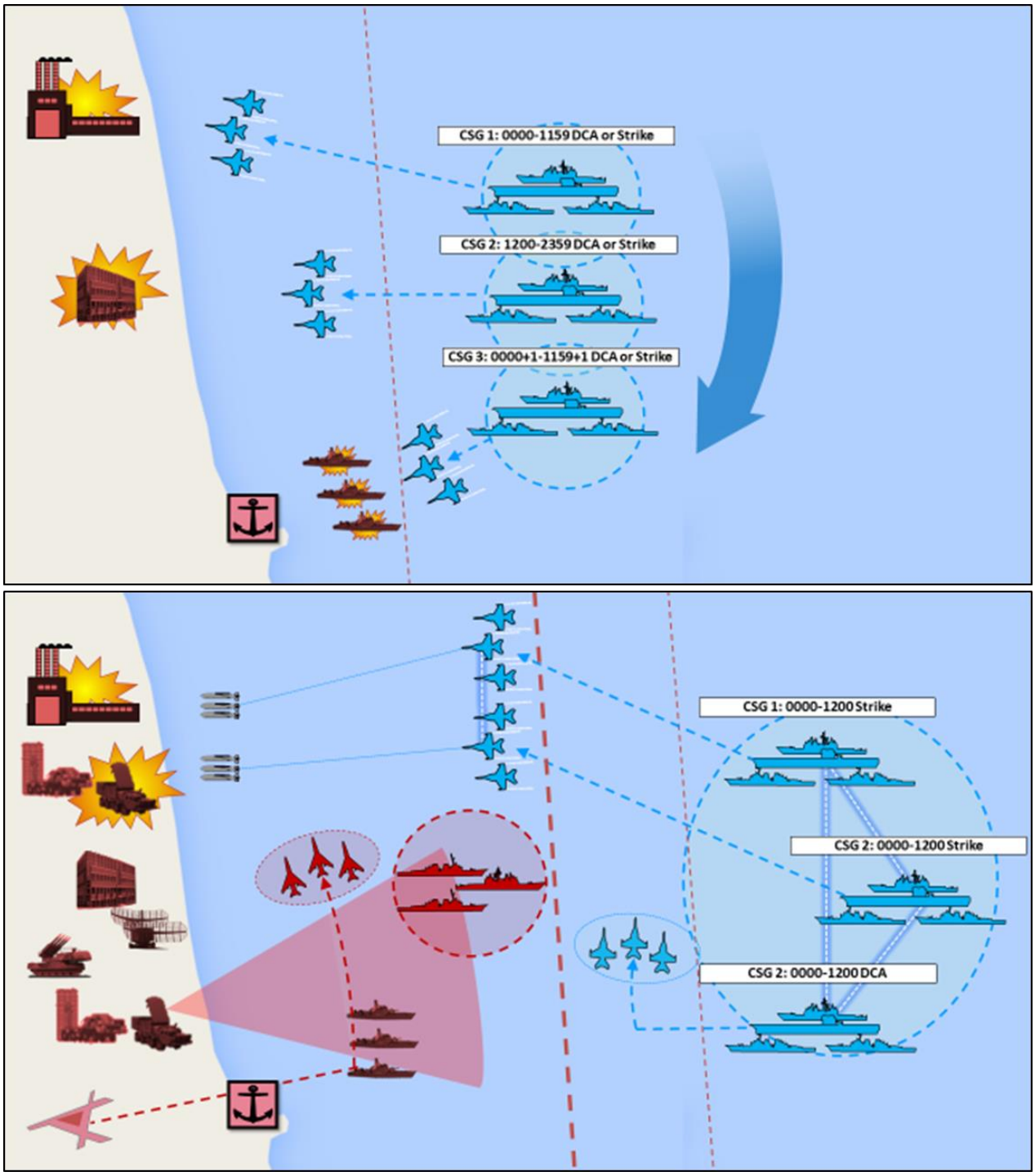

Figure 12: Cooperative vs Integrated Multi-CSG Operations

distance that gains the best advantages of massing effects while dispersing platforms to improve concealment and deception capabilities. This proposed concept has significant implications for command and control systems and procedures, especially in a GPS and satellite communications-denied environment. It also requires increased initial

individual CSG unit hardening in order to ensure that CSGs caught within a high-threat A2/AD envelope at the conflict's start can successfully egress in case of an attack with little or no indications or warning.

It is recognized that the logistics and planning necessary to practice truly integrated CSG operations with three or more carriers is significant, and will be difficult to accomplish without significantly disrupting peacetime carrier global force management goals. However, realistic simulations involving strike group staffs (including air wing and destroyer squadron staffs) could be accomplished ashore on a recurring basis in order to war game concepts of mutual support and massing of firepower among aircraft of different air wings at the same point of emphasis. Lessons learned could be gathered and disseminated, and smaller demonstration events could be undertaken in order to evaluate insights. Multiple carrier operations in the past strove for high levels of coordination. Coordination against a high-end opponent will be insufficient to the task given the scale and complexity of threats. Selective integration of air and missile defense, ASW, SUW, AAW, and strike will be necessary. Additionally, as long as the CVN force remains at current levels, exercising multi-carrier operations would likely require relaxation (perhaps for extended periods) from current Global Force Management requirements for carrier presence.

Renew CSG Emphasis on Sea Control: Although not an operational concept, the Navy should critically examine the burgeoning future requirements for sea control and adequately adjust its programmatic portfolio to meet those threats.

The Joint Force almost exclusively relies on the Navy to counter sea control threats. Although efforts by the Air Force and potentially the Army to develop new or revitalize old sea control and sea denial capabilities should be pursued (to include land-based anti-ship missile systems), ultimately the Navy has responsibility for countering threats to U.S. sea control. Trends suggest continuing growth in both Chinese and Russian sea control and sea denial capabilities, and in response to the National Security Strategy and the Quadrennial Defense Review, the changing threat environment, and the evolving needs of the Joint Force, the Navy should begin to focus more CSG capabilities on sea control. A continuing capability for long-range strike is essential for CSG operations and Joint Force success, as long-range strike is essential for both power projection and sea control, and highly mobile CSG strike capabilities introduce a significant level of uncertainty for enemy operational planners. However, with increased emphasis on sea control requirements, the Navy should address the emerging gap in counter-sea control capabilities.

Critical sea control missions include strike against land-based anti-ship threats, strike against naval forces, anti-submarine warfare, maritime surveillance, and air warfare. This sea-control focus has implications for aircraft acquisition, (placing a priority on a new air superiority fighter, sea control aircraft and weapons, and carrier-based strike and surveillance capabilities), the size and composition of the CLF, the capabilities of escorting and independently operating surface combatants and other naval forces, and the general need for operations from increased range.

Develop Single Naval Battle: In 2012/3 the Navy and the Marine Corps developed a concept titled Single Naval Battle that sought to develop concepts and capabilities to improve Navy/Marine Corps integration.[116] By creating a moving "bubble" of maritime power in which Navy and Marine Corps weapons and systems are integrated under a single Maritime Commander, and command and control scheme, Single Naval Battle creates an optimized base of adaptive force package operations in which the capabilities of the two Services are leveraged. At this point in 2015, it is unclear what the status of Single Naval Battle is, and both Service Chiefs who began the initiative have been replaced. The size of the theater, the historic operational experiences between the Navy and the Marine Corps, and the synergy available to the Maritime Commander with the full use of all the capabilities at his disposal argues strongly for continuing to develop this idea.

The concept has increased relevance in light of growing Chinese power projection and sea control capabilities. These Chinese capabilities would enable the seizure of territory (to include areas currently subject to Chinese artificial feature construction efforts) in order to project forward powerful A2/AD systems, effectively increasing China's defensive perimeter in a keep-out tactic designed to further exacerbate U.S. range limitations. The United States' ability to counter that aggression and enter and maneuver within the operational environment is essential, and the Navy-Marine Corps team plays a critical role in the Joint Force.

During such operations, it is possible that CSGs would support Amphibious Task Forces consisting of amphibious landing ships and escort combatants. During the initial stages of an operation, CSG air power would play a critical role by providing pulses of large-scale strike, air warfare, surveillance, and jamming capabilities not embarked on amphibious assault ships (a limitation discussed elsewhere in this report). Conversely, either

[116] Dan Lamothe, Gina Harkins, and James K. Sanborn. "With Pacific pivot, Marines eye 'Single Naval Battle' Strategy," *Marine Times*, April 13, 2013, http://archive.marinecorpstimes.com/article/20130419/NEWS/304190010/With-Pacific-pivot-Marines-eye-8216-Single-Naval-Battle-strategy.

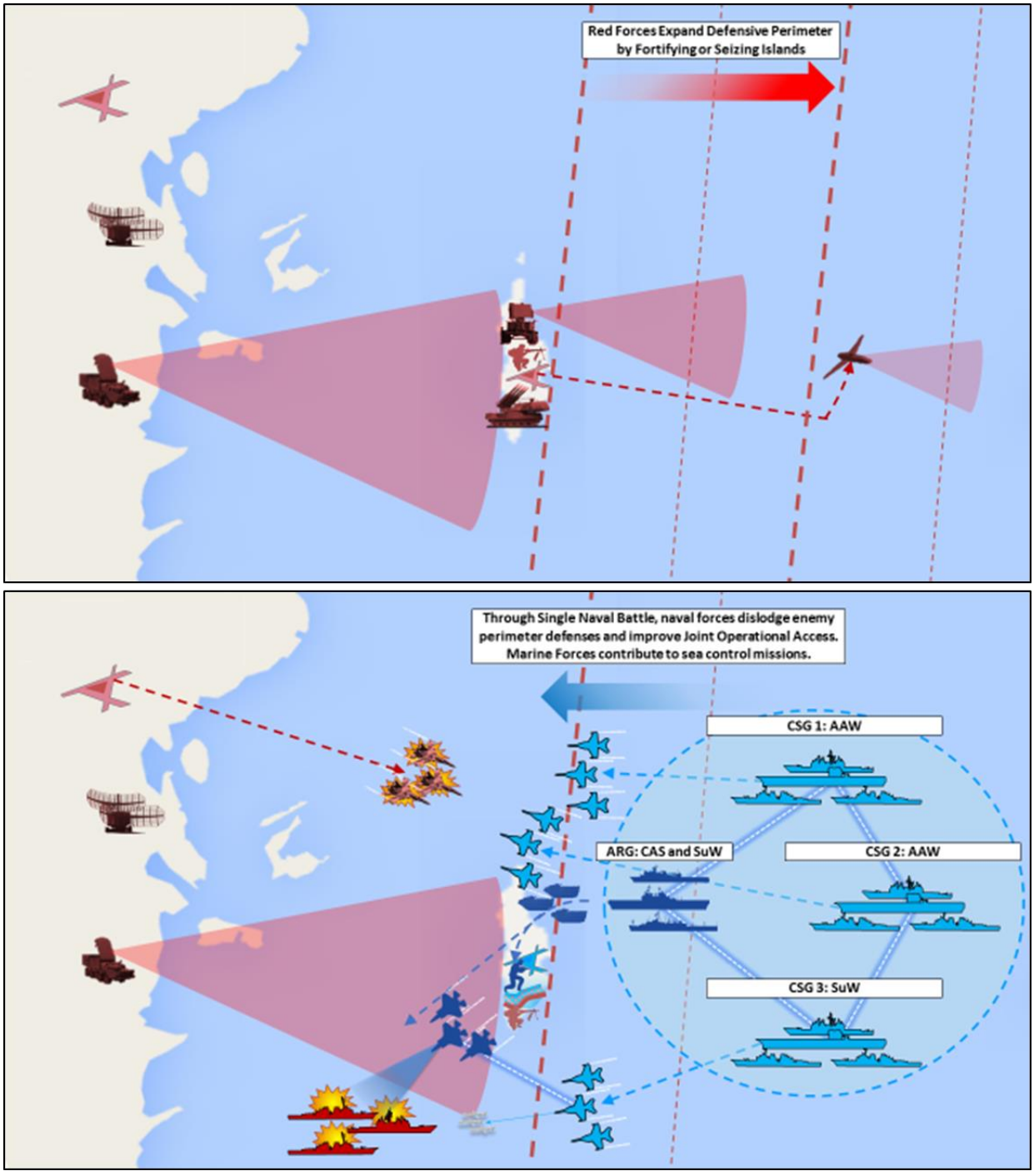

Figure 13: Develop Single Naval Battle

during such amphibious operations or during other periods, Amphibious Task Forces would be integrated into CSG operations to provide surface warfare, maritime security, and air

warfare capabilities.[117]

Distributed Basing Dynamics: The Navy, along with the other Services (the Air Force in particular), should once more develop the capability to operate from a larger number of advanced and intermediate staging bases.

During the Interwar Period, the Navy recognized the enormous logistical challenges involved in conducting Trans-Pacific combat operations, as well as the challenges involved in establishing and defending fixed bases. Consequently, the Navy developed both an UNREP capability and the capability to refuel, rearm, and conduct limited ship repairs at shifting advanced and intermediate staging bases in the Pacific. Under this model, the Navy's fleet logistics train would follow the fleet's main striking force, providing logistical support to the force as it advanced and reducing the requirement for forces to return to Hawaii or the continental United States. During World War II, this capability paid great dividends as the United States exploited a network of advanced bases on islands and atolls to effectively support the force.

During and after the Cold War, the Navy divested itself of this capability and relied more heavily on a network of forward operating bases to provide close-range operational support and maximize forward presence. Currently, a number of forward operating bases and locations on U.S. ally and partner territory face significant A2/AD threats that could significantly degrade their operational effectiveness during conflict. It is important for the United States to learn to operate forward in spite of A2/AD threats; however, trusting that forward operating bases will be available during high-intensity conflict is imprudent and reduces operational flexibility. Developing the capability to operate from a more dispersed advanced and intermediate staging base architecture would significantly improve the resiliency of the force by providing more options for the provision of fuel and supplies, complicating enemy targeting efforts against base infrastructure, and complicating enemy targeting efforts against ships or aircraft operating to or from base infrastructure. By increasing the number of logistical bases, especially ones located farther from an enemy's primary A2/AD threat envelope, security for the Joint Force would improve. Benefits to this capability would be conferred not only for naval forces, but air forces as well. Improving the ability of Air Force aerial refueling and other forces to operate from bases in the Second Island Chain and Central Pacific, for example, would greatly enhance the capabilities of forward

[117] The F-35B operated by the USMC from amphibious assault ships would of necessity be equipped and trained for SUW missions and outer air battle employment to include as part of the NIFC-CA architecture. Additionally, Marine attack helicopters—with sufficient marinization—could contribute to the close in anti-surface/anti-swarm problem that could develop.

operating CSGs.

If the bases were on land, this capability requires Government or Contractor-Owned fuel and/or supply storage sites and appropriate port/offshore fueling and cargo transfer location infrastructure and ships. If the bases were at sea, in an atoll for instance, this capability requires floating transfer systems, and tankers and cargo as well. Both capabilities require additional tanker and cargo ships that have experience operating from these austere locations and adequate defenses.

One additional benefit to the CSG would be the capability to conduct VLS reload in a timely manner, either underway or at protected anchorages or smaller ports. The ability to reload VLS cells would increase the endurance of a CSG, a limitation discussed in the earlier effects chain analysis.

Air Force-Navy Theater Strike: The Air Force and the Navy should continue to develop concepts and capabilities for employing complementary capabilities (such as pairing Air Force bombers with Navy carrier fighter wings) to conduct integrated operations, including strike, against mature A2/AD threats.

Carrier tactical aircraft have escorted Air Force bombers with fighters and electronic attack support in the past. For instance, they escorted B-52s in Operation Linebacker I and II in Vietnam, F-111s in Operation El Dorado Canyon, and B-52s in Desert Storm. More recently, the Air-Sea Battle Office (now called the Joint Concept for Access and Maneuver in the Global Commons) began an effort to more thoroughly pursue opportunities for inter-Service integration. Among other publicly touted capabilities, the Navy and Air Force revealed tests in which an Air Force F-22 provided updated targeting information to a Navy submarine-launched Tomahawk missile.[118] Another foreseeable instance in which carrier aircraft would provide support to the Joint Force arises in the likely case of carrier fighter and electronic warfare escorts being assigned to Air Force bomber aircraft en route to their launch points. Again, the likelihood of large numbers of land-based Air Force tactical aircraft being available for this mission is reduced in the event First Island Chain bases had come under fire, and land based fighters stationed in the rear might not have sufficient endurance to perform the mission. Conversely, improved coordination of the use of Air Force tankers operating from the Second and Third Island Chains in support of carrier operations would greatly enable CSG effectiveness.

[118] Jonathan Greenert and Mark Welsh. “Air-Sea Battle; the challenge we can’t ignore,” U.S. Navy, 2012, www.navy.mil/cno/greenertwelsh_final_asb.docx.

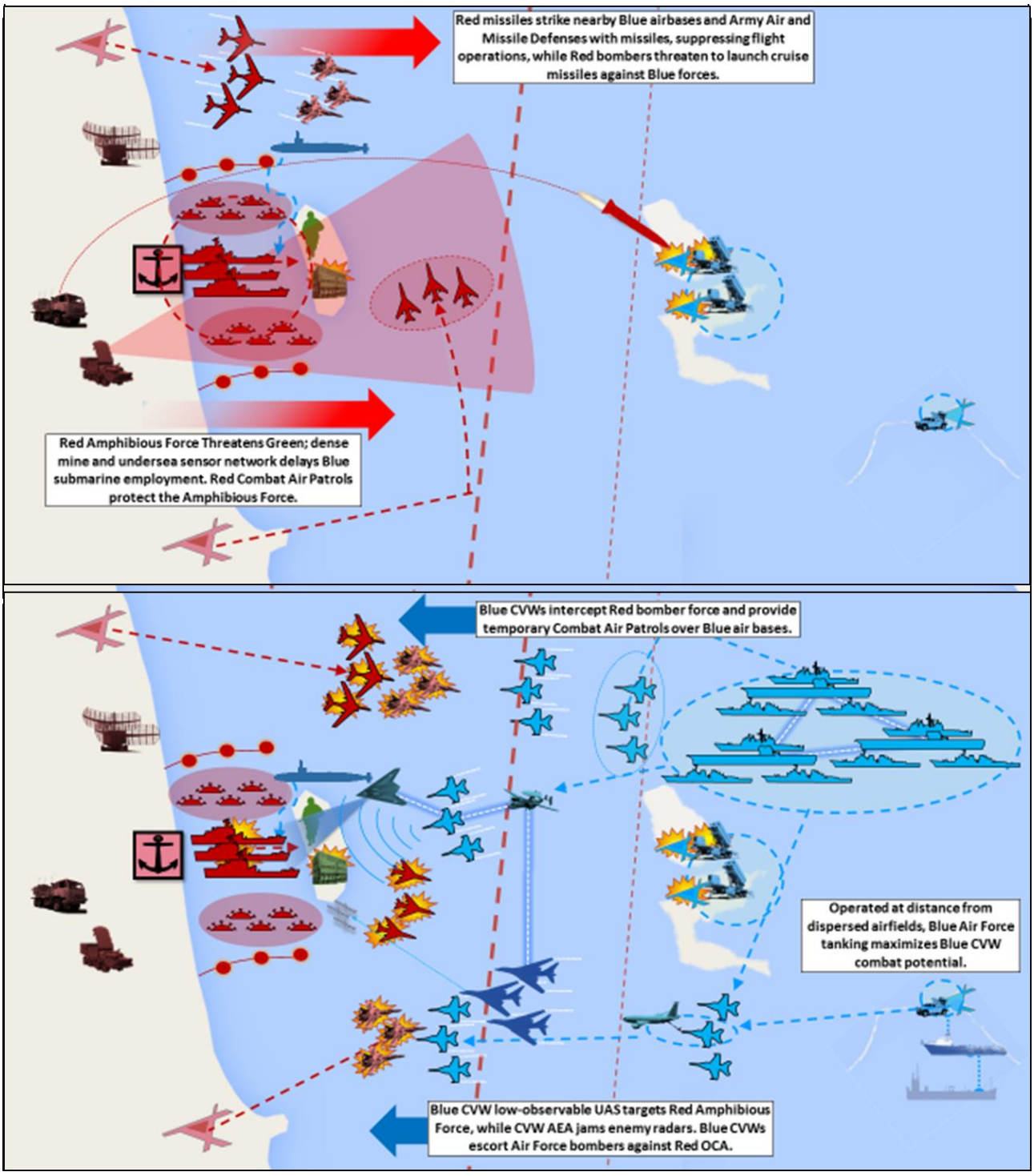

Figure 14: Potential Threats and Employment of Air Force-Navy Theater Strike

The CSG as a system currently faces limitations that hinder its effective employment against mature A2/AD threats, and the development of new employment concepts will assist in addressing these constraints and weaknesses. The six employment concepts

offered should be critically evaluated by the Navy. Opportunities for employment of the CSG that capitalize on its mobility, flexibility, and sustainability should be developed and exercised. However, to fully address the emerging gaps, the development of new capabilities will be necessary.

NOVEL CSG CAPABILITIES

Capability improvements to the CSG can be summarized into four categories: the aircraft carrier; the air wing, other ships in the CSG, and carrier infrastructure and supplies. This analysis identifies improvements to the CSG, while generally eschewing discussion of existing capabilities.

THE AIRCRAFT CARRIER

The *Ford* Class introduces a number of improvements over the *Nimitz* Class that raise the ship's operational performance against advanced threats. These include increased sortie generation capability (of considerable importance in establishing battlespace dominance against advanced sea denial threats), more flexible launch and recovery systems, a more resilient electrical infrastructure, a 250% increase in electricity generation, improved signature reduction (such as a lower overhead infrared and lower lateral radar cross section signatures), and improved hardening.[119] Moreover, the new *Ford* Class has a 7.5 percent weight margin, providing ample capacity for future improvements. [120] In contrast *Nimitz* Class carriers have approximately 1 percent margin remaining; consequently, *Nimitz* carriers cannot incorporate design changes without adopting offsetting weight and stability changes.[121] Moving forward, the *Ford*, *Nimitz*, and future carrier classes should adopt new capabilities that are necessary to address mounting threats to the carrier.

The extended period and cost associated with designing new carriers undercuts arguments for designing a new class for construction in the next 5-10 years. The *Ford* Class, which is based off of the *Nimitz* Class hull, required over a decade of design work, costing $3.3 billion. A new design that diverges from the *Ford* Class hull could take much longer to prepare and require a significantly higher level of cost. Nonetheless, as technology (such as friendly and enemy weapons and aircraft planform design changes), concepts, and requirements change, the role of carriers and the appropriate design should be periodically re-examined. It may be possible that at some point in the future a smaller, or a larger, or a

[119] "Aircraft Carrier Construction from *Nimitz* Class to *Ford* Class," Program Executive Office Aircraft Carriers, Rev 13 (3.6.13), 2.
[120] "Defense Science Board Task Force on the Future of the Aircraft Carrier," Office of the Undersecretary of Defense for Acquisition, Technology, and Logistics, October 2002, 28.
[121] Ibid.

fundamentally different aircraft carrier design would be the best option for the U.S. fleet. In the meantime, carriers can adopt a number of capabilities and practices that would significantly improve combat performance.

With regard to navigation, carriers normally rely on regular radio communication with aircraft and other ships in the CSG. Additionally, carriers make extensive use of satellite precision, navigation, and timing (i.e., GPS). Given major threats caused by and directed against both of these systems, carriers should improve their ability to operate with extensive EMCON. During the Cold War, the Navy developed a robust capability to conduct carrier navigation and complex air operations using radio silence and deceptive measures. The Navy should improve its ability to use active and passive measures to mask its position, while conducting required operations. Similarly, the Navy should improve its ability to conduct operations in a GPS-denied environment. A combination of new capabilities and extensive, CSG-and-above level training is necessary to develop this capability.

In addition to EMCON, there are passive and active systems and measures that can frustrate detection of carriers by adversary surveillance systems. These measures include active, non-kinetic weapons and decoys to disrupt, destroy, and defeat enemy surveillance systems and weapons at various stages of their effects chains. Given the carrier's significant radar, acoustic, and infrared signatures, the development of effective tactics and technologies that counter multiple phenomenology sensor fusion for operational and tactical deception is essential.[122]

Although the air wing is the carrier's most powerful weapon, continued improvement of a carrier's organic defensive weapons merits consideration. The Surface Ship Torpedo Defense (STTD) program (first tested on the USS *George H.W. Bush*) seeks to achieve Initial Operational Capability by 2019, providing aircraft carriers and other high value combatants a defense against torpedoes, especially against challenging wake-homing torpedoes.[123] Its incorporation should be supported and accelerated as possible.

Current CVNs employ three kinetic ship self-defense systems (SSDS): two 8-round MK-57 NATO Seasparrow Surface Missile System (NSSMS), two 21-round RIM-116 Rolling Airframe Missile (RAM), and three Gatling gun Phalanx Close-In Weapon System (CIWS). As directed energy weapons improve, their incorporation on the Navy's carrier fleet

[122] Jonathan F. Solomon. "Maritime Deception and Concealment," *U.S. Naval War College Review*, Autumn 2013, Vol. 66, No. 4.
[123] Sam LaGrone. "Navy Develops Torpedo Killing Torpedo," *USNI News*, June 20, 2013, http://news.usni.org/2013/06/20/navy-develops-torpedo-killing-torpedo. Figure 16 image (following page) drawn from NAVSEA presentation.

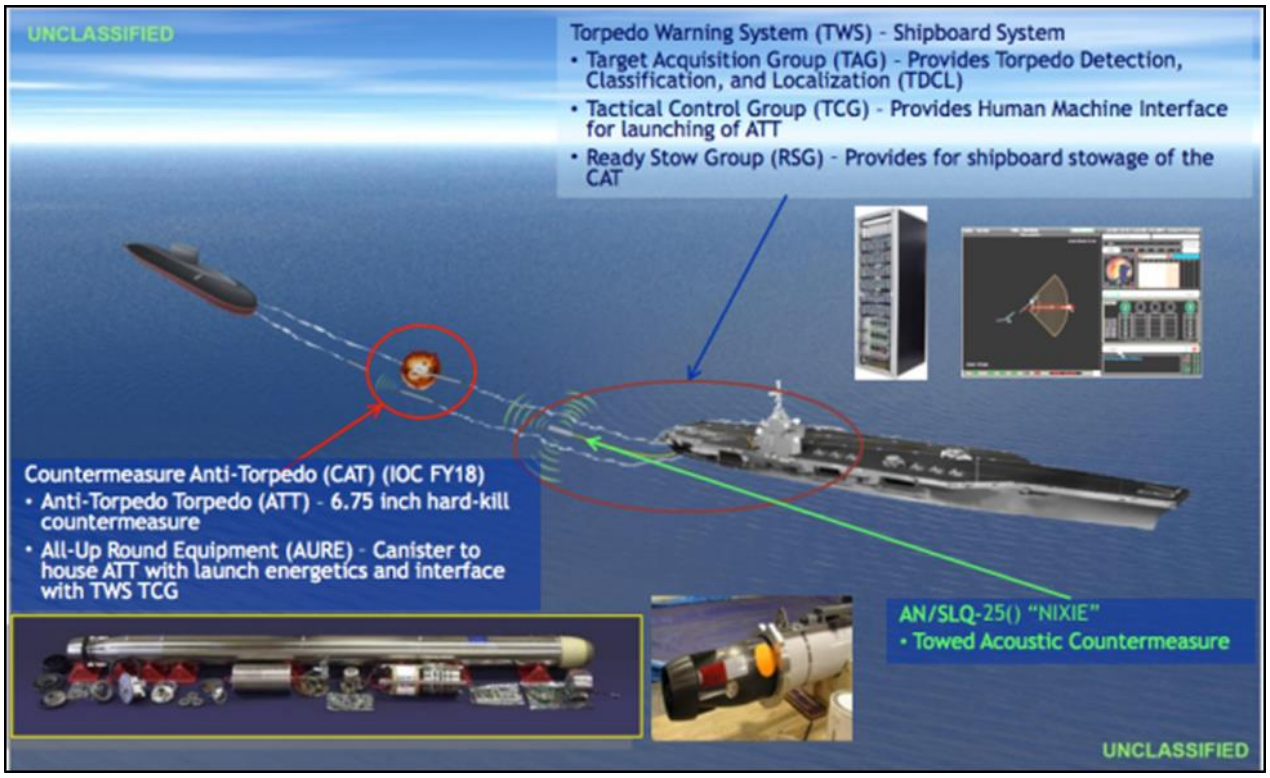

Figure 15: Depiction of STTD

should become a high priority, enabled by these ship's powerful electrical generation capabilities. The *Ford* Class in particular has a 250% increase in available power over the *Nimitz* Class, making it a prime candidate for directed energy weapons. The Navy should continue to evaluate the promise of High-Power Microwave (HPM) systems to engage certain inbound categories of air threats by transmitting microwaves that destroy target electronics. The carrier's large hull and significant electrical capacity could potentially be used to mount large-aperture HPM arrays that could effectively focus HPM beams out to operationally relevant distances and thus improve a carrier's terminal defense capability.

Additionally, one of the ship's three kinetic SSDS could be replaced with a laser. This would require laser systems to have demonstrated sufficient operational reliability in testing and for lasers to emit operationally-relevant power levels. For example, to defeat electro-optical/infrared sensors, UAS, or small boats approximately 100 kilowatts of power is necessary; however, to defeat subsonic cruise missiles approximately 300-500 kilowatts are necessary, and even higher levels are necessary for supersonic

missiles.[124] If the *Ford* Class selects an appropriate radar to replace the Dual Band Radar, two lasers could potentially be placed on the carrier's island, utilizing excess power and chilled water from previous Dual Band Radar infrastructure. The placement of a total of four lasers on the ship would provide overlapping coverage and improved probability of kill.

In the event carriers are successfully struck, recoverability (operating in a degraded condition) is essential. Given mounting threats, improving the capability of the carrier to withstand enemy strikes and continue effective (albeit perhaps limited) operation through both technology and training is critical. In particular, the Navy should develop the ability to more effectively repair significant damage to carrier decks while underway or at advanced and/or intermediate staging bases. This capability is essential to ensure carriers can continue to launch aircraft despite damage and thus continue to provide defensive protection to other ships and assets operating under its aegis. This capability could include organic or pre-positioned storage of adequate pre-fabricated supplies and rapid repair molds and epoxy coatings. Looking toward the future, the incorporation of additive manufacturing devices on carriers could enable the printing of ship and aircraft components, assisting with routine maintenance and battle damage repair.

Finally, the Navy should examine projected capabilities for aircraft operation and maintenance on carriers. The proposed removal of intermediate-level maintenance from carriers for the F-35C should be reexamined. The elimination of intermediate-level maintenance could significantly increase the logistical burden faced by CLF supply ships and the Carrier-Onboard-Delivery (COD) force.[125] Given mounting threats against logistics networks, forces, and forward operating bases, the ability to organically conduct repairs onboard the carrier should be retained. Moreover, the incorporation of future additive manufacturing technologies to carriers could assist with addressing the demand for aircraft parts. Lastly, the Navy should accelerate the incorporation of side-cooling panels on carrier jet blast deflectors during maintenance periods. This will enable all carriers to operate F-35C aircraft without thrust or weight limits.[126]

CARRIER AIR WING

Launching and recovering aircraft is the

[124] Mark Gunzinger. "Changing the Game: The Promise of Directed-Energy Weapons," Center for Strategic and Budgetary Assessments, 2012, 14.
[125] Jonathan Greenert. "Statement before the Senate Subcommittee on Defense Committee on Appropriations on the Joint Strike Fighter," June 19, 2013, 4, http://www.appropriations.senate.gov/sites/default/files/hearings/Greenert%20Testimony.pdf.
[126] "CVN-78 *Gerald R. Ford* Class Nuclear Aircraft Carrier," FY 2014 Navy Programs, Department of Defense Office of Test and Evaluation, January 2015, 167.

carrier's raison d'être, and naval aviation constitutes the CSG's most powerful and flexible set of weapons. Analysis of the role of the CSG in the Joint Force identifies discrete and growing responsibilities that, if not for carrier-launched naval aviation, would be difficult to address by other elements of the Joint Force, especially in the event of the unavailability of convenient land based air forces.

At the same time, the current and projected carrier wing is arguably the greatest weakness of the CSG when considering long-range strike in an A2/AD environment. The carrier air wing is extraordinarily useful in a wide range of low-to-medium threat environments; however, against the most challenging high threat environments, its utility is decreasing. The development of aircraft that sacrificed range for speed in the1980s and a focus on littoral power projection during the 1990s and early 2000s resulted in an air wing with inadequate capability, range, numbers, and qualitative superiority to adequately counter the most challenging threats, in particular the threat posed by China.

This problem is not irreversible, and throughout its history, the aircraft carrier has routinely and by design incorporated new aircraft designs and technologies. This report recommends improvements to the carrier air wing organized around three lines of effort: capability gaps, capacity gaps, and critical evaluation of the naval aviation portfolio. By pursuing these three lines of effort, the carrier would be positioned to perform the necessary warfighting tasks upon which the success of the Joint Force may depend.

1. Address Capability Gaps: The Navy should address the existing and projected capability gaps in the carrier air wing. In general, this requires the Navy to pursue three capability focus areas: increase striking range, develop sea control aircraft, and develop new munitions and sensors.

Increase Striking Range. With regard to the first focus area of increasing striking range, the Navy has four options. The first is to rely on more aerial refueling, or tanking. Air Force tankers provide higher offload quantities of fuel; however, their availability is jeopardized by competing Joint demands (that will likely increase during operations at distance in the Pacific), by the availability of fighter escorts and their ability to defeat threats while in-flight, and by threats to the land air bases from which they operate. By developing an adequate basing posture and training, the Air Force can improve the ability of its tanker aircraft to provide fuel to Air Force, Navy, and other aspects of the Joint Force. Ultimately though, excessive reliance on Air Force tanking reduces the organic capability of the carrier, thus reducing its value to the Joint Force. Additional tanking capacity can also be provided organically by the carrier air wing through either "buddy tanking" by F/A-18E/F

aircraft or by a newly developed, purpose built tanker (manned or unmanned). However it is provided, wartime operations in the Pacific will require more organic tanking than the carrier can currently generate. In order to provide this, the Navy should ensure carriers are equipped with sufficient kits to convert a larger portion of its fighter aircraft when necessary to buddy tankers. The Navy should also consider developing a dedicated tanking aircraft based on a new design manned or unmanned aircraft or by modifying existing or retired aircraft, such as C-2s, S-3s, or V-22s. For instance, a flying-wing UAS design with a cruising speed of approximately 465 knots could likely provide approximately 19,000 pounds of fuel at 100 NM from a carrier and 4,000 pounds of fuel at 1,200 NM, this would significantly increase the carrier's strike range.[127] Currently, the Navy does not have a plan for a dedicated organic tanking aircraft. The proposed Unmanned Carrier-Launched Airborne Surveillance and Strike (UCLASS) aircraft is another candidate for organic refueling roles.

Ultimately however, air power designs that rely on excessive amounts of aerial refueling should be avoided, as aerial refueling exposes aircraft to the major vulnerability that threats could interdict the refueling aircraft and thus cause a subsequent loss of the refueled aircraft. Additionally, limited ranges reduce the effective striking power of the air wing by forcing the dedication of a large portion of the air wing to buddy tanking. Moreover, limited range increases the stand-in risk the carrier may need to take in order to conduct missions. The Navy should seek to increase the inherent range of its aircraft while it also improves the state of organic air wing tanking.

The second option for improving air wing striking range would be to make modifications to existing and programmed aircraft. For example, with the incorporation of conformal fuel tanks, the combat radius of the F/A-18E/F could be increased to over 590 NM.[128] Likewise, the incoming F-35C has an approximately 610 NM combat radius.[129] The fielding of a future adaptive cycle engine, could potentially increase the F-35C's combat radius to approximately 830 NM.[130]

A third option would be to design new aircraft with greater range. Innovative options exist that could generate the carrier's pulse and range. The proposed UCLASS aircraft would exhibit a significantly greater range profile

[127] This estimate stems from consultations with aircraft manufacturers.
[128] "Semi-Stealth 'Advanced Super Hornet' Completes First Phase of Test Flights", Defense Update, August 30, 2013, http://defense-update.com/20130830_semi-stealth-advanced-super-hornet-completes-first-phase-of-test-flights.html#.VbsIovlVhBc
[129] "Selected Acquisition Report: F-35 Joint Strike Fighter Aircraft (F-35)," Department of Defense, 14, http://breakingdefense.com/wp-content/uploads/sites/3/2014/04/F-35-2013-SAR.pdf#page=14.
[130] "Adaptive Cycle Engine," General Electric, http://www.geaviation.com/military/engines/adaptive-cycle/.

than other aircraft in the air wing. Given the operational demands of the pacing threat, it is imperative that the future F/A-XX sixth generation fighter envisioned to replace the F/A-18E/F be fielded with operationally relevant increases in range.

Another enabler of longer range operations, one that should be considered irrespective of the direction the air wing takes, is to increase the range of aircraft weapons. For example, the forthcoming Long-Range Anti-Ship Missile (LRASM) with a range of over 500 NM would contribute to a sizeable increase in air wing striking range, enabling effective stand-off attacks.[131] Even though it may eventually be determined that the most cost-effective manner of increasing air wing striking range is to off-load it into the weapon, very long-range weapons alone would be unlikely to be fired in sufficient numbers to penetrate advanced defenses on their own. Therefore, a combination of enhancements to aircraft range should also be pursued, so that numerous medium-range standoff weapons can be fired, in addition to long-range standoff weapons, when desired.[132]

Overall, increasing the range of the carrier air wing is essential for achieving the combat objectives of the Joint Force. Although the current carrier air wing is capable of conducting unopposed organic strikes at ranges of 1,500 NM, prudent sensitivity analysis suggests that the carrier air wing must not only significantly increase its capability at those ranges now but also to prepare for an era in which the ranges of A2/AD weapons will further increase.[133] For instance, China has developed the DF-26. An ASBM variant of the DF-26 significantly extends the Second Artillery's anti-ship strike range, perhaps up to 2,160 NM.[134] If this missile were equipped with a warhead similar to that of the DF-21D ASBM, it could potentially be capable of engaging U.S. surface ships at that long range. Additionally, an at-sea launched version of the ASBM would further complicate U.S. defensive efforts.

Develop Sea Control Aircraft. As the second focus area, the Navy should pursue developing sea control aircraft. As both A2/AD and power projection threats to land-based air mature and develop, the Joint Force will require carrier aviation to play an important

[131] "LRASM," Defense Industry Daily, June 3, 2014, http://www.defenseindustrydaily.com/lrasm-missiles-reaching-for-a-long-reach-punch-06752/.
[132] For example, the Center for Strategic and Budgetary Assessment found a "sweet spot" for weapons may be in the 100-400 NM range. Weapons with this range profile, launched from low observable aircraft, provide sufficient standoff from dense air defenses, while enabling large salvo sizes. (Mark Gunzinger and Bryan Clark. "Sustaining America's Precision Strike Advantage," Center for Strategic and Budgetary Assessments, June 25, 2015.)
[133] Please see footnote 89 for the assumptions involved in this strike capability.
[134] Bill Gertz. "China Fields New Intermediate-Range Nuclear Missile," *Washington Free Beacon*, March 3, 2014, http://freebeacon.com/national-security/china-fields-new-intermediate-range-nuclear-missile/.

role in countering threats to sea control. A critical gap in the air wing is organic, persistent ISR and targeting, something the ongoing UCLASS acquisition is at least partially attempting to address. The carrier's contribution to scouting is one that originates with its very inception. Given the dual trends of increased adversary power projection and sea denial threats, and the trend of increased strike capability of other aspects of the Joint Force, the ability of the carrier to effectively scout is a critical aspect of its capability. For example, carrier scouting by a low observable aircraft could increase the effectiveness of submarine, long-range bomber, and surface ship strikes against adversary land and ship targets.

The recent introduction of the E-2D AEW aircraft provides a major improvement in the ability of the carrier air wing to detect low observable threats at range and pass target-quality tracks to different platforms. Accordingly, E-2Ds are a central node in the Naval Integrated Fire Control Counter Air (NIFC-CA) concept, and the Navy plans to increase the number of aircraft in the carrier air wing from the current four E-2Cs to five E-2Ds.[135]

Nonetheless, the carrier air wing faces major deficiencies when attempting to organically detect and track enemy ships, with its capability largely limited to the MH-60 inner defense zone range and the ISR assets assigned to its escorts (mainly helicopters). Accordingly, the introduction of a UCLASS capable of providing stealthy, persistent ISR and targeting would be a major contribution to the CSG. Such an aircraft would fill in the gaps left by the P-8 and the MQ-4, both of which are incapable of ISR and targeting in a contested environment without escorts.[136] This aircraft could also provide significant tanking support; however, unless the air wing procured dedicated tankers, it is likely the aircraft would be largely devoted to ISR and targeting in a high-threat environment.

The current debate about whether UCLASS should be primarily a strike platform or primarily a surveillance platform diminishes the importance of the requirement for both missions. Clearly, longer range strike in a contested environment is necessary for the sea-based power projection effectiveness in an A2/AD environment. Yet, the likelihood that land based ISR would be curtailed as a result of attack throughout the First or even the Second Island Chain raises an equally compelling case for the surveillance privileged version of UCLASS. The air wing of the future needs airframes to perform both missions.

[135] David Barno, Nora Bensahel, and M. Thomas Davis. "The Carrier Air Wing of the Future," White Paper, Center for a New American Security, February 2014, 12.
[136] The F-35C may be capable of providing moderately stealthy targeting capability, but it would lack persistence.

Increased strike capability at range provides the Joint Force with additional options. A strike-optimized UAS could be used to neutralize enemy combatants, IADS, and land targets. Strikes against defended targets will likely require a combination of manned and unmanned aircraft and airborne electronic attack. Strike-optimized UAS could offer new tactical options for strike packages, such as the release of swarming weapons nearer to a target, while other aircraft fire longer-range stand-off weapons. If properly designed, a strike-optimized UAS could also conduct outer air battle air warfare missions, either through autonomous or directed aircraft engagement or directional airborne electronic attack. Through all-aspect low observable features, these UAS could approach near enemy platforms for taking high probability of kill missile shots. Additionally, the extended range of UAS reduces carrier air wing reliance on aerial refueling, which introduces complexity and risk into CONOPS. Moreover, long range strike-optimized UAS provide the carrier with a sustainable long-range strike capability in the case that degradation of an enemy's reconnaissance-strike capability takes longer than anticipated. Additionally, a strike-optimized UAS could provide scouting for the fleet, albeit for shorter duration than a surveillance-optimized UAS.

Lastly, the introduction of UAS to the carrier air wing could entail significant lifecycle savings by reducing necessary aircrew training requirements. However, proponents of reducing the number of UAS air wings to only those necessary for deployed carriers should be challenged by analysis of the effects of combat attrition, which likely require a larger UAS force more consistent with the existing fighter force.

Another type of new aircraft required is an air superiority fighter. Given the projection of the Joint Force's increased demand for carrier-based fighter support, this capability is critical.[137] However, both F/A-18E/Fs and F-35Cs will face significant deficiencies against supercruising, long-range, high-altitude, stealthy, large missile capacity adversary aircraft, such as the T-50, J-20, and follow-on aircraft. These aircraft will be capable of effectively engaging current and projected U.S. carrier aircraft and penetrating defenses to engage high value units, such as AEW aircraft, ASW aircraft, and tankers. Already, the F/A-18E/F faces a severe speed disadvantage against Chinese J-11 aircraft, which can fire longer range missiles at a higher kinematic advantage outside of the range of U.S. AIM-120 missiles. Similarly, the F-35C is optimized as an attack fighter, resulting in a medium-altitude flight profile, and its current ability to only carry two AIM-120 missiles internally limits its capability

[137] Bryan Clark and Mark Gunzinger. "Sustaining America's Precision Strike Advantage," Center for Strategic and Budgetary Assessments, 2015, 31.

under complex electromagnetic conditions. As an interim measure, the Navy and Air Force should significantly accelerate the F-35C's Block 5 upgrade to enable the aircraft to carry 6 AIM-120 missiles internally.

If the nascent F/A-XX program determinedly focuses on fighter requirements, it has the opportunity to address this major gap. Such an aircraft could feature large passive and active sensor arrays, relatively high cruising speed (albeit not necessarily acceleration), could hold a large internal weapons bay capable of launching numerous missiles, and could have space to adopt future technologies, such as HPM and lasers.[138] This air superiority asset would contribute to Outer Air Battle integrated air and missile defense requirements and would be capable of countering enemy weapons, aircraft, and sensor and targeting nodes at a distance. The danger in its development is that it sub-optimizes the fighter role in the quest for a hybrid fighter/attack jet. This would leave the Joint Force without a carrier-based sixth generation air superiority fighter.

Carrier Strike Group ASW capability must also improve, again, as the carrier's utility as a mobile air base will increase in the event land-bases (from which Navy P-8's would fly) are targeted. The retirement of the S-3 relegated the air wing to rely on short-range helicopters for ASW, and given the projected increase in threat of large AIP SSKs and SSN and SSGNs, the Navy must proactively consider aircraft options for providing organic broad-area ASW. This could either be a dedicated or multi-role aircraft, such as a UAS used for strike or surveillance. Additionally, the Navy should pursue improvement of the ASW capability of its surface combatants, both those operating as part of the CSG and independently.

The last class of sea control capability the Navy requires is improved aviation Search and Rescue. A major challenge during combat against a near peer or peer threat would be the search and rescue of downed aviators. The Navy should both improve coordination with Air Force, other Service, and allied and partner assets for rescue of downed aircrews. This coordination can ensure aircrews downed near forward landmasses have a better chance of recovery. For instance, Air Force MV-22 tilt rotors and Japan Maritime Self-Defense Force US-2 amphibious aircraft operating from the First Island Chain could rescue some aviators. However, given the vast distances in the Pacific and the insecurity of First Island Chain installations in war-time, it is likely additional options for rescue should be developed. Although some of these will involve using Navy ships or aircraft launched from other Navy ships, the ability to improve

[138] For further information on innovative future air warfare capabilities, please see: John Stillion. "Trends in Air-to-Air Combat: Implications for Future Air Superiority," Center for Strategic and Budgetary Assessments, April 14, 2015.

carrier organic rescue capability over MH-60S aircraft should be pursued. The use of long-range Navy V-22 tilt-rotor aircraft procured for the Carrier Onboard Delivery mission could be one option.

Develop New Munitions and Sensors. A third focus area the Navy should pursue is the development of new munitions and sensors. As mentioned earlier, new weapons with increased range are needed for the air wing. In particular, the Navy requires new long range anti-ship missiles in order to have more survivable anti-ship weapons given Harpoon's short-range and low survivability. Against land targets, the Navy should acquire different stand-off weapons capable of penetrating defenses using both sophistication and mass, such as the JASSM-ER (and the derivative LRASM) and JSOW-ER, respectively.

In terms of air warfare, carrier fighters need a long-range air-to-air missile, preferably with a hybrid seeker. The United States AIM-120C/D missiles are either comparable to or out-ranged by Chinese and Russian multi-seeker missiles, placing U.S. fighters at a disadvantage.[139] This disadvantage is compounded by the aerodynamic inferiority of U.S. carrier aircraft compared to the best Chinese and Russian fighters, which grants enemy missiles a longer lofted range.[140] Overall, a situation exists in which enemy fighters are likely to have a qualitative advantage over many U.S. naval fighter aircraft. An LRAAM would work to offset that situation for both U.S. existing and projected fighter aircraft. Similarly, the introduction of aerial search Infra-Red Search and Tracking systems to F-18 aircraft could improve their performance by reducing their reliance on active sensor operation.

Another class of weapon that should be considered is the incorporation of ASW weapons (such as the MK 54 torpedo) and sensors (such as sonobuoy and radars) on carrier aircraft, such as V-22s, F-18s, or new unmanned aircraft. These additions to the carrier or the overall CSG would seek to address the gap caused by the lack of organic broad-area ASW detection and attack capability, as well as the projected reduced coverage of land-based P-8 aircraft under contested conditions. In addition to providing a new method to attack submarines, the introduction of these weapons would improve the ability of the CSG to provide deceptive and dislocating ASW screens.

The Navy should also consider options to employ swarming mass in its attacks. This

[139] Dave Majumdar. "Pentagon Worries That Russia Can Now Outshoot U.S. Stealth Jets," T*he Daily Beast*, December 4, 2014, http://www.thedailybeast.com/articles/2014/12/04/pentagon-worries-that-russia-can-now-outshoot-u-s-stealth-jets.html.
[140] Oriana Skylar Mastro and Mark Stokes. *Air Power Trends in Northeast Asia: Implications for Japan and the U.S. – Japan Alliance*, Project 2049 Institute, 29, http://project2049.net/documents/mastro_stokes_japan_airpower_paper.pdf.

includes increased procurement of MALD-J decoys that can be used to jam and decoy enemy defenses. MALD-J could also be modified to provide a lethal attack capability as well. Another weapon concept could be a carrier catapult-launched flight body that dispenses large numbers of swarming lethal drones. Such a capability would contribute to a "tunneling" concept in which swarming low-cost weapons and decoys would complement sophisticated weapons, such as LRASM, JASSM-ER, and AARGM, by stimulating air defenses and either blinding them or forcing an expenditure of defensive weapons capacity, while sophisticated weapons penetrate.[141]

2. Address Capacity Gaps: The Navy should seek to address the existing and projected capacity gaps in the carrier air wing. During the 1990s and 2000s, the size of the air wing was reduced. The reduction in the size of air wings was justified in part by improvement in the operational reliability of aircraft and through the use of precision-guided munitions that enabled aircraft to self-designate and strike multiple targets, in addition to the perception of a lower sea-denial threat. An over 100 aircraft fighter shortfall has emerged caused by higher than anticipated rates of operational usage, a six-year delay in the F-35C, and delays in fighter maintenance caused by sequestration and a civilian hiring freeze.[142] Approximately half the Navy's F/A-18C Hornets are in long-term maintenance, and approximately 20% of the newer F/A-18E/F Super Hornets are undergoing repairs.[143]

The Navy now faces a new era in which larger numbers of aircraft are needed. In challenging scenarios, a carrier requires anywhere between 26-44 fighters for defensive requirements, highlighting the importance of multi-carrier operations.[144] To conduct offensive operations, such as striking an IADS or conducting a major Offensive Counter-Air Sweep, large numbers of aircraft and weapons with effective airborne electronic attack will be required and significant levels of attrition could be expected. Qualitative improvements in Chinese and Russian IADS and aircraft result in a world in which U.S. aircraft would likely suffer significant losses, making localized quantitative superiority generated by carrier aviation important. For instance, if Navy and Marine Corps F-18 fighters flew four, 40 aircraft offensive sorties per day, even modest levels of attrition could significantly shrink the total inventory.

[141] Bryan Clark and Mark Gunzinger. "Sustaining America's Precision Strike Advantage," Center for Strategic and Budgetary Assessments, 2015.
[142] Mike Hixenbaugh. "As Navy missions pile up, so does jet maintenance," *The Virginian Pilot*, June 21, 2015.
[143] Ibid.
[144] Talbot Manvel. "Storyboard for FORD Development," U.S. Naval Academy Museum, December 15, 2014, Part I.

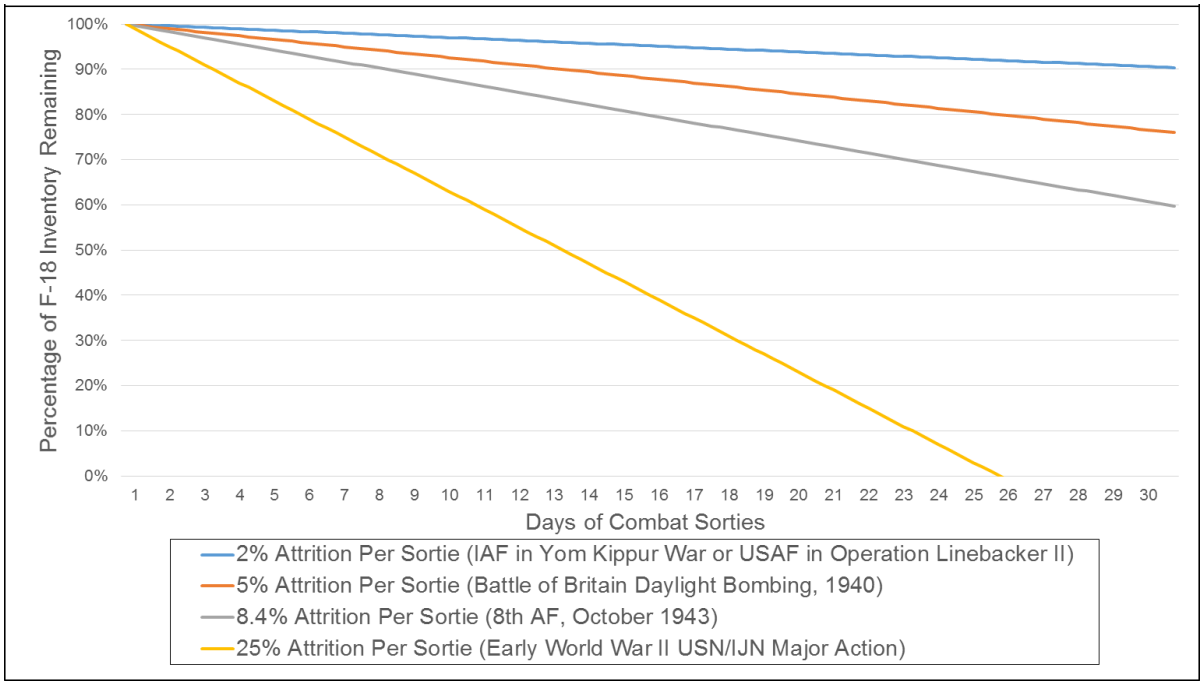

Figure 16: Cumulative Effects of Attrition on Navy and Marine Corps F-18 Force

Although it is difficult to precisely anticipate rates of attrition against a mature A2/AD enemy, historical case studies suggest attrition levels could range from 2 to 25% per sortie against a competent enemy. Against advanced adversaries such as China or Russia, the levels of attrition could be relatively high. Using the U.S. Army Eighth Air Force's October 1943 8.4% attrition rate per sortie as a surrogate (in spite of the fact this period lacked precision anti-aircraft weapons), a week of F-18 operations could eliminate 10% of the force, and a month of operations could eliminate nearly 40% of the force.[145] The sensitivity of aircraft inventories to attrition places a priority on three initiatives: developing appropriate capabilities and concepts to achieve mission objectives without high levels of attrition, adequately sizing the force to ensure there is a sufficient number of aircraft, and preparing the defense-industrial base to be capable of accelerated aircraft and weapon production during a conflict with a potent enemy.

A key capability to offset U.S. disadvantages against advanced IADS and aircraft is the EA-18G Growler. Current Navy tactics call for EA-18G operations in two-plane formations.

[145] This analysis is inspired by Figure 22 in John Stillion and Bryan Clark, *What It Takes to Win: Succeeding in 21st Century Battle Network Competitions*, Center for Strategic and Budgetary Assessments, July 13, 2015. John Stillion graciously provided the historical attrition rates, drawn from the USAAF Statistical Digest, Williamson Murray's *Strategy for Defeat: The Luftwaffe, 1933–1945*, and the USAF Project CHECO Report. This analysis does not account for attrition during defensive sorties or accidents.

Adding a third aircraft to these tactical formations, significantly improves battlespace situational awareness and Electronic Support Measure identification through a time distance of arrival analysis that provides weapon-quality tracks. This capability allows the force to find, fix, track, and identify multiple complex threat emitters in real-time. Moreover, equipped with the Next Generation Jammer, EA-18G will be capable of providing coherent jamming at increased power, interrupting enemy effects chains. This capability assists the penetration of not only F/A-18E/F aircraft or other Joint Force aircraft, but also F-35Cs. The proliferation of L-band radars and other lower frequency fire control radars counters the X-band optimization of the F-35C. The ability of EA-18G to jam these other radars allows carrier strike and air warfare packages the ability to counter enemy sensors and provides jamming coverage for weapons, significantly increasing weapon probability of arrival. In order for the Navy to effectively leverage the capability of the EA-18G, however, the force requires 11 EA-18Gs for each of the Navy's 10 carrier and 5 expeditionary squadrons. The Navy's current program of record calls for a total of 135 EA-18Gs, or 5 EA-18Gs per squadron. In order to field 8 EA-18G per squadron (the minimum number of aircraft to sustain three-ship operations), the Navy would need to procure an additional 70 EA-18Gs.[146] Procurement of additional EA-18Gs would not only work to address existing high levels of risk but also would maintain active the F-18 production line, hedging against the possibility of attrition replacements necessary during a conflict. Critically evaluating the adequacy of the inventory of other carrier-based aircraft should similarly take place.

3. Critically Evaluate the Naval Aviation Portfolio: Over the past five years, DoD has spent more on naval aviation procurement than shipbuilding. Along with the defense budget materials, the Secretary of Defense must submit to Congress an annual, long-range plan for construction of combatant and support vessels for the Navy, commonly termed the 30-Year Shipbuilding Plan.[147] He must also submit a 30-Year Aviation Plan that examines the sufficiency of funding to procure all aircraft specified by the plan.[148] This DoD-wide analysis does not conduct a detailed, scenario-based assessment of the roles of aircraft and does not describe in detail projected inventory changes by specific aircraft types. Consequently, naval aviation has no 30-Year Shipbuilding Plan congressional equivalent. The closest public

[146] Dave Majumdar. "Why the Navy Wants More Growlers," *USNI News*, March 12, 2014, http://news.usni.org/2014/03/12/navywantsgrowlers.
[147] "Annual Long-Range Plan for Construction of Naval Vessels for FY 2015," Navy, July 30, 2014, http://navylive.dodlive.mil/files/2014/07/30-year-shipbuilding-plan1.pdf.
[148] "Annual Aviation Inventory and Funding Plan Fiscal Years (FY) 2016-2045," Department of Defense, April 2015.

strategic planning document is the Naval Aviation Vision 2014-2025, an 11-year planning document that describes desired "pillars" of capability superiority, wholeness, and maintaining capacity without specifically detailing the future force over the next 11 years, much less 30.

The Navy and Congress should critically evaluate the naval aviation procurement plan and ensure the plan is consistent with emerging requirements for operations against a peer or near-peer threat. This evaluation should include potential portfolio trades between naval land-based air and ship-based air. Although it would be imprudent to excessively concentrate capability in the carrier or other sea-based platforms, questions regarding the survivability on land and in the air of systems such as the P-8 and the MQ-4 prompts the question whether a portion of that funding should be reallocated to carrier and surface combatant aviation.[149]

OTHER SHIPS IN A CSG

The carrier operates as a system in concert with other ships in a CSG. Analysis of the CSG as a system finds significant deficiencies in other components of the carrier force. These weaknesses center on the logistical capability of cruisers, destroyers, and CLF and other supporting ships and infrastructure. With opportunities for redress, the capability of other ships in a CSG can be improved, significantly enhancing the capability of not only the CSG but the entire fleet. To scope this analysis, discussion will focus on those capabilities necessary to protect and sustain the CSG's capability.

Cruisers and Destroyers: Cruisers and destroyers suffer from limited organic airborne ISR capability. The Navy should improve surface combatant airborne ISR capabilities.[150] If capable of medium-range and long endurance, these capabilities would effectively complement carrier-borne and other ISR capabilities and enable more distributed multi-carrier defensive concepts. Additionally, an organic surface combatant ISR capability would enable independent or carrier-supported SAGs to more effectively identify, target, and engage enemy threats.

Perhaps the most important area of improvement for surface combatants is the ability to reload VLS cells underway or in advanced or intermediate-staging bases. The inability of cruisers and destroyers to reload VLS cells while at sea or outside of fleet bases dramatically decreases the staying power of the CSG. Consequently, even though the carrier may have large munitions magazines

[149] For more information on modernization options available to the carrier air wing, please see: David Barno, Nora Bensahel, and M. Thomas Davis. "The Carrier Air Wing of the Future," White Paper, Center for a New American Security, February 2014.
[150] "Tern Continues Progress toward Enabling Small Ships to Host Their Own Unmanned Air Systems," DARPA, March 23, 2015, http://www.darpa.mil/news-events/2015-03-23.

that enable it to fly numerous sorties, and its magazines can be replenished via UNREP, surface combatants would need to return to major bases for reload, thus weakening the defensive capacity of a CSG. In cases in which other surface combatants could not substitute for the retiring surface combatant, this could force the retrograde of the entire CSG. In addition to improving CSG performance, VLS reload at sea would significantly improve the striking power of other elements of the Joint Force, such as SAGs.

The Navy should rapidly develop, test, and deploy a VLS reload capability. The ability to reload the Navy's surface primary magazine is a telling metric of whether the Navy is actually prepared to fight against a major threat like China or Russia. Naval Surface Warfare Center Port Hueneme has proposed a concept "for replenishing 15 VLS per hour in Sea State 5 that centers around a transportable VLS rearming device that is stowed and maintained on a CLF ship."[151] Concepts such as these for UNREP reload from CLF ships should be swiftly investigated. Additionally, concepts for reloading surface combatants and submarines from distributed small ports or sheltered anchorages (using dedicated supply ships or tenders, or only using local cranes) should be investigated and implemented even more quickly.

CLF and Supporting Logistics Force: The CSG is on a short and brittle logistics tether, which is the Achilles' heel of the force. Despite the nuclear propulsion of the carrier and its attack submarine escort, other CSG surface combatants and the carrier air wing require a large amount of fuel and munitions on a regular basis. The current CLF is too small and vulnerable for contested operations in the vast Pacific. The Navy's plan to build a new class of 17 TAO(X) fleet oilers is too small and possibly inadequately composed to address existing and emerging threats.[152] Addressing these gaps is essential if the Navy is to credibly commit itself to countering aggression by near-peer or peer threats, principally China.

In response, the Navy needs to ensure the T-AOE force stays either active or in a high Reduced Operating Status (instead of the existing plan to inactivate two T-AOEs and place them in reserve), increase the number of CLF ships (especially oilers) in the fleet, provide defensive armament to CLF ships, and exercise convoy operations for CLF,

[151] Miller, 15.

[152] "The figure of 17 TAO(X)s was determined as part of a Force Structure Analysis (FSA) that the Navy completed in 2012. […] This FSA established a goal of achieving and maintaining a future Navy fleet of 306 battle force ships of various kinds, including 17 oilers." The FSA did not include the more operationally realistic operating assumptions discussed in this report. (Ronald O'Rourke. "Navy TAO(X) Oiler Shipbuilding Program: Background and Issues for Congress," Congressional Research Service, R43546, February 6, 2015, 4-5.)

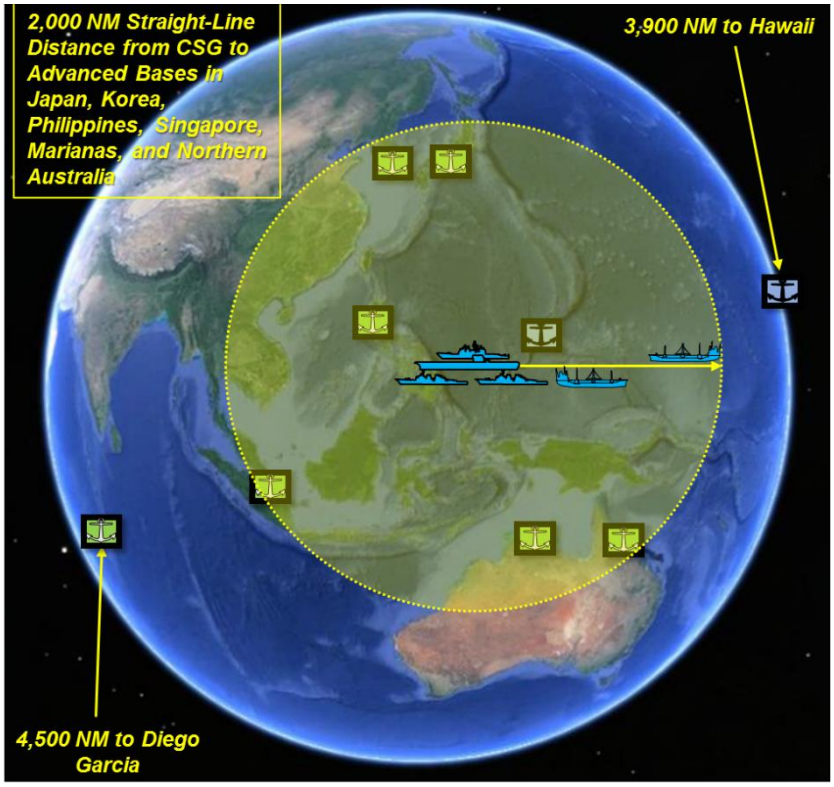

Figure 17: Representative CLF Force Options for Advanced Bases in the Asia Pacific [154]

MSC, and commercial supporting logistics ships. Convoying reduces the distribution of targets so that submarines are less likely to find targets, equalizes convoy loss rates between convoy types, and forces submarines to approach defensive perimeters.[153]

The Navy must also take a keen interest in the vulnerable land-based logistics infrastructure that is under threat, encouraging the distribution and hardening of fuel and munition stores and developing and exercising concepts for the use of advanced and intermediate fixed and mobile staging bases, both within 2,000 NM (which reduces shuttling requirements) and beyond 2,000 NM of the CSG (which decreases operational risk).[154] Similar critical appraisal of the sufficiency and capability of the current Mobile Logistics Force, Oceanographic Survey Ships, rescue and salvage, and fleet ocean tug force should take place.[155]

[153] Owen Cote. "The Third Battle: Innovation in the U.S. Navy's Silent Cold War Struggle with Soviet Submarines," MIT Security Studies Program, 2000, http://www.navy.mil/navydata/cno/n87/history/cold-war-asw.html.
[154] Figure 17 Map Data provided by Google Earth.
[155] As with the CLF fleet, the Navy's Mobile Logistics Force of destroyer and submarine tenders has been dramatically cut since the end of the Cold War. From 23 ships in active service in 1989, only two

INDUSTRIAL INFRASTRUCTURE AND SUPPLIERS

The Navy should carefully examine the industrial base involved in the construction of carriers, their accompanying ships, and aircraft. Detailed plans should be developed in conjunction with key contractors for maximizing wartime platform and munitions production in case of conflict with China or Russia. Concomitantly, Combatant Commanders should be informed of the detailed production build times, allowing them to more effectively gauge the implications of attrition on the force during long campaigns.

Moreover, the Navy should improve efforts to protect key system and component fabrication and shipyard centers during heightened states of tension or conflict. Similarly, the Navy, Coast Guard, and Combatant Commands should improve port defenses at U.S. Navy bases, ports, and shipyards to counter a range of threats that are capable of threatening carriers and other CSG ships in port.

submarine tenders remain. This cut decreases the ability of the Navy to conduct dispersed logistics operations and concentrates Fleet resupply capability at major Fleet bases. Commensurate cuts to the rescue and salvage and fleet ocean tug force have taken place.

VII. FLEET DESIGN OPTIONS

Whatever the cost of the CVN and its impact on total defense spending, any resources applied to the CVN, its air wing, and the personnel attached to both represent allocations that cannot be made elsewhere. Because of the pressurized defense budget environment in Washington since the Budget Control Act of 2011 and its choice of sequestration (among other things) to achieve spending reductions across the government, some analysts would look to re-allocate spending within the Navy budget to achieve both force structure and operational goals that differ from those represented in the Navy's current 30 Year Shipbuilding Plan.

That plan attempts to provide for a balanced Navy that provides capability across a broad spectrum of missions which comprise basic functions the Navy provides the nation: presence, deterrence, and warfighting. Each of these functions is different from the others, and within each, certain platforms and capabilities provide different levels of impact.

To accomplish these three functions, modern, first-rate navies (like the U.S. Navy) tend to operate three main types of vessel: submarines, surface ships (including amphibious transport ships and logistics ships), and aircraft carriers with embarked air wings. Submarines are superb warfighting platforms. Able to operate in the opaque undersea environment, the nation's nuclear attack submarines hunt and kill surface ships and other submarines, provide surreptitious surveillance, and can strike targets ashore. These killing machines are, however, suboptimal presence and deterrence platforms, as they must stay unseen to stay alive. While the threat posed by U.S. attack submarines undoubtedly would cause an adversary to factor in their presence, the psychology of conventional deterrence depends largely on the preponderance of locally available (and recognized) force.

Surface ships are the primary platforms

employed for naval presence and deterrence functions. Presence can be accomplished by unarmed or even modestly armed ships, though these are less useful in deterrence and warfighting. More heavily armed surface ships perform presence missions and are considerably more potent deterrence and warfighting platforms, but are admittedly more vulnerable than submarines to modern weaponry in actual combat.

Aircraft carriers combine the ability to carry out everyday missions well while remaining a deadly warfighting platform. CSGs remain premier instruments for presence, deterrence, and warfighting, able to project power and exert control of the seas around which it operates.

The aircraft carrier has been at the heart of U.S. naval power projection since World War II, and as this study described earlier, that place has been challenged repeatedly based on a number of factors including cost, threat, and alternative fleet design concepts (which invariably seek to respond to cost, threat, or both). Today is no different, and several alternative fleet designs have been advocated that either directly or indirectly question the role and effectiveness of the modern supercarrier. This section of the report will evaluate four alternatives to the current carrier-centric, balanced fleet design: a fleet much like today's fleet, although one in which carrier air power were distributed across more numerous, smaller (and less expensive) aircraft carriers; a fleet with a diminished emphasis on carrier air power (and subsequently, substantially fewer—or no—aircraft carriers), but with the resources currently allotted to carriers and carrier aviation distributed to other elements of the fleet design such as surface ships, submarines, ISR and unmanned vehicles; the current fleet design with necessary improvements to the carrier, its air wing, and the strike group that improve the performance of the CSG; and finally, a larger version of the previous option, which introduces the discussion of how the carrier force should be sized.

THE CURRENT FLEET

Before moving on to the alternatives, a discussion of the current fleet architecture is in order. The U.S. Navy operates a balanced fleet, which means that its capabilities are spread across a number of important missions and functions. In order to carry out these missions and functions, a wide variety of platforms are required, and these platforms have remained relatively stable in terms of design and proportion for decades. The components of this fleet include aircraft carriers (with embarked air wing), large surface combatants, small surface combatants, submarines (attack and ballistic missile), amphibious ships, logistics ships, and special mission/special function ships (hydrographic research, test range ships,

etc.). This fleet design permits the world's most influential nation to protect and sustain its national security interests in littoral regions thousands of miles from its own landmass. Critical to this fleet design is that the United States operates a separate and distinct Coast Guard, which tends to the overwhelming majority of maritime homeland security requirements.

Because this Navy is designed to operate forward, its platforms generally emphasize endurance, and endurance is often associated with size, specifically driven by fuel capacity and space for storing ammunition, spare parts, and food. Nuclear power as a propulsion source alleviates a great deal of the space required for fuel, and in the case of a modern CVN, converts much of that theoretical propulsion fuel into fuel storage for the air wing, which is its main weapon system. But nuclear power comes at a cost, and nuclear platforms—carriers, surface ships, or submarines—tend to be more expensive to build and operate than their conventional counterparts. In the case of the CVN, the expense of nuclear power is considered worthwhile in terms of the added fuel capacity for embarked aircraft and dramatically increased magazine capacity, when compared to the next largest aviation capable platforms the Navy operates—the LHD and the LHA. Both of these attributes contribute to the CVN's endurance, although it—like any forward deployed ship—must be periodically replenished of fuel, food, and ammunition. Additionally, nuclear propulsion significantly decreases CLF refueling requirements, as the carrier itself does not require liquid fuel for propulsion. This advantage not only reduces CLF requirements from what they would be if U.S. carriers were conventionally-powered, but also confers the operational benefit of being able to conduct sustained high-speed operations, which are necessary to reposition rapidly for Power Pulse combat power operations.

The United States submarine force dependence on nuclear power (as opposed to conventionally powered submarines which are quite common throughout the world) is also a matter of prizing endurance near the top of the list of warship attributes. Nuclear power is what enables the submarine to remain submerged for extended periods of time, thus enabling stealthy operations forward with only a limited logistics and resupply requirement. The United States, unlike many other world navies, does not build conventionally powered submarines. Although the state of technology of such submarines is increasing, conventionally powered submarines continue to dramatically lag the endurance gained through nuclear power.

The United States has operated nuclear powered surface ships in the past, and because of the volatility of oil prices, many have called for more use of nuclear power in

the surface fleet. In 2011, the Congressional Budget Office (CBO) studied the prospects for increased use of nuclear powered propulsion plants in the surface force from the perspective of life cycle costs by comparing the life cycle costs represented in the Navy's 30 Year Shipbuilding Plan with the costs associated with the same plan made up of nuclear only versions of guided missile destroyers, amphibious assault ships, and amphibious dock landing ships. Nuclear powered ship life cycle costs across the plan were found to be 19% higher than conventionally powered ships, with nuclear destroyers costing 19% more, nuclear amphibious assault ships costing 4% more, and nuclear amphibious dock landing ships costing 33% more.[156]

Generally speaking, it can be assumed that for the purposes of fleet design in the near to mid-term—that is, where technology remains relatively stable and the CBO cost estimates remain reliable, we are likely to see surface ships remain conventionally powered, and submarines and aircraft carriers remain nuclear powered. This is important to consider, as some of the alternative fleet architectures to be considered not only change the types and numbers of platforms purchased, but also the propulsion plants with which they are equipped.

In addition to fleet design, what the Navy is called upon to do must be taken into consideration as we consider potential alternatives. The Navy's latest statement of purpose, the 2015 Maritime Strategy "Forward, Engaged, Ready: A Cooperative Strategy for 21st Century Seapower," cites the following seven naval missions: defend the homeland, deter conflict, respond to crises, defeat aggression, protect the maritime commons, strengthen partnerships, and provide humanitarian assistance and disaster response. Further, the Sea Services "…organize, train, and equip naval forces to accomplish these missions through the five essential functions: all domain access, deterrence, sea control, power projection, and maritime security."[157] Thus, a fleet balanced across a number of different platform types is at least partially balanced in order to pursue these seven missions by carrying out these five functions.

What must be remembered when assessing the fleet design's effectiveness in achieving stated strategic objectives is the degree to which naval forces are engaged in operations across the spectrum of warfare, by design. As the seven missions and the five functions are evaluated, three general operational states are suggested: presence, deterrence, and warfighting. The fleet design must be flexible

[156] "The Cost Effectiveness of Nuclear Power for Navy Surface Ships," May 2011, Congressional Budget Office Publication no. 4028, 2.
[157] James Dunford, Jonathan Greenert, Paul Zukunft, "Forward, Engaged, Ready: A Cooperative Strategy for 21st Century Seapower," Department of Defense, March 2015, 19.

across these operational states in order to achieve the strategic objectives described by the missions and functions. The diversity and power of the current fleet architecture recognizes the fact that not all platforms are as flexible across the three operational states as others. In fact, some are supreme warfighting platforms without adding much to conventional deterrence. Some platforms make considerable presence contributions but are less effective in a general war. And since the Navy must be equally adept in preventing war as in conducting it, the fleet is balanced accordingly.

ALTERNATIVE FLEET DESIGNS

Alternative fleet designs that focus on reducing or eliminating aircraft carriers generally tend to focus on one or both of the following primary arguments. First, that the resources applied to building, maintaining, and equipping (with modern aircraft) large, nuclear-powered aircraft carriers could be better spent on other elements of naval power (the opportunity cost argument). The second argument is that threats to the aircraft carrier have advanced and proliferated to the point where operating them in wartime carries unacceptable risk. Out of these two main counters flow four general fleet architectures, each of which is discussed below. Elements of these fleet architectures can be combined and aligned to form numerous additional architectures.

Existing Fleet Design, Except with More Numerous, Smaller Aircraft Carriers. This fleet design reflects both concern over the cost of modern, large-deck nuclear-powered aircraft carriers, and the perception of risk associated with operating such large, expensive platforms in risky combat environments with 4,300 lives at stake. Under this approach, the United States would cease to build *Ford* Class aircraft carriers, and operate the carriers it already has until the end of their service lives, and after fifty years, there would be no more large-deck aircraft carriers. In the interim (and as the large decks leave the service), smaller amphibious assault ships would increasingly come to be employed as ersatz aircraft carriers while a new, smaller carrier was designed and acquired. This new class of aircraft carrier would have reduced cost as a key requirement, and in theory that reduced cost would result in a larger number of hulls constructed. Carrier air power would then be distributed across a larger number of hulls which would make the loss of any one of them less of a risk to mission accomplishment, let alone the expense in blood and treasure lost.

Additionally, such distribution of carrier air power would create a number of operational problems for an adversary, to include diluting the attack density that opponent would be able to mount against any one carrier (it also possessing a finite number of weapons), tying up scarce ISR resources that would have to

be devoted to finding, fixing, tracking, and targeting more numerous carriers, and creating doubt and uncertainty in an adversary's planning process by holding more widely spaced targets at risk.

The disadvantages of this approach are notable. First, the notion that amphibious assault ships could perform duties as aircraft carriers during the transition period from the *Ford* Class to its smaller, follow-on (while older *Nimitz* Classes are retired) is debatable. While the LHA-6 and LHA-7 could employ on the order of twenty F-35B's, this is less than half the striking power of a CVN air wing, and the number of generated sorties is significantly less (especially in heavy sea conditions).[158] Unless dramatic alterations to the Marine Air Wing onboard these amphibious assault ships were made, they would be without the AEW capability provided by the E-2D, the Airborne Electronic Attack (AEA) provided by EA-18Gs, and the sea control capability provided by the CVN air wing's MH-60R helicopters. Were these capabilities added to the LHD/LHA at the expense of existing aircraft in the Marine Air Wing, the ship's primary mission as a combat system optimized for the delivery of USMC land operations ashore would be diminished. Additionally, the relatively small fuel tanks and ordnance stores of amphibious assault ships would dramatically increase the demand for logistical replenishment, especially as growing sea control requirements increase the number of battlespace dominance sorties carriers would need to launch. Lastly, the small size of amphibious assault ship's embarked air wings would put into question whether a single ship (or even two or three) could generate sufficient sorties to defend the Amphibious Task Force, much less conduct offensive operations.

Second, there is the question of the carrier that would replace *Ford*. Simply put, the performance and capability gap between a 45,000-65,000, medium sized aircraft carrier and the capability delivered by the *Ford* are not proportional to the savings that could be generated in building such a ship.

Second, there is the question of the carrier that would replace *Ford*. Simply put, the performance and capability gap between a 45,000-65,000, medium sized aircraft carrier and the capability delivered by the *Ford* are not proportional to the savings that could be generated in building such a ship. Navy analysis in the late 1990's indicated that a medium-sized, nuclear powered aircraft carrier capable of supporting 55 aircraft would cost 87-92% of what the *Ford* Class would cost, with a dramatic (nearly 50%) drop in the number of sorties that could be generated over the course of one month in a representative scenario using a notional 75

[158] Other LHA and LHD ships with less aviation space and well decks would embark fewer aircraft.

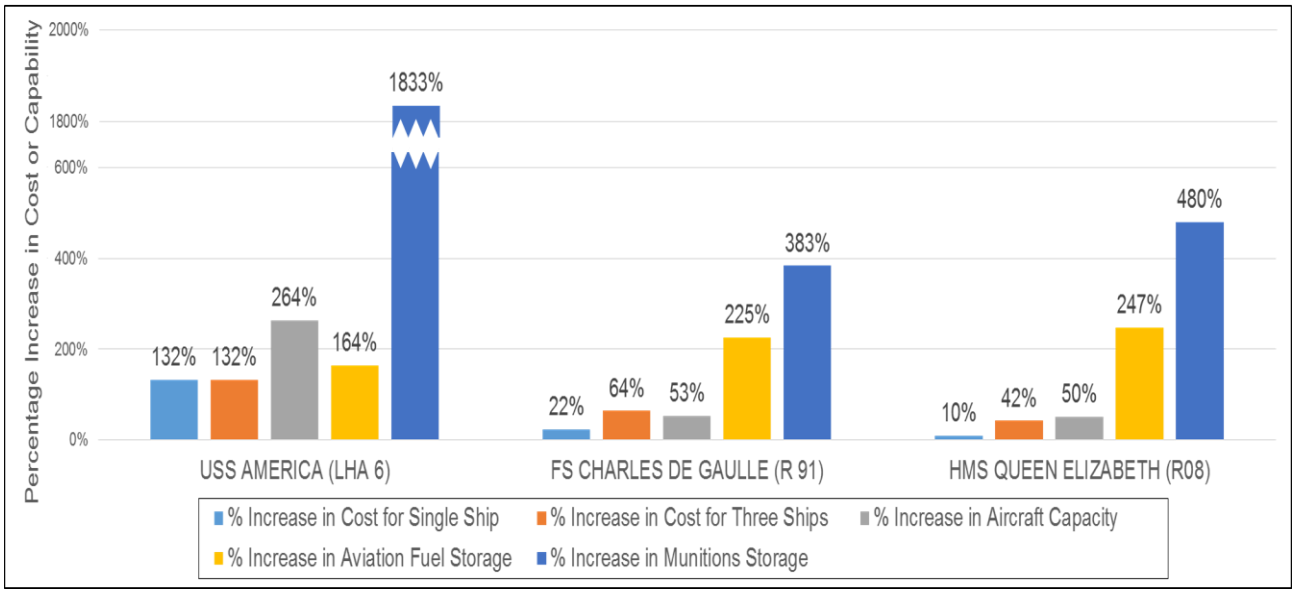

Figure 18: Comparison of *Ford* Class (CVN 80) with Alternate Ship Designs [160]

aircraft wing.[159] Comparing a modernized FS *Charles de Gaulle* that incorporated EMALS and AAG with the third ship of the *Ford* Class (CVN 80), the *Ford* Class would be 22% more expensive, yet would provide a 53% increase in the number of embarked aircraft (and an even higher percentage in the number of sorties generated), a 225% increase in aviation fuel storage, and a 383% increase in munitions storage.[160]

Switching from a large, nuclear-powered carrier (such as *Ford*) to a medium size conventionally powered ship would dramatically reduce cost (up to 40%), but at significant capability decline—especially with respect to the amount of fuel available to the air wing (with which the ship would have to compete for storage room) and the space available for weapons storage. To explain, nuclear powered ships require no "smoke stacks" to ingest or exhaust propulsion air, and require no liquid propulsion fuel, and that extra space contributes to the *Ford* Class magazine volume being 23 times as large as that in the next largest U.S. Navy combatant

[159] Talbot Manvel. "Storyboard for FORD Development," U.S. Naval Academy Museum, December 15, 2014, Part II.

[160] The analysis in Figure 18 incorporates EMALS and AAG onto the alternate ship designs in order to adequately compare them. Foreign designs incur a modest $3 billion design cost (for comparison, the USS *Gerald R. Ford* incurred a $3.3 billion design cost). This comparison does not incorporate nuclear power on the *America* Class or on the *Queen Elizabeth* Class. Costs are normalized in FY 2015 U.S. dollars using weighted currency exchange rates and SCN (NAVSEA/BLS HIST) inflation rates. Alternate ships are compared with the third ship of the *Ford* Class, USS *Enterprise* (CVN 80).

(LHA 6).[161] Both medium-sized nuclear and conventionally-powered aircraft carriers may face difficulties generating sufficient sorties to defend the CSG, much less conduct offensive operations. Furthermore, small and medium-sized carriers may face difficulties conducting year-round operations in high sea states due to decreased sea-keeping ability.

Third, were such an architecture to be acquired, there is little to suggest that the weapons and sensors that critics suggest render the large aircraft carrier vulnerable would be any less capable of targeting these less capable platforms. And since the aircraft carrier operates as part of a larger system (the CSG consisting of escort ships, logistics ships, and submarines), these more numerous but smaller carriers would require a similar number of escorts and likely larger number of logistics ships, both of which would require a dramatically larger number of those platforms than is currently considered. This larger requirement for surface escort and logistics ships would represent a cost not generally considered in the cost of these smaller, conventionally-powered carriers.

Moving to a Navy with No Carriers. In a fleet design without aircraft carriers, the capabilities resident in the carrier air wing would be redistributed throughout the rest of the ensemble, to surface ships, submarines, space assets, and unmanned air, subsurface, and surface vehicles (including missiles). This is the extreme implementation of the argument that carriers are too expensive and too vulnerable, but it is a useful case study for evaluating the degree to which these alternatives are able to account for the capabilities of the aircraft carrier and its air wing.

As discussed earlier in this paper, a dominant Navy must thrive in three operational states—presence, deterrence, and warfighting. Perhaps the single greatest benefit of the current, balanced fleet is its extensibility and effectiveness across each of the three operational states. The United States Navy is forward deployed during peacetime in order to demonstrate U.S. resolve and interest in areas of the world where its interests lie. Should crisis build—the proximity of naval forces can contain it and deter escalation (in the case of man-made crises), or aid in the delivery of aid in the event of natural disasters. Should a nation require a more active demonstration of U.S. power than that necessary to deter, it can be compelled or coerced into desired behaviors by the capabilities of naval forces present. If deterrence were not successful, naval forces can provide for timely and powerful combat operations as the vanguard of the Joint Force.

A fleet architecture in which the carrier force were allowed to obsolesce would eventually

[161] Talbot Manvel. "Storyboard for *Ford* Development," U.S. Naval Academy Museum, December 15, 2014, Part II.

result in a zero-carrier fleet. The resulting fleet would presumably have to continue to demonstrate capability in each of the three operational states discussed above. Many different fleet architectures could develop with resources harvested from eliminating the carrier force. Some would emphasize investment in undersea warfare, taking advantage of our already considerable edge over competitors in this domain and submerging as much combat capability as possible. Some would emphasize a larger surface force, to include a significantly larger number of small, heavily armed fast patrol vessels designed to dramatically increase the Navy's numbers of ships stationed forward. Virtually any future architecture would leverage unmanned capabilities under, on, and over the surface of the ocean. This would include considerably upgraded missiles and other weapons, which fleet architects would project as replacements for the aircraft lost with the carrier force.

Essentially, each of the alternatives "unbalances" the force, because it removes the great leveler of capability across the span of operational states, the aircraft carrier. A Navy in which considerably more capability were submerged in order to leverage the United States advantage in undersea warfare would diminish its effectiveness as a peacetime presence and conventional deterrence force, as the key point in putting things under water in the first place is to hide them. A force which dramatically increased its number of surface vessels—especially small, heavily armed ones—would find itself with a force optimized for presence and deterrence, but somewhat less effective as a warfighting force due to the vulnerability of surface vessels and more importantly, the difficulty of massing effects from so many platforms. An architecture that looked at the cost of missiles versus the cost of aircraft and then advantaged missiles could potentially gain warfighting capability, but would lose capability in all other facets of naval operations as generally speaking, missiles can only be used once.

If the United States Navy seeks to continue to be effective across the span of naval operations—presence, deterrence, and warfighting—it will have to continue to maintain a balanced feet. Thus far, no alternative has arisen to the current large-deck carrier centric architecture that is as extensible and effective across the entire span.

Furthermore, the elimination of aircraft carriers would reduce the Joint Force's naval air power capability. Air power significantly aids in quickly achieving broad area effects, such as surveillance or strike, in a manner that slower-moving ships and submarines would have difficulty matching. The growing threats against forward land air bases and satellites increases the warfighting importance of survivable, mobile, naval air power. This is

especially true for capabilities such as Air Warfare. Even in situations in which technological trends suggested the fleet should significantly prioritize combat systems that used long-range missile systems launched from surface or sub-surface platforms, the ISR-cueing and targeting provided by carrier-based aircraft would be necessary. In such a world, carrier aviation would to some extent reprise its Inter-War role as a scouting force for the Battle Line's long-range missile striking arm.

However, in its current form, carrier aviation also provides significant mass and sustainability to meet power projection warfighting goals that alternate systems would be challenged to replicate. This ability to deliver large quantities of munitions becomes even more acute in an environment where precision is degraded due to the enemies actions.[162] Thus, even if VLS cells were reloadable in theater, a carrier could potentially deliver at distance approximately the equivalent of a cruiser's VLS warhead capacity in a single day and sustain this level of effects.

Improving the Current Carrier Strike Group Combat System. If smaller, more numerous carriers are not the answer, and a Navy without carriers is equally unsatisfying, what about a better version of the current architecture? This report has already laid out such an alternative in its section on "Improving the Carrier as a System," which lays out in detail a series of capability enhancements across four broad areas, the goal of which is to not only to maintain the CSG's effectiveness across all three operational states (presence, deterrence, and warfighting), but to do so in a manner which increases its value to the Joint Force. Enhancements to the aircraft carrier itself, its embarked air wing, its system of escort ships and land based air support, and its system of logistics, support, and infrastructure—all would contribute to a system more capable of operating in the anticipated threat environment within an acceptable level of risk, performing operations that are key to the success of the Joint Force.

A derivative question then, is if an enhanced version of the current carrier centric fleet architecture is a step forward across all three operational states, what would be the prospects for a larger, enhanced version of the current fleet architecture? This discussion is taken up in the next section of this report, after first evaluating the current fleet's capacity to carry out national objectives. That section concludes with a discussion of the required number of aircraft carriers to meet the nation's security objectives.

[162] For more information on challenges to existing precision-strike capabilities, please see: Bryan Clark and Mark Gunzinger. "Sustaining America's Precision Strike Advantage," Center for Strategic and Budgetary Assessments, 2015.

VIII. HOW MANY CARRIERS DOES THE UNITED STATES NEED AND WHY?

The number of aircraft carriers operated and maintained by the U.S. Navy has changed over time based on warfighting and presence requirements, available resources, and public law. The practice of legislatively setting the number of required carriers was established by Section 126 of the FY2006 National Defense Authorization Act (NDAA), which set the number at 12 carriers.[163] That number was reduced to 11 in the 2007 John Warner National Defense Authorization Act.[164] The Navy sought a waiver from this requirement in the 2010 NDAA because of the desire to inactivate the USS *Enterprise* (CVN 65) (which would reach its end of service life in 2012) prior to the commissioning of the ship that would replace it—the USS *Gerald R. Ford* (CVN 78). That waiver was granted in October 2009, and will result in a ten carrier force until *Ford* is commissioned in 2016.

The actual statute setting out the required number of carriers reads: "The naval combat forces of the Navy shall include not less than 11 operational aircraft carriers. For purposes of this subsection, an operational aircraft carrier includes an aircraft carrier that is temporarily unavailable for worldwide deployment due to routine or scheduled maintenance or repair."[165]

This section is important in two respects other than simply specifying the number. First, it recognizes that for counting purposes, an aircraft carrier in a maintenance period remains "operational." This is important given the fact that carriers undergo routine

[163] Please see: H.R. 1815/P.L. 109-163 of January 6, 2006
[164] H.R. 5122/P.L. 109-364 of October 17, 2006
[165] 10 USC 5062(b)

maintenance throughout their life cycles, to include a three to four year mid-life refueling and upgrade period, during which the ship could not be made available for combat without extreme effort.[166]

The second important take-away from this legislation is the implicit understanding of just what an aircraft carrier is. And to the extent that this law prescribes a number, its understanding of what an aircraft carrier is boils down to what the Navy says an aircraft carrier is. This distinction becomes an issue when analysts begin to suggest that the Navy's amphibious assault ships (LHD's and LHA's) would be counted as aircraft carriers in most other nation's navies.[167] This approach then leads to the conclusion that the United States actually has 21 or 22 aircraft carriers—the 11 (waivered to 10) specified in public law and the 11 LHD/LHA amphibious assault ships.

This study treats the distinctions between U.S. aircraft carriers and amphibious assault ships elsewhere, but suffice it to say that where Congress and its requirement is concerned, an aircraft carrier continues to be an aviation capable platform so designated by the Navy, and in the Navy's current plans, the only ships designated as aircraft carriers are the large, nuclear powered members of the *Nimitz* and *Ford* Classes. In theory, the Navy could design aviation capable ships that were not as large as the *Nimitz* or *Ford* Classes, and which were not nuclear powered—and still refer to them as aircraft carriers. This is in fact what it did through much of the aircraft carrier era in which it fielded both nuclear powered and conventionally powered platforms, and in which platforms of varying sizes operated in the same fleet. What ultimately was critical in the designation was the missions that the platform would be optimized for, and aircraft carriers are optimized to carry out sea control and power projection missions, while amphibious assault ships are optimized to support U.S. Marine Corps operations ashore.

Thus far, this discussion has centered around how many aircraft carriers the Navy is required to operate, but the more interesting question is how many carriers does the Navy (or more properly, the nation), need? The legislative requirement for 11 carriers is unlikely to have been arrived at without detailed discussions between the Department of Defense and the Congress, and those discussions in all likelihood revolved around classified force structure analyses that

[166] Huntington Ingalls shipbuilders estimate that 24-30 months would be the minimum length of time required to turn around a carrier in its mid-cycle overhaul. This estimate is built around the minimum amount of time required to re-fuel the nuclear reactor, the dissipation of which is the key driver in the requirement for the overhaul in the first place.

[167] Robert Farley. "Why Are We So Afraid of Small Carriers?," *Real Clear Defense*, June 9, 2014, http://www.realcleardefense.com/articles/2014/06/09/why_are_we_so_afraid_of_small_carriers_107265.html

integrated formal war-plan requirements with worldwide forward presence demands. Factored into those force structure analyses are available forward bases, carrier maintenance schedules, and the considerable transit times required for continentally-based forces to reach their forward operating areas.

The 11 carrier requirement is contemporaneous with the 2007 release of the Navy's maritime strategy document "A Cooperative Strategy for 21st Century Seapower." In that document, the Navy for the first time formally acknowledged what had begun in the 1990s, namely a post-Cold War shift from maintaining naval combat power forward in three regions (or hubs) to maintaining naval combat power forward in two regions. During the latter stages of the Cold War, the hubs from which naval combat power was employed included the Mediterranean Sea, the Arabian Gulf/Indian Ocean region, and the Western Pacific. The 2007 Strategy cited only the latter two hubs, with the Mediterranean having been largely de-emphasized as an area of U.S. naval interest since the mid-1990s.

It is beyond the scope and classification of this work to attempt to replicate the detailed force structure analysis required to assess the number of aircraft carriers required to support actual warfighting and presence requirements as specified in formal war plans and combatant commander requirements. It is not, however, difficult or illegitimate to look at the Navy's stated strategic narrative and assess whether the prescribed carrier force is sufficient to meet its requirements.[168] Put another way, is 11 carriers sufficient to execute a two-hub strategy? The answer is yes.

In a perfect world where ships require no maintenance, eight aircraft carriers would be required to maintain 365-day coverage at two forward employment hubs. This number is arrived at through fairly straightforward (though admittedly unsophisticated) math. One ship is required at each hub. One ship from each hub is engaged in the extensive CONUS-based training and workup operations necessary to achieve required combat readiness. Because of the great distances required for CONUS-based ships to reach their forward operating locations, one ship destined for each hub has completed its workups and is headed to replace the on-station carrier, and one ship from each hub has completed its deployment and is proceeding back to homeport. This architecture requires eight carriers to maintain indefinitely—in a maintenance-free perfect world.

[168] The 2007 Maritime Strategy was "refreshed" in 2015, and the "two-hub" construct was eliminated altogether. For the purposes of this study, the 2007 strategy's two-hub construct is selected for analysis, as its development was contemporaneous with the fixing of the size of the carrier force, first at 12 in 2006 and then at 11 in 2007.

But the world is not perfect, and ships do require maintenance. As discussed earlier, in order to achieve their planned fifty-year life cycles, aircraft carriers are taken off line for 3 to 4 years midway through that life for refueling of their nuclear reactors and for major overhauls to virtually every system fielded on the ship. At any one time, one aircraft carrier is in this extensive mid-life overhaul. Therefore, when only this extensive mid-life overhaul requirement is added to the theoretical minimum to maintain carrier coverage of two hubs, a force of nine carriers is required.

But the world is even less perfect than that, because ships require routine maintenance in excess of their extensive mid-life overhaul. In fact, in every cycle stretching from the beginning of one deployment to the beginning of the next, an aircraft carrier will enter a maintenance availability of several months in duration. In that time, it is not servicing a combat hub, it is not working up for its next deployment, nor is it in transit to or from a combat hub. Given two hubs that ultimately need to be serviced, this then creates a requirement for two more carriers to account for the requirement for periodic scheduled maintenance. Therefore, to maintain carrier coverage of two forward-deployed combat hubs indefinitely, eleven carriers are required.[169] The symbiosis between the 2007 Strategy and the 2007 NDAA requirement for 11 carriers is manifest. It should be remembered though, that this straightforward analysis does not take into consideration either formal war-plan requirements or wholly foreseeable (and routinely encountered) contingencies in which one hub or the other requires more than one CVN to adequately service the requirement.

Evidence to support this assertion arose from reports in June of 2015 of a "carrier gap" of 2-3 months in the United States Central Command area of responsibility (AOR).[170] Although the Navy has been tight-lipped about the nature of the gap, a Navy spokesman speaking on background indicated that the gap was the result of "years of strain placed on the fleet by increasing demands and

[169] This analysis provides an effective rule-of-thumb for calculating required carrier fleet size: 5*(Number of Hubs) + 1. The Navy's Optimized Fleet Response Plan (O-FRP) provides a more rigorous method of calculating required fleet size. Nonetheless, the more sophisticated method generally confirms the more straightforward formula. Under O-FRP, one 8-month deployment in a 36-month cycle per O-FRP means each carrier is underway on deployment 22% of the time. The Forward Deployed Naval Forces (FDNF) carrier is in maintenance 4 months a year, resulting in it providing 0.67 presence. Therefore, using the equation: 2.0 (Number of Hubs) + 0.5 (Carrier in Transit) = 0.67 (FDNF) + X carriers*(0.22). The result is a requirement for 8.3 carriers (in turn meaning a requirement for 9 carriers, since the Navy cannot have partial carriers). With 9 carriers not in Refueling Complex Overhaul (RCOH), 1 FDNF carrier, and 1 RCOH carrier, the Navy needs 11 carriers total. Thank you to Bryan Clark of the Center for Strategic and Budgetary Assessments for explaining the O-FRP methodology.

[170] David Larter. "Navy to pull carrier from Central Command this fall," *Navy Times*, June 5, 2015.

decreasing budgets."[171] Left unsaid was the impact of the waiver which reduced the required carrier force to 10. Even had there been no increasing demands and decreasing budgets, over time, the requirement for periodic maintenance between deployments would have stressed a 10 carrier force's ability to meet a two-hub requirement. Where such gaps arose in the past or where more than one carrier per hub was required by ongoing operations, the Navy historically has responded by extending deployment lengths of on-station CVN's and by accelerating the movement of the next carrier to deploy. The impact of the increasing demands and decreasing budgets—when added to the straightforward insufficiency of 10 carriers to meet a two hub requirement indefinitely—appears to have resulted in a relatively foreseeable gap, one that will likely be mitigated by the growth of the CVN fleet to 11.

IS A TWO-HUB NAVY SUFFICIENT?

Given the relatively simple foregoing analysis in which a two-hub Navy was shown to be continuously and indefinitely serviced by an 11 carrier fleet (and increasing evidence that a ten carrier fleet can only imperfectly service this requirement), the question then arises as to whether a two-hub Navy is sufficient to achieve U.S. national security needs. In a frank assessment of the world as he sees it, the Navy's Program Executive Officer for Aircraft Carriers Rear Admiral Thomas Moore stated in 2013, "We're an 11-carrier Navy in a 15-carrier world."[172] By the earlier analysis, 15 carriers would represent a force in excess of that required to continuously and indefinitely service two combat hubs. Ironically, the 15 carrier force is equal to that called for in the Reagan Era "600 Ship" Navy, a Navy postured to implement a forward deployed conventional war strategy against the Soviet Union from three general geographic locations: the North Atlantic, the Mediterranean Sea, and the Western Pacific Ocean.

Bearing in mind that the 2007 "two-hub" maritime strategy represented formalization of what had been at that point the operational practice for over 10 years, it is logical to assume that Navy planners viewed this posture as sufficient to serve both presence and warfighting needs in the post-Cold War security environment within an acceptable level of risk. This environment was characterized by a dramatic reduction in great power competition, the absence of any threat that could challenge U.S. Navy dominance, and the rise of littoral disorder fueled by Islamic radicalism. The Mediterranean Sea

[171] Ibid.
[172] Jon Harper. "In era of tight budgets, how many aircraft carriers are enough?," *Stars and Stripes*, June 8, 2014, http://www.stripes.com/news/in-era-of-tight-budgets-how-many-aircraft-carriers-are-enough-1.287563.

was de-emphasized as a hub for major U.S. naval forces, as the threat to NATO's southern flank evolved into what amounted largely to a maritime security requirement for the nations of NATO's southern rim. Additionally, the requirement to routinely operate in the North Atlantic also faded.

In the summer of 2015, the security environment looks dramatically different. China is building a Navy that is both quantitatively and qualitatively challenging U.S. naval preponderance in the Western Pacific, and its long term plans include a carrier force of 3-4 ships. This buildup, and China's aggressive "island-building" effort in disputed areas of the South China Sea, represents a direct challenge to U.S. national security interests and signals the possibility of contention between the United States and a revisionist China. Recognition of this changed dynamic can be found in the 2012 Defense Strategic Guidance, which asserted that "while the U.S. military will continue to contribute to security globally, we will of necessity rebalance toward the Asia-Pacific region."[173] The DSG suggests a requirement for continuous and indefinite naval combat presence in the Western Pacific, or what could be considered "Hub #1." The 2014 QDR confirmed the United States' intent to "maintain a robust footprint in Northeast Asia while enhancing our presence in Oceania, Southeast Asia, and the Indian Ocean."[174]

Even as the Obama Administration issued its 2012 guidance, questions arose as to where the forces required to implement it would come from, and given the stated policies of that Administration (and the previous one) to wind-down war efforts in Afghanistan and Iraq, it became clear that there was at least a desire to modestly alter U.S. force commitments in the Middle East. What this meant in actual practice has not been fully described, but for naval forces at least, little alteration has occurred.

Since the guidance was issued in 2012, the United States Central Command area of responsibility, which includes much of the Middle East, has had continuous CSG coverage of at least one ship, and for extended periods was assigned two (even as the nation continued to service its Western Pacific Hub—another factor in the reported Fall of 2015 "carrier gap"). Put another way, as China has become more clearly identified with a new era of great power competition, the requirement to maintain significant naval power in the Middle East has not diminished, and if anything has increased, as the United States relies more heavily on sea and air forces in the region for operations in

[173] "Sustaining U.S. Global Leadership: Priorities for 21st Century Defense," The White House, January 2012, 2.
[174] "Quadrennial Defense Review," Department of Defense, 2014, 34, http://www.defense.gov/Portals/1/Documents/pubs/2014_Quadrennial_Defense_Review.pdf.

Afghanistan, Iraq, and Syria and less on ground forces that have largely redeployed to their U.S. bases. It is difficult to consider a future U.S. national security policy that does not seek to maintain stability in the Middle East and deter Iran, and it is difficult to conceive how doing so will not rely heavily upon the combat forces of the U.S. Navy. Thus, a requirement for a second hub remains.

But what of Europe, North Africa, or the High North? What are the implications of Russian revanchism demonstrated in Georgia in 2008, in Ukraine in late 2014, and now? Or Russia's return to maintaining naval task groups in the Mediterranean Sea?[175] When Russia entered Ukraine, there was no U.S. CSG in the Mediterranean Sea, and U.S. naval forces have only sporadically operated in the Baltic Sea and the High North in the 21st century.[176]

Additionally, no American CSG was in the Mediterranean at the outbreak of the conflict in Libya in 2011, nor was a U.S. carrier in the Mediterranean when a U.S. diplomatic outpost in Benghazi, Libya was attacked and America's Ambassador to Libya and three others were murdered. No American aircraft carrier was in the Mediterranean when Syria attacked its own citizens with chemical weapons, presumably challenging President Obama's "red line." One cannot draw too fine a line between this brief number of cases, but the pattern is discerning and only reinforces the long established intuitive logic of operating carrier-based presence forward in order to sustain global order, increase executive options and maximize decision space. Presence matters.

Carrier Strike Group forces that would have or could have responded to these and other crises in Europe, generally are based on the East Coast of the United States and deploy forward to the Central Command region, only sporadically operating in the Mediterranean Sea as they transit to and from CENTCOM. Therefore, not only are the most logically available forces to respond to European contingencies primarily assigned elsewhere, but the Defense Strategic Guidance sustained momentum to unbalance naval combat forces between the two traditional "fleets" (Atlantic and Pacific), to a 60/40 proportion in favor of the Pacific. Based on U.S. commitments to NATO, a resurgent Russia, and instability across North Africa and the Levant, it is clear that the United States should re-evaluate its post-Cold War decision

[175] Thomas Fedyszyn. "The Russian Navy Rebalances to the Mediterranean," *Proceedings of the United States Naval Institute*, Vol. 139/12/1330, December 2013.
[176] NATO BALTOPS 2015, conducted from 5 June-20 June signaled the growing sense of urgency among NATO nations (including the United States) to Russian aggressiveness in the Baltic Region and the High North. European reactions to Russian moves are described in an April 2015 Defense News piece. (Gerard O'Dweyer. "Nations Respond to Russian Buildup in Baltics," *Defense News*, April 12, 2015.)

to eliminate the Mediterranean as a hub for forward deployed combat forces and once again begin to apply a three hub construct to its force structure planning.

HOW MANY CARRIERS ARE REQUIRED FOR A THREE-HUB NAVY?

The simple answer to how many CVN's are required to continuously and indefinitely maintain three combat hubs is 16, which would describe a carrier fleet 45% larger than that which is currently mandated by the Congress.[177] Using the analytical framework suggested earlier in this section, this breaks down to three hubs, each of which must have four CVN's to maintain coverage, with an additional CVN in each hub in some kind of routine maintenance period and one CVN in mid-life refueling and upgrade.[178]

A 16 carrier force would be capable of maintaining continuous coverage of three hubs indefinitely, with little or no risk of gap. In such a force laydown, if Iran begin to threaten the stability of the Persian Gulf, the Mediterranean carrier could steam to the region and provide extra combat power. Of course, this then opens a hole in the Mediterranean. This "shell game" is unfortunately, the rule rather than the exception, irrespective of how many hubs or how many carriers the nation maintains. And if such a two-carrier requirement in CENTCOM occurred at the same time as instability arose in Egypt, the "surge carrier" (one most recently returned from deployment but which has not yet entered its routine maintenance phase) could be sent to the Mediterranean to fill a temporary gap, which would mean that four carriers were deployed to three hubs, a situation that would begin to create the exact same "gap" situation we see today with our ten carrier/two hub force.

As currently allocated, DoD resources do not support a 16 carrier force. The purpose of this discussion was not to describe the carrier force that can be afforded, but the carrier force necessary to continuously and indefinitely maintain coverage in three geographically dispersed hubs. And while many military requirements are funded at levels below the desired amount in the quest to balance risk across a broad portfolio, the foregoing discussion attempts to lay out two broad points. The first, is that a two-hub Navy is insufficient to the requirements of world

[177] The use of the phrase "continuously and indefinitely" in this section is chosen with forethought. Clearly, if "gaps," or something other than "1.0" presence is acceptable in one or more of these hubs, than the number of carriers required to provide presence drops. If however, one seeks to maintain 3.0 CVN's deployed "continuously and indefinitely", gaps are unacceptable and must be eliminated with sufficient force structure.

[178] The Navy O-FRP equation would be: 3.0 (Number of Hubs) + 0.75 (Number of Carriers in Transit) = 0.67 (FDNF) + X(0.22). In this equation, X=14, which means the Navy would require 16 carriers total (14 carriers not in RCOH, one carrier in FDNF, and one carrier in RCOH).

leadership to which it appears that the United States continues to aspire.[179] Second, that the current 11 carrier force (and 308 ship Navy that supports it) is insufficient to support the requirements of a three hub Navy, and while a Navy built around 16 carrier strike groups may be unaffordable, the current Navy is misaligned with our national security requirements.

[179] Of note, the 2015 "refresh" of the 2007 Maritime Strategy eliminates even the "two-hub" approach. Please see: http://www.navy.mil/local/maritime/150227-CS21R-Final.pdf

IX. CONCLUSION

This study concludes that while the operational environment for the aircraft carrier is becoming increasingly dangerous, with proper enhancements to concepts, capabilities, and capacities, the CSG will continue to play a critical role in the Joint Force architecture in high-end warfare, even as it continues to be the option of choice for naval presence and response throughout the entire range of military operations. The process of periodically evaluating the effectiveness and relevance of the aircraft carrier is an important one, and policy-makers should continue to ask cogent questions and force carrier proponents to examine their assumptions.

Accordingly, the *Ford* Class should not be considered the final word on the subject of naval power projection, nor should policy-makers feel constrained to fifty years of acquiring these ships. That said, the decision to move away from the large, nuclear powered aircraft carrier-centric Navy to some other fleet design must be held up to similar levels of scrutiny. Those who would build smaller, conventionally-powered carriers need to account for the major decrease in warfighting capability and capacity. Those who would build smaller, nuclear powered carriers in order to harvest savings to distribute to other parts of the Navy (or elsewhere) need to account for the mismatch between actual savings and actual capability decrements. Those who would de-emphasize the carrier altogether need to account for the decrease in Navy capability across the span of operational states and the gaping hole left in Joint warfighting, especially in the absence of forward, land-based airfields. And those who would attack the carrier solely on the basis of its cost must also account for its value, its flexibility, and its durability.

The Chinese A2/AD complex represents the greatest threat to the aircraft carrier; paradoxically, the requirements of this high-end engagement argue strongly for the CVN. Put another way, whatever the degree of risk that applies to the carrier and its strike group in a war with China, that risk is greatly

exceeded by the risk to U.S. land-based power projection, sea-control, and ISR activities; and if the Joint Force is to prevail in such a conflict, the operational contributions of the nation's carrier fleet will prove essential.

This continuing utility and Joint Force interdependence argues strongly for increased investment in concepts, capability, and capacity to enable the CSG and other naval forces to operate with acceptable levels of risk against high-end A2/AD opponents. These investments include a sufficiently sized carrier force to service the nation's strategic requirements in peace and war, an air wing optimized for the high-end A2/AD threat, escort ships with the capacity to stay in the fight longer and rejoin it quicker, a logistics force up to the task of sustaining multiple-CSG operations at extended ranges from forward operating and logistics bases, and innovative concepts of operation to tie them all together.

Perhaps some other platform, or combination of platforms, or combination of platforms and capabilities, could more effectively and efficiently provide all of the capabilities currently fielded and anticipated to be fielded in the future in the CVN. Our survey of the alternatives to the large CVN leads us to conclude that while there are some capabilities that offer portions of the capabilities that the carrier provides, no approach provides them all.

Furthermore, to the extent that these approaches attempt to replicate the CVN's capabilities at a lower capacity and cost, we find that the savings are modest and the performance decline is considerable. We do not advocate for these enhancements simply to "save" the aircraft carrier. If our research had concluded that ridding the fleet of carriers added in some demonstrable way to U.S. naval effectiveness in both peace and war, the navalists associated with this report would have so stated.

But late in 2015, the country finds itself in a quandary, in that such an argument has not been persuasively made, while at the same time, the resources going into the present instantiation of the carrier and the CSG poorly account for either the advances made by threats or the increasingly obvious requirements of future Joint Force warfighting. Without a change in the allocation and amount of these investments, after eight decades of trying, the critics of the aircraft carrier will justifiably be correct, and the value of the aircraft carrier to the nation will have sunk.

X. LIST OF ACRONYMS

A2/AD	Anti-Access/Area Denial
AAW	Anti-Air Warfare
AEA	Airborne Electronic Attack
AEW	Airborne Early Warning
APN	Aircraft Procurement, Navy
AOR	Area of Responsibility
ASB	Air-Sea Battle
ASBM	Anti-Ship Ballistic Missile
ASW	Anti-Submarine Warfare
CBO	Congressional Budget Office
CIWS	Close-In Weapon System
CLF	Combat Logistics Force
CSG	Carrier Strike Group
CVN	Nuclear-powered aircraft carrier
CVV	Aircraft Carrier Medium
CVW	Carrier Air Wing
CTOL	Conventional Take-Off and Landing
DCA	Defensive Counter-Air
DEAD	Destruction of Enemy Air Defenses
DLA	Defense Logistics Agency
DoD	Department of Defense
EMCON	Emissions Controls
FDNP	Forward Deployed Naval Forces
HA/DR	Humanitarian Assistance and Disaster Relief
HF	High Frequency
HII	Huntington Ingalls Industries
HPM	High-Power Microwave
IAMD	Integrated Air and Missile Defense
ISIS	Islamic State of Iraq and Syria
ISR	Intelligence, Surveillance, and Reconnaissance
JASSM	AGM-158 Joint Air-to-Surface Standoff Missile
JSOW	AGM-154 Joint Standoff Weapon
LHA	Landing Helicopter Assault
LHD	Landing Helicopter Dock
LRASM	Long Range Anti-Ship Missile
MIW	Mine Warfare
MIO	Maritime Interception Operations
NASSCO	National Steel and Shipbuilding Company
NDAA	National Defense Authorization Act
NIA/D3	Networked, Integrated Attack-in-Depth to Disrupt, Destroy and Defeat
NIFCA	Naval Integrated Fire Control – Counter Air
OCA	Offensive Counter-Air
OCO	Overseas Contingency Operations
O-FRP	Optimized-Fleet Response Plan
OTH	Over-the-Horizon
PLA	People's Liberation Army
PLAN	People's Liberation Army Navy
PRC	People's Republic of China
RAM	Rolling Airframe Missile
RCS	Radar Cross Section
RCOH	Refueling Complex Overhaul
SCN	Shipbuilding and Conversion, Navy
SCS	Sea Control Ship
SEAD	Suppression of Enemy Air Defenses
SSTD	Surface Ship Torpedo Defense

SSK	Diesel-powered attack submarine
SSN	Nuclear-powered attack submarine
STOVL	Short Take-off Vertical Landing
SUW	Surface Warfare
T-AO	Oiler
T-AOE	Fast combat support ship
T-AKE	Dry cargo/ammunition ships
UCLASS	Unmanned Carrier-Launched Airborne Surveillance and Strike
UNREP	Underway Replenishment
VLS	Vertical Launch System
VSTOL	Vertical/Short Take-off and Landing
VSS	VSTOL Support Ship

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