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Executive Summary

Title: The Future of Power Projection – Is the US Navy Aircraft Carrier Still Worthwhile?

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Thesis: Modern carrier-based aviation comes with its own unique set of vulnerabilities; its continued use as the premier power projection asset of the US Navy demands renewed evaluation in terms of capability, survivability, expense, and comparison to alternative platforms.

Discussion: The US Navy and aircraft carriers are largely synonymous in the public mindset. Often the first question asked by both civilian oversight and media outlets alike when a conflict breaks out is "Where are the carriers?" Such a dominant force in the national psyche should not be taken for granted. No other nation can field and maintain such a magnificent symbol of military, industrial, and technological might.

Even so, how long has it been, since carrier-based aviation, the enterprise as a whole, has been examined by an impartial third party with respect to its continued viability? The ultimate expression of the utility of a military asset should be its efficacy in combat against a near peer. Has the pace of technological growth in terms of guided missile technology both foreign and domestic rendered the reach of carrier-based aviation too short? Is it time for carrier aviation to take a reduced role in US strategic thinking?

This essay will address historical parallels, capability, survivability, and economic evidence in an effort to evaluate whether the US Navy's continued reliance on carrier-based based aviation as its core power projection platform is still warranted.

Conclusion: Carrier-based aviation is an unjustifiably vulnerable concentration of national power projection that has been surpassed both in capability and survivability by alternative platforms; moreover, the expense of purchasing aircraft carriers and their associated air wings is economically unsound compared to those same alternative platforms.

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Acknowledgements

It has been a pleasure researching the topic of aircraft carriers and their continuing relevance to the Fleet. No small part of that has been the positive assistance and feedback I have received from Marine Corps University staff. Specifically, I would like to thank Dr. Craig Swanson for his mentorship and candid discussion on my subject of interest. As well, I would like to thank the reference librarians of Gray Library for their assistance in locating source material relevant to the topic. They make it look easy. Finally, I would like to thank my wife, Hayley; who, as always, served as my editor-in-chief and local sounding board for all things MMS. She did more than her fair share of wrangling our children while I worked, too.

Introduction

The US Navy and aircraft carriers are largely synonymous in the public mindset.[i] Often the first question asked by both civilian oversight and media outlets alike when a conflict breaks out is "Where are the carriers?" Such a dominant force in the national psyche should not be taken for granted. No other nation can field and maintain such a magnificent symbol of military, industrial, and technological might.

French aircraft carrier Charles De Gaulle as compared to USS Abraham Lincoln. France maintains one aircraft carrier. The US presently maintains ten.

The fact that the US has them, both in size and quantity, and other nations do not is a testament to the wealth of the US in terms of people, industrial, and economic might.[ii] They are symbols

[i] For the purposes of this paper and unless otherwise identified, the term aircraft carrier refers to the US Navy's *Nimitz* and *Ford* class CVNs. Light aircraft carriers such as the *Wasp*, *Tarawa*, and *America* class LHDs and LHAs are not being considered.

[ii] Current US law requires the Navy to maintain a minimum of eleven aircraft carriers. The Navy presently has ten.

of US military dominance, conveying America's unrivaled ability to project power anywhere in the world. So goes the common line of reasoning for those unaffiliated with the US Navy.

That same truism is often taken at face-value inside Navy circles as well. With a large proportion of flag and general officers coming from the naval aviation community, lines of thought other than outright acceptance of carrier-based aviation as the pre-eminent form of naval power projection constitutes an outright assault on the livelihoods of the entire naval aviation community and that portion of the US defense industry which sustains them. Can the US public expect the naval aviation community to be objective when examining its own relevance in future conflicts? How long has it been since carrier-based aviation, the enterprise as a whole, has been examined by an impartial third party with respect to its continued viability?[iii]

The ultimate expression of the utility of a military asset should be its efficacy in combat. Furthermore, it must be effective when pitted against an opponent whose military might is a credible threat to our own, a near peer. Potential adversaries such as Russia and China have almost certainly developed contingency plans to counter the approach of a carrier battle group. Some have developed weapons (e.g. DF-21D) specifically intended to thwart our use of aircraft carriers as an aviation platform.[1] Has the pace of technological growth in terms of guided missile technology both foreign and domestic rendered the reach of carrier-based aviation too short? Is it time for carrier aviation to take a reduced role in US strategic thinking?

This essay will address four categories of questions that will prove valuable in the evaluation

[iii] It is important to note that the subject of this paper is the aircraft carrier and carrier-based aviation not naval aviation in general. Shore-based naval aircraft e.g. maritime patrol aircraft are beyond the scope of the discussion.

of the US Navy's continued reliance on carrier-based based aviation as its core power projection platform:

1. History. How did aircraft carriers become today's capital ships? What was the dominant naval asset before it? What initiated a transition from one to the other? Were there recognizable pre-conditions that should have prompted action sooner than it actually happened? What capability, survivability, and economic comparisons can be made between past and present?
2. Capability. What is the typical number of strike missions required per deployment? What is the strike capacity of a typical carrier air wing? What is strike capacity of various alternative assets? What comparisons can be drawn between the two? Are there any competing power projection strategies besides the traditional carrier battle group?
3. Survivability. How vulnerable is an aircraft carrier? To undersea attack? To air attack? Do alternative platforms have similar vulnerabilities? Does investing in a single concentrated power projection asset provide greater survivability than multiple smaller assets? Are there any competing strategies that allow for greater survivability by surface assets?
4. Economics. How much does it cost to purchase and maintain an aircraft carrier? Similarly, how much does it cost to purchase and maintain alternative platforms?

Modern carrier-based aviation comes with its own unique set of vulnerabilities; its continued use as the premier power projection asset of the US Navy demands renewed evaluation in terms of capability, survivability, expense, and comparison to alternative platforms.

History – Lessons Learned from the Interwar Period

Carrier-based aviation has not always been the centerpiece of large scale naval warfare. Certainly, there were organized navies long before there was manned flight; the predecessor to the aircraft carrier was the battleship. It is worthwhile, then, to look critically at the transition from battleship to aircraft carrier and apply the lessons learned from that transition to present day problem this essay aspires to address.

The Interwar Period, a portion of history spanning the time between World War I and World War II, and World War II itself is the time period most useful for examination. This essay's intent with respect to history is to examine obstacles that prevented the US Navy from transitioning from battleship-centric operations to doctrine centering on carrier-based aviation. Specific discussion items include innovation in peacetime vice conflict, the capabilities of the battleship and aircraft carrier, issues associated with survivability, as well as some economic realities at the time. Applying a historical subtext to capability, survivability, and economics will provide for a better appreciation of the arguments presented later in this essay i.e. these are hard won lessons from the past that are worth remembering.

> They came in waves, until they stretched almost from horizon to horizon, row upon row of these flying machines. What chance, I thought, would any ship, any fleet have against an aggregate such as this? You could shoot them from the skies like passenger pigeons, and still there would be more than enough to sink you. Now I loved the battleship, devoted my whole career to it, but at that moment I knew the battleship was through.[2]

> The fleet that advanced through the Pacific in World War II was not the fleet of prewar [pre-WWII] plans. The prewar Navy had centered on a battle fleet, a battleship-centric formation that concentrated together with a large fleet train, would move as a unit, seizing objectives along its path.[3]

Consider the two preceding quotes. The first occurred in 1918. The second occurred during World War II. Early on, officers in the highest echelons of the Navy service noted the inevitability of aviation-dominated naval conflict, and yet, more than twenty-four years later, the battleship was still at the center of all fleet tactics.[4] Military historians often remark that the warfighters of a given era tend to prepare for the wars that preceded them. Aircraft carriers existed alongside battleships in WWI and received positive marks from the naval services that employed them; they were respected for their value in conducting reconnaissance and raiding missions.[5] The victorious conclusion of WWI for the Allied powers bred an aversion to changing the winning formula for conflict. Despite observations like that of Admiral William F. Fullam above and successful demonstrations of the potential of aviation assets to sink ships, core US Navy warfighting doctrine would retain its change averse, battleship-centric focus until 1942.[6] In short, the US Navy never discounted the value of the aircraft carrier and its associated air wing; it was widely recognized for its reconnaissance and raiding capabilities. Innovation focused along those lines. Its failing was that despite evidence that should have promoted the issue of re-evaluating the utility of both the aircraft carrier and the battleship, the Navy found itself institutionally incapable of doing so. Violent conflict was needed to effect change.

WWII provided the motivation required. Interwar period strategy primarily revolved around the idea that there would be a decisive battle somewhere on the high seas and that opposing forces need only find each other, close distance, and exchange blows. "The chief strategic function of the fleet is the creation of situations that will bring about decisive battle, and under conditions that will ensure the defeat of the enemy."[7] Whoever brought the biggest guns and the most armor to the fight would win.[8] This type of conflict, a slugging match of sorts, was

uniquely suited to the battleship, the capital ship of the day. What was discovered in the first phases of the war, however, was a preference for long range engagements via aircraft.

Battleships played a defensive role in long range engagements, protecting their aircraft carriers from adversary aircraft.[9] This was a sensible move. The risk-reward calculation for two battle fleets exchanging broadsides with each other simply did not add up when compared to the alternative of sending aircraft over the horizon to engage the adversary. Carrier-based aviation could provide offensive action against the adversary while keeping friendly (and expensive) surface vessels safely beyond the reach of the salvos of enemy coastal defenses, battleships, and destroyers.[iv] For the first time, a US Navy platform had achieved real power projection, a capability that had been suggested since the earliest days of the Interwar period, but was not achieved until conflict. Transitioning to aircraft carriers and their respective air wings was clearly a net-positive development; however, those same Interwar Period aircraft carriers were not without a few negative considerations.[v]

Opponents of the transition from the battleship-centric Navy to the carrier-centric Navy were quick to point out the down sides of investing in these vessels. The primary arguments fell into one of two categories: survivability or economics.[vi]

> Despite the unknowns attached to carrier operations, several things were clear from the pre-war fleet problems. First, it was essential for any carrier to get in the first strike against an enemy. That was because carriers under concerted air attack were almost impossible to defend.[10]

[iv] The sudden wartime recognition of the utility of carrier-based aviation should not convey the idea that battleships were suddenly worthless. They retained immense value as escort ships and shore bombardment vessels for decades following WWII. Likewise, modern day aircraft carriers would find lively employment for decades in the US Navy even if it was determined that they are obsolete in terms of great power conflict.

[v] Air wings were actually called air groups during the Interwar period. Air wing will be used exclusively for consistency purposes throughout the remainder of the document.

[vi] Survivability shall be defined as the vessel's ability to remain mission capable, not necessarily sunk.

Fleet evaluations conducted prior to WWII highlighted the aircraft carrier's potential vulnerability as a critical issue. Concerted attack could quickly render the flight deck of the aircraft carrier unusable, leaving the warship mission ineffective. This, in turn, made the Navy extremely reluctant to use carriers in areas where their dominance could be contested e.g. providing close air support for amphibious operations.[11] The risk of losing a mission-capable aircraft carrier often became more important than employing it against the adversary.

Gaining historical perspective on the economic realities of buying an aircraft carrier is best served by looking to the British. Britain was satisfied with the reconnaissance and raiding roles of its carrier-based aviation at the end of World War I and, being a nation with a limited defense budget at the time, committed itself to purchasing similar aircraft carriers early. The aircraft carriers they purchased were certainly serviceable in that regard, but were unable to be adapted to the better uses revealed in the first stages of World War II. "Scarce funds ensured that Britain would be stuck with carriers built before requirements for sustained carrier operations were understood."[12] The budget-minded nation could neither dispose of them early nor build additional warships that better suited their needs.[vii] As a result, the British, keen on maintaining the capability that won the last war, were stuck entering World War II with an expensive aircraft carrier force that was incapable of fully exploiting the weakness of the enemy.

A review of relevant historical material is the critical first step in discussing the utility of the contemporary aircraft carrier. The following are key takeaways with respect to the transition

[vii] It is worth acknowledging that British aircraft carriers were built with different design criteria than US aircraft carriers. Britain was more concerned with defending its homeland and colonial holdings than participating in long range blue water engagements. What is germane to the discussion here, however, is that they bought the aircraft carriers they thought they needed early, found them wanting, yet were stuck with them due to sunk costs.

from a battleship-centric navy into a carrier-centric navy as well as historical elements related to capability, survivability, and economics:

1. The need for a transition from a battleship-centric Navy to a carrier-centric Navy was recognized decades earlier by senior Navy officers, yet the transition could not be made to occur without the forcing function that was violent conflict in World War II.
2. The primary advantage that made carrier-based aviation the logical successor to the battleship was power projection. The struggle to be able to apply offensive capability against the adversary and remain beyond his capability to retaliate in a meaningful way has persisted all the way to the present.
3. First strikes and concerted assaults against an aircraft carrier were a significant vulnerability of aircraft carriers in WWII. The collected power projection capability of an entire battle group could be rendered mission ineffective with the loss of a single vessel, resulting in tactical decisions heavily weighted toward saving the aircraft carrier from potential damage so as to be used in future battles rather than fully committing it to present battles.
4. Failure by the British to recognize significant advances in carrier-based aviation left them financially over-committed to warships that, once tested in conflict, were not the best tools to complete the job.

Capability – Cruise Missiles Marginalize the Strike Power of the Aircraft Carrier

History has shown us that the attribute that made carrier-aviation indispensable was its unrivaled ability to project power, primarily in terms of strike operations against an enemy.

From WWII forward, the arrival of an aircraft carrier with its associated air wing signaled that the US Navy could then reach deep into adversary territory and conduct offensive operations that the adversary would not be able to retaliate against. This is not to say that US adversaries rested on their laurels when it came to countermeasures. A significant portion of naval innovation in past seven decades revolved around defeating the carrier battle group construct. In response, the US Navy continuously refined its own defense-in-depth concepts that utilized a tight web of cruisers, destroyers, and submarines to decrease the likelihood of a strike from adversary torpedoes, cruise missiles, and mines. Suitably defended, the aircraft carrier or "high value unit" could then go about its mission in relative safety.

F-18C

F-35C

Tomahawk launch from a guided missile destroyer.

Destroyers, cruisers, and submarines, traditional aircraft carrier defense units, have developed an intrinsic strike capability of their own. They make extensive use of the RGM/UGM-109E Tomahawk land attack missiles. Is it possible that the strike qualities of these

warships exceed that of the warships they are charged with defending?[viii] This section of the essay will examine some of the basic strike limitations of two carrier-based aircraft, the F/A-18 and the F-35C, and compare them to that of the Tomahawk missile.[ix] A concept call "Distributed Lethality" which would divide the strike capability of the fleet among a myriad of warships as opposed to concentrating it on a single warship will also be briefly examined.

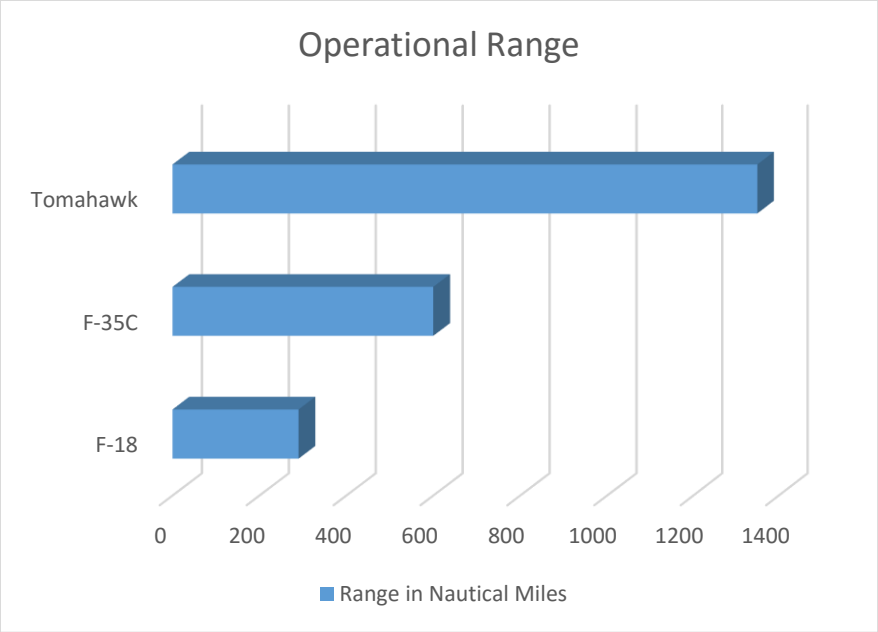
Operational range will be our first comparison. Beginning with the F-18, we see an estimated maximum operating range of 290 nm.[13] For the F-35C, the carrier variant, we see an estimated maximum operating range of 600 nm.[14, x] The RGM/UGM-109E Tomahawk land attack missile has an estimated maximum range of 1350 nm regardless of the platform (cruiser, submarine, etc.) from which it is launched.[15, xi]

[viii] It is worth acknowledging that aircraft carriers employ a range of multi-purpose aircraft capable of serving a number of functions beyond strike e.g. ISR, transport of goods and passengers, etc. Strike i.e. power projection, however, is the lynchpin justification for continued carrier pre-eminence.

[ix] The F-35C has not yet been delivered to the Fleet as an operational platform. It is included in this discussion because its future employment is near certain.

[x] Air-to-ground munitions provide a negligible amount of additional range to the total operating range of the aviation platform that employs them.

[xi] The cited reference for the RGM/UGM-109E Tomahawk provides an official US government stated range (869 nm) as well as a convincing argument based on inferences from earlier versions of the missile that the actual range of the missile is 1350 nm. This essay will use the larger range as its reference.



If operational range is indeed a factor, the F-35C is clearly an evolutionary leap forward in manned-aviation technology. It more than doubles the operational range of the F/A-18. Both, however, are eclipsed by the Tomahawk which more than doubles even the F-35's range. For illustrative purposes, this means a Tomahawk-capable platform located 600 nm *behind* an aircraft carrier could conduct a strike mission 700 nm *in front* of said aircraft carrier and still exceed the reach of the carrier air wing by a decisive margin. This is a real tactical advantage with both offensive (can reach further inland) and defensive (can achieve greater standoff distance) implications. Aircraft tanking could (and *is*) employed to extend the range of the strike aircraft that comes with its own dangers. Various aspects of survivability will be covered in depth later in this essay.

A likely counterargument to the simple math conducted above is that carrier-based aviation is not just about range but also the number of strike missions (i.e. sorties) an aircraft carrier can provide compared to alternative platforms. On the surface, this is a reasonable

argument. "*Nimitz* class carriers can generate approximately 120 sorties a day."[16] Assuming every sortie is a strike mission, the carrier air wing would exceed the maximum strike capability of the entire remainder of its carrier battle group (nominally: two destroyers, one cruiser, one submarine for a generous total of approximately 200 Tomahawk missiles) in only two days.[17, 18, 19] The truth is a little more ambiguous as the following assessment of ordnance spent from 2002-2012 indicates:

> Ascertaining the actual number of weapons expended [by strike aircraft] in combat is difficult at best as there are no unclassified reports detailing this information for current and recent activities in Afghanistan and Iraq. However, logic suggests that weapons dropped in combat must be replaced in the inventory. Available budget documents reveal that the Department of the Navy has purchased approximately 18,000 air-to-ground weapons since Fiscal Year 2002. Taking into account that perhaps 2,000 of these weapons were intended to build up inventories, the data suggests that the U.S. naval services have expended approximately 16,000 air-to-ground weapons in the past 10 years. While this number seems impressive at first glance, when divided across the approximately 1,000 air-to-ground strike-capable aircraft in the Navy's inventory, that works out to an average of just 16 weapons per aircraft during the decade.[20, xii]

It is important to note that during a decade of uncontested, continuous strike missions in Iraq and Afghanistan, the amount of ordnance expended in that *decade* for all strike airframes was sixteen. Supposing that a carrier air-wing (approximately forty strike aircraft) deploys four times in a ten-year period, this amounts to 160 strike-munitions expended per deployment, well under the estimated 200 Tomahawk missile inventory of the remainder of the carrier battle group. It can thus be inferred that a discussion regarding the total number of sorties an aircraft carrier can conduct in a day is largely irrelevant as there simply are not enough targets to prosecute in a given deployment. Even if conflict with a near peer competitor required a higher

[xii] This paper asserts that it might be time for the aircraft carrier to take a reduced role in the US Navy, not that it should have no role at all. It is reasonable to infer that the amount of ordnance expended in the cited paragraph would be enough to soften the battle space against a near peer and allow our existing 40-year inventory of aircraft carriers, in a second wave, to conduct uncontested flight operations once it is safe.

number of sorties, the existing aircraft carrier fleet is more than capable of providing it once surface and subsurface combatants use their own strike capability to neutralize adversary defenses.

If cruisers, destroyers, and submarines assigned to a carrier battle-group can provide the strike capability required of a typical carrier battle group deployment, what benefits could be gained from simply leaving the aircraft carrier at home and freeing its respective support ships from the need to defend it? The Navy's senior surface warfare leadership are developing a concept called "Distributed Lethality" which addresses this subject. While careful not to incite the wrath of naval aviation stakeholders, "the surface fleet will always defend the high-value and mission-essential units; that is in our core doctrine," the concept's primary focus is to go on the offensive and disaggregate the fleet.[21]

> The objective is to cause the adversary to shift his own defenses to counter our thrusts. He will be forced to allocate critical and limited resources across a larger set of defended targets, thereby improving our operational advantage to exploit adversary forces… By distributing power across a larger number of more geographically spaced units, adversary targeting is complicated and attack density is diluted.[22]

Spreading out the surface fleet forces an adversary to spread out his. US Navy surface ships are not at a significant disadvantage when doing this as each ship is equipped with a robust self-defense capability, the kind that develops as a result of perpetually playing the role of defender in a carrier battle group. Not so for our adversaries. No longer seeing a single, massed carrier battle group on the horizon but rather a multi-axis US Navy approach, our adversaries must spread out their assets in an effort to counter it. In doing so, US Navy relative combat power is strengthened. Strike missions i.e. power projection can be conducted over swaths of territory that it, under the traditional carrier battle group construct, could not.

It would be foolish to abandon the aircraft carrier and its air-wing if no alternative to its ability to project power was available. Nor is it enough to for the alternatives to be an even match. A strong argument for change requires that the power projection capability of the aircraft carrier be exceeded. The following key takeaways support such an argument:

1. Advances in the capabilities of carrier-based fixed-wing aviation notwithstanding, the maximum operating range of the Tomahawk missile is more than double its closest power projection competitors.
2. The superior sustained strike capacity of aircraft carriers and their air wings is largely irrelevant. The rate of use of strike ordnance from the last decade indicates the Tomahawk missile inventory of the carrier battle group was sufficient to meet the needs of a deployment by a wide margin.
3. Warships that are disaggregated can conduct operations in multiple locations at once and force the enemy to attempt to defend multiple locations at once. The US Navy becomes stronger by forcing an adversary to spread out his defenses.

Survivability – Too Large and Too Valuable to Commit to the Fight

Deriving power projection capabilities from a single unit results in a singular vulnerability. An adversary that removes an aircraft carrier from the battle problem has removed our present primary means of offense. As discussed earlier in this essay, history has shown that this has been a concern regarding the use of carrier-based aviation since its inception. The result is a reluctance to commit so valuable a warship to a conflict where it could potentially be within

weapons release range of the enemy. This is certainly not an unreasonable thing to do given the value of the asset. Despite the constraint, adversary nations in the past seven decades have seldom come close to having the technological edge necessary to engage an aircraft carrier before its concerted air power could engage them. Times have changed. In this section of the essay, the air and subsurface vulnerabilities of the aircraft carrier will be considered and contrasted with that of the fleet's most prolific surface combatant, the *Arleigh Burke* class destroyer.

Arleigh Burke class destroyers in formation with a *Nimitz* class aircraft carrier.

Air and subsurface vulnerabilities share similar arguments when it comes to detection. Specifically, the radar cross-sections and acoustic profiles of aircraft carriers are enormous when

compared to other surface combatants in the fleet.[xiii] A common (and accurate) bumper-sticker phrase of sailors when stepping onboard an aircraft carrier is, "welcome to 4.3 acres of sovereign US territory."[23] Awe-inspiring as that sounds, 4.3 acres or 195k ft^2 of flight deck space also makes for an enormous target for acquisition by enemy radar or anti-ship cruise missiles. Compare this to less than 34k ft^2 of exposed horizontal surface area on the *Arleigh Burke* class destroyer and note the difference by a factor of six.[xiv] Similarly, for an acoustic argument, the total displacement, number of screws, and total horsepower, 92k tons, four, and 280k hp respectively, dwarfs that of a destroyer at 9k tons, two screws, and 100k hp.[xv] These numbers confirm what is likely obvious to even a casual observer by simply looking at the two ships side-by-side. What makes the fact that the aircraft carrier is more easily tracked relevant?

Being easier to track and target renders the entire carrier battle group more vulnerable. Aircraft carriers do not travel unescorted. They must be defended vigorously by other warships. Carrier aircraft, after delivering their munitions, supported by tanker or otherwise, must also fly back to the ship, again giving away its position. By finding the aircraft carrier, the adversary finds the entire carrier battle group. The US Navy currently employs ten aircraft carriers.[24] Remove those ten aircraft carriers from the equation, and you remove the need for the fleet to steam together. Tracking the whereabouts of ten easily detectable aircraft carriers is a relatively attainable goal for an adversary to contemplate when compared to tracking a disaggregated fleet

[xiii] Exact values for the radar cross-sections and acoustic profiles of these two vessels are classified. It is sufficient for comparison purposes to point out differences in major factors related to their calculation, using data available to the general public.
[xiv] This comparison discounts any consideration for the stealth enhancements of the *Arleigh Burke* class destroyer. *Nimitz* class carriers have none and their inclusion would only bias the comparison further in favor of the destroyer.
[xv] Again, this comparison discounts any stealth enhancements of the *Arleigh Burke* destroyer. *Nimitz* class carriers have none and their inclusion would only bias the comparison further in favor of the destroyer.

of 62 destroyers, 22 cruisers, and 40 fast attack submarines as well as other more specialized ships and aircraft.[25, 26, 27]

Concentrating the fleet's power projection capability around a singular platform encourages an adversary to concentrate their efforts on defeating it. In the US Navy's own exercises, a crowning achievement of the opposing force is the sinking of an aircraft carrier.[xvi]

> To put it simply, if naval exercises in the last two decades involving foreign diesel-electric submarines had been actual combat, most if not all, U.S. aircraft carriers would be at the bottom of the ocean: as many as 10 U.S. aircraft carriers have been reported "sunk" in these exercises.[28]

Exercise results are exacerbated by real world examples as well. In 2006, a *Song* class Chinese submarine penetrated the defensive perimeter of the *Kitty Hawk* Carrier Strike Group and surfaced, within torpedo range of the carrier, presumably merely to show the US Navy that it could. This feat was duplicated again in 2015 with the *Reagan* Carrier Strike Group.[29, xvii] Adversaries are not limiting themselves to submarine attacks either. China's DF-21D "Carrier Killer" has been developed specifically for the purpose of mission killing a US aircraft carrier. It is likely no accident that the missile has an estimated 836 nm range when compared to the strike range of the F-35, 600 nm as previously stated.

Finally, if primary strike capability is located on an aircraft carrier, then, reflexively, the loss of that aircraft carrier results in the loss of primary strike. The loss of a destroyer in a typical carrier battle group leaves a cruiser, destroyer, and submarine to conduct strike missions.

[xvi] Sinking an aircraft carrier is not actually a necessity. Making the flight deck unusable, a mission kill, is sufficient in conflict. Aircraft carrier proponents correctly note, however, that it takes more raw damage to sink a larger vessel than a smaller one.

[xvii] USS Kitty Hawk was a diesel-powered aircraft carrier that has since been decommissioned.

Would it not be economically sound to spend the purchase price of an aircraft carrier on multiple, more survivable vessels that do not put all of our proverbial strike "eggs" in one "basket?" This question is considered in the next section of this essay.

Aircraft carriers render the fleet vulnerable in a myriad of ways. Understanding those vulnerabilities should be a key component to any sort of value based judgement on whether we should continue to produce them. Key takeaways for this section of the article include:

1. Aircraft carriers are eminently more detectable and trackable when compared to the other surface vessels in the US Navy inventory.
2. The need to continuously defend the aircraft carrier forces the carrier battle group to steam together in close proximity. When an adversary finds the carrier he finds all ships associated with it.
3. The very nature of having an aircraft carrier as the Navy's primary mechanism for power projection has incentivized its adversaries to produce specialized technologies and strategies aimed at defeating it.
4. Deploying without an aircraft carrier would allow strike missions to be spread among the other surface combatants in the former carrier battle group. Losing a destroyer to an adversary results in a fractional loss of power projection as compared to losing a carrier, where all of it is lost.

Economics – Aircraft Carriers are Expensive

Aircraft carriers are expensive. Massively so. In this section of the essay the unit cost of the aircraft carrier and its associated strike complement will be compared to that of alternative strike platforms. The intent is to determine "dollars spent per strike mission" and show that an alternative group of ships minus the aircraft carrier can provide the same function for less money.

The latest estimated price for the Ford class aircraft carrier currently under construction is 13 billion dollars.[30] A nominal complement of 40 F/A-18 Hornets at 81 million dollars per unit is 3.2 billion dollars making the total cost of the warship and associated strike complement add up to 16.2 billion dollars.[31, xviii] Even discounting the price of ordnance for those aircraft you could field another carrier battle group's worth of supporting warships e.g. a *Zumwalt* class destroyer for 4.3 billion dollars, two *Arleigh Burke* class destroyers at 1.5 billion dollars per unit, a *Virginia* class submarine at 2.6 billion dollars, and a Littoral Combat Ship at 400 million dollars for a total of 10.3 billion dollars.[32, 33, 34, 35] Use another 600 million dollars to buy 400 Tomahawk missiles at 1.5 million dollars per unit and the Navy would still have over 5 billion dollars left over.[36]

As was previously asserted in an earlier section of this essay, typical carrier battle group deployments averages roughly 160 strike missions. Consider the following "dollars spent per strike mission" comparison between an aircraft carrier and its associated air wing and that of the

[xviii] An F-35 complement would almost certainly cost much more.

"carrier-less battle group" described above. The calculations come out to 10 million dollars per strike and 6.25 million dollars per strike respectively.

Economical takeaways are straight-forward:

1. Aircraft carriers and their air wings are expensive.
2. Alternative platforms that replicate and even surpass the aircraft carrier's capabilities can be had at a relatively steep discount.

Conclusions

The key takeaways of the previous four sections in this essay can be assembled and organized to create a compelling narrative in support of a reduced role for the aircraft carrier. Consider the following.

Superior ability to project power is what made the aircraft carrier the logical successor to the battleship, not carrier-based aviation for the sake of aviation. A decision to continue to invest in carrier-based aviation is only viable if it can continue to demonstrate merit in terms of capability, survivability, and economics.

Carrier-based aviation, from a capability standpoint, no longer provides superior long range power projection capability to the Fleet. The Tomahawk missile, a versatile weapon able to be loaded upon a myriad of different ships, provides a maximum strike range of more than double that of its closest carrier-based competitor, the F-35C. And while it is true that the superior sustained strike capacity of a carrier air wing on an aircraft carrier could exceed that of

Tomahawk equipped vessels, this is largely irrelevant. The rate of use of strike ordnance from the last decade indicates that the Tomahawk inventory of the carrier battle group was more than sufficient to meet the needs of a deployment.

Aircraft carriers, when compared to other warships in the US inventory, are the Fleet's weakest link in terms of initial and sustained detectability. Mitigating the dimensional requirements of this vessel, which are necessary in order to support fixed-wing aviation, requires careful placement in the battlespace. Special placement of aircraft carriers in the battle formation has been a concern of aircraft carriers since WWII. First strikes and concerted assaults against an aircraft carrier were, and still are, a significant survivability issue for US aircraft carriers. More alarmingly, tactical decisions, both in WWII and now, are heavily weighted toward saving the power projection vessel the US Navy cannot afford to lose rather than committing it to the conflict for which it was purchased to be of use. US adversaries recognize the aircraft carrier as our primary means of power projection as well; this has incentivized the production of specialized technologies and strategies aimed at defeating it.

The aircraft carrier's ease of detection and relative lack of self-defense capabilities forces the carrier battle group to steam together in close proximity. Finding the aircraft carrier will in turn lead to the discovery of all of the warships associated with it. As a result, survivability of the entire battle group is decreased. Disaggregating ships allows for multiple simultaneous strike operations in geographically separated locations. By forcing the adversary to spread himself out and attempt to defend many locations at once, the US Navy becomes stronger. This, necessarily, would require the aircraft carrier to be left behind until an adversary's anti-ship defenses have been neutralized.

Deploying with additional warships i.e. cruisers, destroyers, submarines in lieu of an aircraft carrier reduces the chance of a total loss of power projection capability. The loss of a Tomahawk-equipped destroyer results in only a fractional loss of power projection capability as compared to losing an aircraft carrier, where all of it is lost. Moreover, producing new aircraft carriers is a questionable choice given their capability and survivability issues; they and their respective air wings are more expensive than any other warship in the fleet. Cheaper, more survivable platforms have been shown to duplicate and even surpass the aircraft carrier and its air wing's capabilities. They have shown merit in terms of capability, survivability, and economics.

Finally, the need for a transition from battleship to the aircraft carrier as the capital ship of the US Navy was recognized decades earlier by senior Navy officers, yet the transition could not be made to occur without the forcing function that was violent conflict in WWII. Present day sentiment shows a similar reluctance to abandoning an asset so useful in the past despite evidence indicating growing obsolescence. History shows us that this has happened before. The British, once failed to recognize significant advances in carrier-based aviation during the Interwar period and it left them financially over-committed to warships that, once tested in conflict, were not the best tools to complete the job. The US follows in their footsteps. The required violent conflict has simply not yet occurred.

Aircraft carriers have held an esteemed place in US Navy history for over a century and the Navy has every right to be unabashedly proud of its carrier-based aviation force. The existing inventory of aircraft carriers will likely remain a source of pride as many of them have almost forty years of service left in them. The Navy, however, must overcome its own institutional bias

and that of the defense industry and its benefactors and recognize that like many other revolutions in military technology, the aircraft carrier has had its day in the sun and must give way to its successors. New platforms, countermeasures, and strategies are rendering it increasingly obsolete, and the only real question that remains is: Can the US Navy act on the need to transition from carrier battle group-centric warfighting or must it first be motivated by the shame of losing such a powerful symbol of national ego to a near peer adversary such as China or Russia? Carrier-based aviation is an unjustifiably vulnerable concentration of national power projection that has been surpassed both in capability and survivability by alternative platforms; moreover, the expense of purchasing aircraft carriers and their associated air wings is economically unsound compared to those same alternative platforms.

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