FEBRUARY 2014

WHITE PAPER

The Carrier Air Wing of the Future

By David Barno, Nora Bensahel and M. Thomas Davis

Center for a New American Security

Acknowledgements

The authors would like to thank the many dedicated and talented people who contributed to this paper. In particular, we thank CDR Clay Beers, USN for his useful comments on several earlier drafts and his tireless efforts to help us track down accurate information. Kelley Sayler provided superb research assistance, and Liz Fontaine once again did a great job designing this report under some extremely tight deadlines. We are grateful to them all.

Cover Image

A U.S. Marine Corps F/A-18C Hornet aircraft, left, assigned to Marine Fighter Attack Squadron (VMFA) 323 and a Navy F/A-18F Super Hornet aircraft assigned to Strike Fighter Squadron (VFA) 154 launch from the flight deck of the aircraft carrier *USS Nimitz* (CVN 68) May 1, 2013, in the Pacific Ocean. The Nimitz and the embarked Carrier Air Wing (CVW) 11 were underway on a Western Pacific deployment.

(MASS COMMUNICATION SPECIALIST 3RD CLASS CHRIS BARTLETT/U.S. Navy)

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The U.S. Navy faces several choices in the near term that will shape the future of its carrier air wings into the 2020s and beyond. Despite some questions about their enduring relevance, aircraft carriers will likely remain influential instruments of U.S. power projection for many years to come. Making the right choices now on the composition and capability of their planned air wings will determine, to a great degree, their future operational relevance and longevity.

As the Navy wrestles with shrinking budgets, evolving threats and shifting technology, it should consider four options to shape its future carrier air wings:

1. Continue the current program, but at reduced budget levels.

2. Delay the carrier variant of the stealthy Joint Strike Fighter (F-35C) until the next Future Years Defense Program (FYDP) – which lasts from Fiscal Year (FY) 2020 to FY 2024 – and invest in battle network enablers.

3. Delay the F-35C until the next FYDP, and improve the F/A-18E/F Super Hornet fleet.

4. Delay the F-35C until the next FYDP, and accelerate the transition to carrier-based unmanned aircraft.

While none of these options presents a clear right answer for the U.S. Navy, the tradeoffs that each represents frames the challenges well, and allows for combinations of choices that may deliver an effective solution. As is evident, most of these options involve delaying the F-35C, which remains in development. Given the aircraft's vital capabilities for the Navy's future, however, it should not be terminated.

Introduction

Since supplanting the battleship as the fleet's primary capital ship in World War II, aircraft carriers have occupied center stage in American naval operations and force structure planning for the past 70 years. Today's nuclear-powered aircraft carriers (abbreviated as CVNs) provide 4.5 acres of sovereign U.S. territory and a floating airbase that can be readily relocated to provide rapid response across vast stretches of the world's oceans. Together with their embarked carrier air wings (abbreviated as CVWs), American carriers fill numerous roles including forward presence, deterrence, reassurance to allies, crisis response, sea control and deep strike. Carriers also play diverse roles in power projection, ranging from the carriers *USS Nimitz* and *USS Independence* showing force in the Taiwan Straits in 1996 to the unconventional roles played by the carriers *USS America* and *USS Eisenhower* as invasion force command ships and launch platforms during the September 1994 American intervention in Haiti.[1] The versatility of U.S. carriers has also been repeatedly demonstrated in recent humanitarian and disaster relief operations.[2]

Some now question the future relevance of carriers in an age of proliferating precision weaponry and growing anti-access and area denial (A2/AD) threats. These threats include, for example, advanced mines, sea skimming anti-ship missiles and long-range precision-guided ballistic missiles. Recognizing this emerging threat, last year Navy Captain Henry J. Hendrix published a paper called "At What Cost a Carrier?" which argues that carriers have outlived their usefulness.[3] Given the great opportunity cost of procuring nuclear-powered carriers and their assigned air wings in a period of declining resources, Hendrix suggests the Navy should begin to replace them with long-range, unmanned combat aerial vehicles (UCAV) operated from smaller amphibious carriers, and rely more on conventional cruise missiles for strikes ashore.[4]

While resolving the question about the long-term viability of the aircraft carrier is a central task for U.S. naval force planners, it is not the subject of this paper. Even if their numbers decrease, this paper assumes CVNs will still play outsized roles around the world for some time. Consequently, the presumption is they will continue to be a central part of the Navy's force structure well into the future. Accordingly, the purpose of this paper is to outline choices the Navy leadership should consider as it manages the evolution of the current carrier air wing from today's mix of platforms and capabilities into the carrier's striking arm of tomorrow. The following discussion assumes that the current program of record – a force of 11 CVNs and 10 CVWs – remains viable and serves as a baseline for discussing future carrier air wing options.[5]

This paper focuses on the CVW for one reason: the carrier air wing is the carrier's "Sunday punch," providing a wide range of defensive, offensive and enabling capabilities for Navy fleet operations. As such, the composition and capabilities of the future CVW will determine, in no small way, whether or not the aircraft carrier remains operationally relevant, and for how long. During the next two decades, the aircraft currently flying off of carrier decks will have to be replaced. Decisions made within the current FYDP (which lasts from FY 2015 to FY 2019) will affect investment opportunities in the next FYDP (FY 2020 to FY 2024) and will set the stage for the third and fourth FYDPs, which will extend to the mid-2030s. Given the long timelines involved in developing and fielding modern, high-performance aircraft, the Navy is thus making choices today that will shape the composition and capabilities of the CVW for decades to come. The Navy needs a strategic approach that manages its existing aircraft through the operational and planning period of the next two FYDPs, while simultaneously planning to transition new types of aircraft into the CVW in the third and fourth FYDPs.

The Navy needs a resource-informed *strategic approach to the next carrier air wing that accounts for the fact that the operational environment of the 2020s and 2030s could involve very different threats, technologies and capabilities.*

Because of decisions made toward and since the end of the Cold War, the Navy has a broad set of choices available in shaping the evolution of its air wings over the next decade. Although budget pressures will constrain these choices, the debate about what sort of air wing the Navy needs in the 2020s and beyond should be driven first and foremost by strategy. Navy leaders would need to critically examine their choices for how to best shape the carrier air wing of the future even if resources were unconstrained. Said another way, the Navy needs a *resource-informed* strategic approach to the next carrier air wing that accounts for the fact that the operational environment of the 2020s and 2030s could involve very different threats, technologies and capabilities.

Before framing the choices that the Navy confronts as it manages the evolution from the current carrier air wing to the future, however, it is first important to understand the Navy's current thinking and plans about future CVW composition and capabilities. These judgments and the programs that derive from them are informed by the way the Navy intends to fight in the future, the shape of its current carrier air wing and how today's threats are evolving into a more deadly future operating environment.

Battle Networks: How the Navy Fights Today

In the early 1990s, strike platforms often had to be relatively self-sufficient, both detecting and launching weapons on self-identified targets at sea and ashore. Today, the Navy fights as an integrated battle network, where an ever-increasing number of platforms can link and share target-quality data.[6] Put simply, once the battle group detects a target with any sensor, it should be able to attack that target with any means available – regardless of whether the "shooter" can see the target or not. The shooter could be an aircraft, a surface ship or even a submarine. The integrated battle network also substantially improves the carrier battle group's defensive capabilities. In that domain, the Navy is developing a concept called Naval Integrated Fire Control – Counter Air (NIFC-CA), which is primarily designed to network all available defensive assets to protect the battle group from attacking aircraft and cruise missiles. Yet the broader advanced battle network concept is rapidly being extended to fleet-wide situational awareness and cooperative targeting against heavily defended targets ashore. Future variants will include sea- and land-based NIFC-CA elements that "would form an overarching battle network."[7]

These networks effectively create a whole whose combat power far exceeds its individual parts. Every component will serve as a key node in an integrated system providing offensive, defensive, attack and targeting information that will be widely distributed and instantly shared. However, networked warfare also raises a potential vulnerability. Even the most advanced networks are susceptible to jamming and disruption, and the greater the reliance on the network, the greater the consequences if the network fails to operate properly. To mitigate these risks, the Navy is moving aggressively to build redundancy and resilience into its planned systems through additional space capabilities, existing fleet data networks such as Link-16 and new multi-layered variants, and new tactical targeting network technology (TTNT).[8] These investments clearly signal that the Navy sees integrated battle networks as here to stay, and will be an inherent part of delivering both effective strike and defensive capabilities in any future conflict.

Today's Carrier Air Wing

Consistent with its overarching move towards integrated battle networks, the Navy's carrier air wings will become even more heavily networked in the years ahead with the arrival of new aircraft and significant enhancements to older aircraft. This change will improve the current CVWs, which contain more than 70 aircraft of various types, depending on the specific squadrons assigned during a particular deployment (see Table 1).

The core offensive striking power of the carrier is provided by four strike fighter (VFA) squadrons that total 44 aircraft. These squadrons also conduct other missions to support of the battle group (see text box on page 9). In the latter years of the Cold War, the Navy decided to combine CVW squadrons comprising aircraft with separate functions – fleet interceptors, light attack and aerial reconnaissance – into squadrons comprised of a single multi-mission aircraft that could operate flexibly across the entire set of mission requirements. The result was the F/A-18A/C Hornet, which reached initial operational capability in 1981. While the Hornet proved itself capable of performing a broad range of CVW missions, its performance lagged behind some of the specialized aircraft it replaced, especially in terms of unrefueled range and combat radius.[9]

When the Navy's controversial A-12 carrier-based medium bomber program was cancelled in 1991, and before the F-35 Joint Strike Fighter (JSF) program was established in 1994, the Navy faced the possibility of operating a CVW for two decades with a severely limited radius of action and without a fully modernized fighter and attack aircraft that incorporated the latest technologies available in stealth and electronics. Fortunately, an alternative was available in the relatively near

TABLE 1: THE CURRENT CARRIER AIR WING

AIRCRAFT TYPE	COMPOSITION	NUMBER
Fighter/Attack	1 or 2 squadrons of F/A-18C 2 or 3 squadrons of F/A-18E/F	44
Electronic Attack	1 squadron of either 4 EA-6B or 5 EA-18G	4 or 5
Airborne Early Warning	1 squadron of E-2C	4
Helicopter Sea Combat	1 squadron of 8 MH-60S	8
Helicopter Maritime Strike	1 squadron of 11 MH-60R	11
Total		**71 or 72**

Source: Norman Polmar, *The Naval Institute Guide to the Ships and Aircraft of the U.S. Fleet* (Annapolis, MD: Naval Institute Press, 2013), 349.

term. The Navy moved quickly to procure the F/A-18E/F Super Hornet, a significant upgrade of the F/A-18 A/Cs then operated by both Navy and Marine squadrons.

The Super Hornet looked quite similar to earlier F/A-18 models, but it was much closer to a new aircraft.[10] It was about 25 percent larger, which provided more power, speed, payload and potential for future growth in its avionics suite. Moreover, it bettered the combat range of the F/A-18A/C by 33 percent. Since the airframe itself was well understood, developmental risk was relatively low, and it could be modified so that the E/F had greater stealth qualities than the older A/C models. Initiated in 1992 and continuing after the F-35 program began, the E/F was flying by 1995 and reached initial operational capability in 2001.

The initial production version of the Super Hornet were so-called Block I aircraft with the same mechanically scanned multimode radar found in the latest versions of the F/A-18C Hornet. However, production soon switched over to the Block II version of the aircraft, with its cooling systems modified to accept a much more powerful and capable advanced electronically scanned array (AESA) radar. The AESA radar's many modes include air-to-air search and track, sea-surface search, ground moving target indicator tracking and synthetic aperture radar mapping.[11] Beyond advanced radar, the Block II aircraft also have better system integration capabilities and higher survivability.[12]

With the retirement of the F-14 Tomcat fleet interceptor in 2006, all Navy VFA squadrons now operate some variant of the F/A-18. Most of those squadrons currently operate Super Hornets in the single-seat F/A-18E or the two-seat F/A-18F variants. Those Navy squadrons that have not yet transitioned to the Super Hornet fly the older model single-seat F/A-18C Hornet, as do the three Marine squadrons currently assigned to certain CVWs under the Department of the Navy Tactical Aircraft (TACAIR) Integration program.[13]

Each carrier air wing also includes an electronic attack (VAQ) squadron. The aircraft in this squadron are important battle network assets and work closely in support of the strike fighters. They provide jamming support for strike packages, and are key to suppressing or confusing threat air defenses. Navy electronic attack squadrons long operated four EA-6B Prowlers, a heavily modified version of the Vietnam era A-6 Intruder all-weather attack aircraft. Now, however, these aircraft are being replaced in a manner similar to what happened in the strike fighter squadrons.

In 1998, after the Air Force and Navy agreed to consolidate the airborne electronic attack mission, the Navy's EA-6B Prowler became the only stand-off and escort jamming asset in the joint force. When these aircraft began to reach the end of their service lives, the F/A-18F Super Hornet airframe provided a solution. In relatively short order and within budget constraints, the EA-18G Growler was evolved from the Super Hornet and entered into service in 2009 in five-plane VAQ squadrons. The fielding of the F/A-18E/F and the EA-18G Growler means that between 2015 and 2016, all of the Navy's electronic attack and strike platforms will be based upon F/A-18C or F/A-18E/F Super Hornet variants until the arrival of the F-35C, which will simplify squadron maintenance and training. The decision to pursue the Super Hornet and the Growler has given the Navy enhanced-capability aircraft with some stealth qualities, modestly greater range and further growth potential. All of this has proved particularly useful as the development of the F-35 lagged behind schedule.[14]

Another important battle network asset is the CVW's single airborne early warning (VAW) squadron, which now consists of four E-2C Hawkeyes. With their large APS-145 radars in rotating domes above their fuselages, these aircraft warn the carrier task force of approaching air threats and can provide both threat identification and positional data to a range of potential shooters in the battle group. Hawkeyes also provide strike command and control, sea and air surveillance, and air traffic control, and can also act as a transmission relay asset that extends communications ranges.[15]

The remaining CVW aircraft are rotary-winged, typically including a Helicopter Sea Combat Squadron of 8 MH-60S aircraft, and a Helicopter Maritime Strike Squadron of 11 MH-60R aircraft. These helicopter squadrons perform a variety of missions including logistics support, search and rescue, anti-submarine warfare, interdiction, close air support and special warfare support.[16] During deployments, eight of these aircraft are normally distributed to other ships within the carrier battle group, so they can conduct their missions while also freeing precious deck and hangar space on the carrier.

Missions of the Carrier Air Wing

Although the composition of the carrier air wing will change in the next decade and beyond, its tactical missions will remain largely the same. These include:

- Fighter escort: providing fighter protection and escort to airborne platforms in an offensive or defensive role.
- Offensive and defensive counter-air operations: neutralizing or destroying enemy air and missile capabilities, and defending the battle group against attack by hostile aircraft and missiles.
- Day and night precision strike: attacking enemy targets at sea and ashore under all conditions of visibility.
- Suppression and destruction of enemy air defenses: disrupting, destroying or degrading enemy air defense systems through kinetic or non-kinetic means.
- Intelligence, surveillance and reconnaissance: acquiring and integrating timely intelligence and information from sensors, assets, and processing, exploitation and dissemination systems to support the battle group's needs.
- Other specialized fleet missions, including anti-submarine warfare, anti-surface warfare, combat search and rescue, and logistics support.[17]

The Evolution of Today's Threats

The modern, networked carrier strike group is a highly capable and flexible organization that at its core gives the United States a sea-based sovereign platform with offensive capabilities that no other nation enjoys. Carriers provide power projection, long-duration presence and crisis response capabilities that have served the nation well for decades. But the operational and strategic environments in which carriers must effectively survive and operate are changing.

Beginning as soon as the end of this decade, future carrier battle groups will face a much more deadly threat environment than today. The current CVN and its air wing have been optimized to sustain a high number of sorties launched from as close as 200 nautical miles (nm) from their targets, but rapidly evolving threats to both carrier and embarked aircraft mean that the carriers are far less likely to operate at such close ranges in the future. Emerging regional powers are developing strategies designed to extend their economic and military zones of influence further from their shorelines. Many analysts have noted that a growing number of states are adopting A2/AD strategies and are developing the means to enforce them.[18] Long-range anti-ship sea-skimming missiles fired from shore or from surface ships, submarines and aircraft, as well as submarine-launched wake-homing torpedoes, make carrier operations only 200nm from an enemy's coastline far more risky. Indeed, long-range bombers armed with anti-ship cruise missiles and new long-range anti-ship ballistic missiles such as the Chinese DF-21 now threaten to push strike group operating areas as far as 900nm from shore, if not more. These ranges will significantly limit the operational effectiveness and endurance of the current air wing. Given that the nominal unrefueled range of the F/A-18E/F is 570nm and that of the F/A-18C is even less, these distances will require all strike fighters to be serially refueled from airborne tankers.[19] The contested A2/AD environment thus seriously challenges the limited range of the current carrier air wing fleet.

Once over their targets at sea and ashore, CVW strike fighters and their supporting aircraft will encounter an increasingly lethal array of surface-to-air and air-to-air threats that will also push them further and further from their intended targets. So-called "double-digit" surface-to-air missiles (SAMs), such as the SA-10D and SA-20, have much improved acquisition and guidance systems and are being fielded with ranges from 200 to 400 kilometers, some of which are expected to be able to find and defeat stealthy platforms.[20] Operational ranges of CVW strike fighters have not expanded as fast as the range of these advanced SAMs. Moreover, both at sea and ashore, modern SAMs are typically mobile and can be easily relocated, making their suppression and destruction more difficult. They are also proliferating widely, and nations that acquire them are often adding upgrades and improvements to make them even more deadly. Furthermore, the acquisition and fire control radars associated with advanced SAMs are becoming far more effective in detecting and attacking incoming aircraft, including some with stealthy attributes.[21] Operating across a range of frequencies, these modern air defense radars can scan wide bands and frequencies in ways heretofore impossible. This technological evolution in concert with mobile, dispersed and networked firing batteries makes carrier air wing operations in this emerging air defense environment increasingly fraught.

In naval terms, these threat changes – those occurring in the near term and those that will emerge in the coming years – will require future carrier strike groups and naval battle networks to operate at greater ranges and to disperse more than in the past, have more highly networked and integrated passive and active defenses against increasingly sophisticated and lethal kinetic and cyberattacks, and have assets that can penetrate sophisticated enemy defenses and attack their targets with precision. In short, this means that future carrier strike groups will likely have to operate further from enemy target sets – or find effective counters to permit close-in operations – and carrier-based aircraft will have to

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fight from longer ranges and be able to overcome or penetrate highly networked defenses to find and attack their targets. These significantly shifting threats are driving the Navy's ongoing adjustments to its current CVW capabilities and structure.

Navy Plans for a Changing Environment

In January 2012, the Navy published a comprehensive *Naval Aviation Vision*, describing how it plans to transition existing naval aviation assets to meet shifting 21st century challenges. It states that carriers will deploy long-range and stealthy manned and unmanned aircraft, will generate flexible combat power and will rely on joint operational concepts that "will leverage the military strengths of all the services, bringing cooperative muscle to the fight and a potent synergy across the warfare continuum."[22]

Among the three services that operate high-performance aircraft, over the past two decades the Navy has positioned itself to have the largest number of options in how to balance the competing demands for attack and defensive assets; intelligence, surveillance and reconnaissance; and command and control. This balance is also affected by rapidly changing technology and increasingly difficult budget limitations. The *Naval Aviation Vision* describes a pathway to a more modern air wing that will evolve into an even more capable force.

As noted above, the Navy's CVWs include four strike fighter squadrons now composed entirely of F/A-18C legacy Hornets and F/A-18E/F Super Hornets. Ultimately, the Navy intends to replace two of the four squadrons with F-35Cs, which will replace all legacy C-model Hornets and some older Super Hornets as they arrive in the fleet. When they do, the F-35C will represent a truly game-changing platform for the carrier air wing. Highly stealthy, endowed with much greater unrefueled range than the aircraft it will replace, and with enhanced sensor fusion capabilities through its advanced distributed aperture system, the F-35C will provide capabilities never before seen aboard carriers. When armed with two AMRAAM air-to-air missiles and two 1000-pound Joint Direct Attack Munitions (JDAM) carried internally, the F-35C has a combat radius of 600nm – better than any carrier strike aircraft since the A-6 Intruder medium bomber (and including the F/A-18E/F Super Hornet) and, more importantly, in a fully stealthy configuration.[23] It will not only provide a "first day of the war" platform capable of operating at extended ranges and penetrating highly defended airspace, but its sensor and networking suite will give the battle group unprecedented access to targeting information that can be shared with any battle network "shooter."

Based on its plans to introduce the F-35C as quickly as possible, the Navy intends to end its production of the F/A-18 E/F Super Hornet in 2015 after 565 aircraft are built (though the production line will stay open until 2016 to deliver an additional 47 aircraft to the Royal Australian Air Force).[24] This decision was premised on the F-35Cs timely arrival, but delays in the maturation of the F-35 may require this plan to be re-looked (see text box on page 17). Under any circumstances, however, the Navy remains fully committed to the stealthy F-35C, and plans to maintain its central role in the air wing of the future. That said, the Navy is keen to ensure its first operational F-35C squadrons deploy with the most advanced capabilities possible. In practical terms, this means the first F-35Cs will not be operational with the fleet until 2019 at the earliest.[25]

To mitigate risks of further F-35C delays, the Navy currently is upgrading approximately 130 older Block I F/A-18E/F aircraft to a Block II-like configuration by replacing their older mechanically scanned radars with the more modern AESA radars found in current production versions of the Super Hornet.

The current electronic attack squadron of five modern EA-18G Growlers is expected to remain unchanged in the future carrier air wing, although their already formidable capabilities will be further enhanced by the arrival of the Next Generation Jammer (NGJ), a powerful external jamming pod that is now being developed.[26] However, the imminent replacement of older E-2C Hawkeye airborne early warning aircraft with the new E-2D Advanced Hawkeye will significantly improve the capabilities of the CVW's airborne early warning squadron. Equipped with a new AESA radar that combines the E-2C's radar overwater track capability with vastly improved overland and littoral performance in cluttered environments, the E-2D will provide enhanced "state-of-the art radar with a two-generation leap in capability and upgraded aircraft systems that will improve supportability and increase readiness."[27] With its ability to locate stealthy targets and provide fire control data to diverse battle group shooters, the E-2D will be the primary "quarterback" for NIFC-CA. The Navy plans to increase the number of aircraft in the VAW squadron from the current four E-2Cs to five E-2Ds in the future CVW, reflecting the Advanced Hawkeye's increasing importance to the battle network.

The Navy also plans to integrate unmanned aircraft into the CVW for the first time. During the past year, the Navy extensively tested an unmanned flight demonstrator with a tailless design as part of the Unmanned Combat Air System Demonstration (UCAS-D) program. These tests demonstrated that unmanned tactical aircraft can be successfully launched from and recovered aboard carriers, and operated safely in carrier controlled airspace. The tests were so successful that the Navy decided to continue the UCAS-D program for the next several years.[28] These tests will help inform the follow-on Unmanned Carrier-Launched Airborne Surveillance and Strike (UCLASS) program, which aims to deploy an operational CVW test squadron of up to six aircraft by 2020. As the Navy's first operational unmanned carrier-certified platform, UCLASS may offer new possibilities for long-range and long-duration capabilities for both the ISR and strike missions. Because they are not limited by human physiology, if properly designed and capable of aerial refueling, unmanned aircraft will have better range and endurance than manned platforms while carrying similar payloads. Moreover, with no cockpit to worry about, unmanned aircraft can generally be made quite stealthy. These characteristics will likely prove to be critical in addressing the more challenging operational environments of the mid-2020s.

The Navy is currently refining the requirements for UCLASS. Even as it does so, the carrier aviation community is now thinking of capabilities beyond a stealthy ISR/strike platform. These might include roles such as an aerial refueler, stand-in jammer, standoff electronic attack platform or remote missile magazine for F/A-18 E/F Super Hornets or F-35C Joint Strike Fighters. Based on experience gained with the first UCLASS squadron, the Navy will refine its plans for an unmanned follow-on system in the 2020s.[29]

Finally, the Navy must consider how it will replace the Super Hornets now in service as they begin to reach the end of their 9,000-hour airframe lives, which will occur around 2035.[30] Tentatively

TABLE 2: NAVY PLANS FOR THE FUTURE CARRIER AIR WING

AIRCRAFT TYPE	COMPOSITION	NUMBER
Fighter/Attack	2 squadrons of 10 F-35C 1 squadron of 12 F/A-18E 1 squadron of 12 F/A-18F	44
Electronic Attack	1 squadron of 5 EA-18G	5
Airborne Early Warning	1 squadron of 5 E-2D	5
Intelligence, Surveillance and Reconnaissance	1 squadron of Unmanned Carrier Launched Surveillance and Strike (UCLASS)	6
Helicopters	MH-60R/S or MH-60R/S replacement	19*
Total		**79**

Source: U.S. Navy, *Naval Aviation Vision* (January 2012), 19.

*The Navy plans to deploy 11 helicopters aboard the carrier and 8 aboard other ships in the strike group.

described as the F/A-XX program, the Navy will begin an analysis of alternatives for this next generation aircraft starting in FY 2015.[31] The *Naval Aviation Vision* notes that this platform could be "manned, unmanned, or optionally manned."[32] It will also add new capabilities to the air wing. Rear Admiral Mike Manazir notes that the F/A-XX "must [be] something that carries missiles … has enough power and cooling for directed energy weapons and … has a weapons system that can sense the smallest radar cross-section targets."[33]

Table 2 summarizes the basic structure of the planned future CVW. The Navy's goal is for all carrier air wings to be configured this way by about 2030; in the meantime, CVWs will reflect various configurations as squadrons transition to new aircraft as they arrive.

Currently, the Navy force structure includes 10 CVWs to support the 11-ship carrier inventory. The CVWs are actually organizational headquarters to which various aircraft squadrons are assigned, which means that the size and composition of assigned squadrons can vary based upon deployment schedules, training schedules and transitions to new aircraft as they are assigned to units. Tables 1 and 2 show that each carrier air wing generally includes four fighter/attack squadrons, so the Navy needs 40 fighter/attack squadrons to support 10 carrier air wings. Right now, the Navy has 35 fighter/attack squadrons: 15 F/A-18E squadrons, 10 F/A-18F squadrons and 10 F/A-18C squadrons (which will transition to other aircraft). Additionally, the Marines provide three Marine F/A-18C squadrons for carrier air wing operations. This means that the fleet has a total of 38 fighter/attack squadrons, which is two less than the requirement. If future plans reduce the number of CVWs from 10 to nine, however, then the requirement would drop to 36 fighter/attack squadrons and the Navy would instead have two extra squadrons.[34]

This basic structure will remain set, even as the CVW evolves as newer aircraft (such as the Super Hornets, Growlers and E-2Ds) replace older aircraft, and squadrons go through the necessary training, operational familiarity and logistical conversions. For example, with the final Super Hornets now scheduled to be procured in 2015, the Navy will ultimately have 20 F/A-18E, 10 F/A-18F and eight F/A-18C squadrons (five Navy, three Marines) before it starts to transition to the F-35C. These newer Super Hornet and Joint Strike Fighter aircraft will help the Navy respond to the emerging strategic and threat environments where greater range becomes more important and penetrating more robust defenses becomes more challenging. But since F-35Cs are not likely to join operational squadrons until at least 2019 and will continue arriving through at least 2035, it will probably be a decade or more before each CVW has the two squadrons of stealthy F-35Cs able to operate effectively on the first day of a war against advanced air defenses. As mentioned previously, F-35C squadrons will replace all legacy F/A-18C Hornet and 10 older F/A-18E/F Super Hornet squadrons. At that point, the F/A-XX will begin to replace the remaining Super Hornets on the carrier decks.

On balance, the Navy's current transition and modernization plans for its CVWs are sound, and by its choices has postured itself well for the future. But declining budgets will affect all of these plans and will exacerbate the challenges of balancing Navy shipbuilding and aviation programs. While moving forward to provide modern capabilities and replace aging aircraft, the next version of the Navy's aviation plans must take maximum advantage of cost efficiencies. It must make tradeoffs between its current and desired capabilities, with cost very much now a central factor. The Navy has to make strategic choices that maximize its aviation capabilities while having fewer dollars available to do so, while continuing to operate effectively in an increasingly demanding threat environment.

More than at any time in the recent past, today's Navy has to modernize its forces amidst significant budget constraints and an uncertain budget environment. The Budget Control Act (BCA) of 2011 set in place a process that will cut almost $1 trillion from the defense budget over a decade.[35] In addition, the continuing exclusion of the personnel

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accounts from the BCA cuts, and the concerns within the services about restoring readiness funding for training, repair parts and installations, means that modernization accounts are particularly vulnerable to cuts, perhaps as much as 10 percent below currently programmed levels. Navy aircraft procurement (which includes more than just CVW platforms) was budgeted for $17.9 billion in FY 2014, but could be cut by as much as $2 billion a year through FY 2023.[36] This will put enormous pressure on the Navy's current plans to recapitalize its carrier air wings, and force the Navy leadership to make hard choices on CVW capabilities and capacities based on clearly stated priorities.

Alternative Options for the Future

Under current budget circumstances, the number, composition and structure of Navy CVWs are bound to change, one way or another. The Navy's leadership has four general options for managing this change. One option simply executes the current CVW transition plan as it now exists more slowly, meaning planned capabilities will come more gradually. Three options seek to free up money to make prioritized investments in order to keep the CVWs operationally capable and relevant. In practical terms, these three options defer currently planned purchases of the F-35C Joint Strike Fighter from the 2015-2019 FYDP to the 2020-2024 FYDP, but do not cancel it outright.[37] This approach takes into account three exigent circumstances. First, there is no realistic alternative to the F-35C in order for the

CVW to achieve needed future capabilities in the areas of stealth, range and sensor fusion. The F-35C will play an important role in the Navy's future battle network and operations in A2/AD environments, and terminating the F-35C would also have very negative consequences for the other services and U.S. allies that also participate in the F-35 program. Second, the Navy has insisted that it will only accept the F-35C with the Block 3F software configuration for operational use, and that will not be available until 2019 at the earliest.[38] And third, the currently estimated unit cost of an F-35C is $144 million, nearly three times more than the $54 million unit cost of the Block II F/A-18E/F Super Hornet.[39]

By preserving its plans to transition to the Joint Strike Fighter but delaying buys of the F-35C in the 2015-2019 FYDP, the Navy would free up money to invest in near-term CVW combat capabilities and capacities while preserving its long-term plans. In addition to saving a great deal of money, this approach would also allow the F-35C's technology to mature further, so the first F-35Cs in the operational fleet would have much greater capabilities than they would in 2019.[40] Since the Navy already plans to keep the F/A-18E/F in the fleet until the early 2030s, slipping the replacement of older model Super Hornets with F-35Cs into the middle of the next decade would create significant savings with manageable operational risk. Such savings could allow the Navy to meet its assigned budget cuts and still have some funds available for investments. Those funds could be used for a variety of purposes. They could be used to expand and accelerate the battle networking technology (such as NIFC-CA), procure additional battle management and electronic attack aircraft, such as the E-2D or EA-18G, or pursue other enablers, such as NGJ pods.[41] Alternatively, the Navy could invest those funds to procure more Super Hornets or modernize older Super Hornets, or it could elect to accelerate a move toward unmanned carrier combat aircraft. All of these options are discussed in more detail below.

OPTION 1: CONTINUE THE CURRENT PROGRAM, BUT AT REDUCED BUDGET LEVELS

Strategic Rationale

The current plan would remain in place, but budget constraints would cause capabilities to be acquired later than desired. This option assumes that the Navy's current CVW transition and modernization plan is a solid one, and that the A2/AD threat will evolve slowly enough for the CVW to address it effectively. It preserves the current strategy, but would slow its implementation, buy fewer platforms, or both. This might entail slower buys of F-35Cs and E-2Ds; slower buys or delay to UCLASS; and slower implementation of NIFC-CA and other advanced battle networking technologies.

Supporters of this approach could argue that Navy decisions regarding the timing and acquisition of the F/A-18E/F, the F-35C and the EA-18G have set conditions for a well-balanced and capable air wing for the future. Slowing modernization accepts some risks, but they appear manageable. Few current threats can seriously challenge the existing carrier air wing mix, and the Navy is developing enhanced networking capabilities that will improve its capabilities even further. Pursuing more closely integrated operations with the Air Force and the Marine Corps will further improve CVW capabilities and decrease some of its vulnerabilities. That said, slowing the modernization program or truncating parts would require careful analysis of the capability tradeoffs, budget impacts and industrial implications.

Advantages

This approach requires no major change in direction from the established Navy aircraft program. Depending on the extent of the budget cuts, it could be executed with limited impacts to

CVN deployments, air wing schedules and the fighter portion of the defense industrial base. This approach would keep the Navy roughly set on a path that would give it a new generation of aircraft having more stealth, longer range and expanded network connectivity.

Disadvantages

Continuing the current program with slower modernization or truncated buys would take risk if new threats emerge rapidly or unexpectedly. For example, if China becomes more aggressive in defining its regional security or economic zones of interest, and begins accelerating fielding of systems such as the DF-21 anti-ship ballistic missile, the CVN would be threatened more directly and its capabilities would need to be enhanced as quickly as possible.[42] Similarly, fully networked battle group operations would become even more crucial under this option. Since this option relies on networked synergy, combat effectiveness would be at risk if the technology enabling an expansion of Navy plans for network-centric operations encounters obstacles. Of greater concern, this option sets up a problem where airframe Fatigue Life Expended limits cause F/A-18Cs and F/A-18E/Fs to reach the end of useable service and start retiring long before the Navy has adequate F-35Cs to replace them, much less F/A-XX. The outcome would ultimately require reducing the size and overall capacity of air wings, or disestablishing some air wings.

OPTION 2: DELAY THE F-35C UNTIL THE NEXT FYDP, BUT INVEST IN MORE NETWORK ENABLERS

Strategic Rationale

This option compensates for the likelihood that the total number of strike fighters will decrease over time due to fiscal pressures by improving battle network capabilities and capacities and therefore improving overall fleet effectiveness. This option assumes that building capabilities more gradually assumes too much risk, and it hedges against the possibility of rapidly emerging threats.

This option would accelerate the networking technology and associated capabilities necessary to fully leverage future integrated battle networks, such as NIFC-CA. It would invest dollars saved by delaying the F-35C in key enablers that would accelerate and expand the battle network capacities. This might involve some combination of accelerating NIFC-CA; increasing the number of EA-18Gs in VAQ squadrons; accelerating NGJ pods, decoys and stand-in jammers; increasing the number of E-2Ds in VAW squadrons; or investing in more long-range, network-enabled weapons.[43]

Advantages

This option accelerates the CVW's ability to operate effectively against higher end threats by improving the overall battle network, and achieving greater synergy with the same or fewer numbers of platforms. It improves the ability of the CVW to penetrate highly defended airspace by adding critical needed capabilities such as stand-in jammers, greater numbers of air-launched decoys and more rapid development of the NGJ.

Disadvantages

This option trades off strike fighter improvements and stealth for network improvements in the near term. It does not invest in upgrades to the Super Hornet, and the F-35C would not join the fleet until after 2020. Delaying the F-35C potentially jeopardizes the Navy's ability to operate effectively on the first day of future high-end combat operations when the air defense threat is at its peak. It could also incur risk in efforts to fully mature operational concepts that depend upon an extensive networking of assets that partly relies upon F-35Cs.[44] These risks would increase if the strategic environment begins to change rapidly, and threat technologies and capabilities materialize sooner than expected. Delaying the F-35C would also increase the unit costs for all F-35 variants, which would affect not only the Navy but also the other services and international customers.[45] Furthermore, from the industrial perspective, ending production on the F/A-18 line

Should the United States Keep Two Fighter Lines Open?

Under current plans, the F/A-18E/F and the EA-18G will stop being produced by 2016. The programmed buy for the Super Hornet ended in FY 2013, and funds for the last 21 Growlers were contained in the FY 2014 budget.[46] After 2016, the F-35 production line will be the only remaining aircraft production line for tactical fighters in the United States.

Beyond the strategic and technological considerations that this involves, the Navy also needs to carefully consider how this would affect the industrial base. The Air Force endured almost a decade without procuring any new fighters, which has significantly narrowed the options it has today. In 1980, the United States had nearly 15 companies that were in the military aviation design and manufacturing business – an advantageous situation that China finds itself in now.[47] Yet today, the United States essentially has two such aviation companies, with a handful of others capable of designing and manufacturing modifications and improvements. Further shrinking the industrial base would dramatically narrow the options available to the Navy and all of the Department of Defense in the future, at a time when more options would help hedge against some of the uncertainties about the future strategic and threat environments.

A decision to keep the Hornet production line open beyond 2016 would have several advantages for the Navy. It would hedge against further technological risk in the F-35C program. It would mitigate problems with Option 1 by keeping the industrial base operating, incentivizing continued tactical air innovation and making more fighters available more rapidly should the need arise. It would enable the Navy to buy more electronic attack aircraft, which would improve network performance in Option 2. It would help improve the Super Hornet force more rapidly in Option 3. And it would allow on- and off-ramps for various manned aircraft as unmanned testing expands and opens new unmanned choices in Option 4. Finally, it might also benefit the industrial base, particularly if the Navy decides to move forward with plans to develop a FA-XX in the 2030 timeframe to replace the F/A-18E/F aircraft.[48]

Yet the question of whether the Super Hornet line should remain open or be closed extends far beyond the Navy and decisions about the future of the carrier air wing. This is a strategic decision of great significance for the nation as a whole. Accordingly, in many ways, it should be considered separately from decisions about the future of the carrier air wing. In any event, the final decision over the fate of the Super Hornet line will definitively open or close certain doors that the nation's leadership, and not just the Navy, needs to fully consider.

by 2016 and then delaying delivery of F-35Cs until 2025 may leave the nation without a fully operating production line for Navy tactical fighters for a decade – a substantial strategic risk (see text box). The significantly narrower military aircraft design and manufacturing base that would result might limit the Navy's future options for replacing the E/F/G fleet and eventually the F-35C (and would limit the other services' options for replacing their tactical aircraft as well).

OPTION 3: DELAY THE F-35C UNTIL THE NEXT FYDP, AND IMPROVE THE SUPER HORNET AND GROWLER FLEETS THROUGH MORE AGGRESSIVE MODERNIZATION

Strategic Rationale

As in Option 2, delaying the F-35C until the next FYDP creates substantial savings, which here would be reinvested to enhance and expand the current Super Hornet and Growler fleets, and accelerate the retirement of older F/A-18Cs. This option assumes that that today's F/A-18E/Fs are highly capable platforms against current threats and, when paired with E/A-18G Growlers, may provide some similar capabilities to the still maturing and much more expensive current version of the F-35C.[49] It further assumes that enhancing the F/A-18E/F fleet by either acquiring new Block II aircraft to replace older Block I aircraft or by procuring even more capable Advanced Super Hornets will reduce risk by hedging against both near-term threats and further delays in the development of the F-35C.[50] Three different alternatives illustrate the possibilities.

Under current plans, approximately three of the Navy's 30 Super Hornet squadrons will be equipped with the least capable Block I configuration without an AESA radar and other improvements. One way to execute this option would be to keep the Super Hornet line open, procure the equivalent of approximately four squadrons of Block II F/A-18E/Fs and replace all squadrons operating the older Block I aircraft (the "extra" squadron would provide attrition and test aircraft). This would result in a "pure fleet" of Block II Super Hornets, providing greater near-term CVW capability and delaying the start of the transition to F/A-XX. This alternative requires keeping the F/A-18 Super Hornet production line open beyond 2016.

A second alternative would substitute the more capable Advanced Super Hornet prototype for further Block II Super Hornets. It is a major modification and improvement of the F/A-18E/F that adds several major enhancements. Chief among them are conformal fuel tanks (CFTs) that increase the aircraft's combat radius to over 700nm, approximately 100nm more than that of the F-35C; an enclosed weapons pod (EWP) and other signature enhancements that significantly increase the aircraft's frontal aspect stealth; and a 19-inch color cockpit display with advanced sensor gathering and fusion capabilities, provided by off-board and on-board battle network sensors.[51] As such, the Advanced Super Hornet might provide greater range and some of the stealthy advantages and advanced data fusion capabilities of the F-35C, with a much lower price tag.[52] This alternative also requires keeping the F/A-18 Super Hornet production line open beyond 2016.

A great advantage of these Advanced Super Hornet features is that they can all be retrofitted into legacy Block II Super Hornets. A third alternative would thus invest in modernizing as much of the legacy Super Hornet fleet as possible. Adding CFTs and EWPs, both of which improve nose-on stealthy characteristics of the aircraft, could significantly enhance the current generation Super Hornets' range and survivability.[53] Moreover, the addition of new AESA radars together with advanced sensor fusion in every F/A-18 E/F cockpit would also provide a major capabilities leap for today's aircraft. In the meantime, fielding the NGJ could enhance the Growler, while the Navy's battle network is further developed, evaluated and matured. The Growler fleet could also be enhanced by adding CFTs to offset their weight limitations imposed by adding multiple NGJ pods to their mission profile. This alternative does *not* require keeping the F/A-18 Super Hornet production line open past 2016.

Advantages

This option would effectively modernize the current carrier strike fighter and electronic attack fleets. It would add significant capabilities to the legacy F/A-18 E/Fs at more modest cost than buying new aircraft by retrofitting options such as CFTs and EWPs developed for the Advanced Super Hornet. Buying more NGJs and improving Growler fuel capacity with CFTs would also substantially improve the EA-18G capabilities. This option also improves common logistics and continues to upgrade the strike components of the carrier air wing, avoiding a path of slow obsolescence at reasonable cost.

Disadvantages

Most of the disadvantages of Option 2 apply here as well, including risks to first-day penetration capabilities, delaying the full benefits of networking concepts and increasing unit costs. It would also limit the carriers' ability to conduct strikes from more distant standoff ranges using stealthy platforms. Current strike aircraft would require additional refueling tanker support to achieve this standoff, although adding CFTs to Super Hornets increases their range.[54] Additionally, keeping the F/A-18 Super Hornet production line open beyond 2016 would incur additional costs.

OPTION 4: DELAY THE F-35C UNTIL THE NEXT FYDP, AND ACCELERATE THE TRANSITION TO CARRIER-BASED UNMANNED AIRCRAFT

Strategic Rationale

This option assumes that emerging A2/AD threats are outpacing improvements to manned platforms. It contends that a bold shift to a future characterized by the proliferation of unmanned systems is needed, and that failing to make this shift may place the future operational relevance and longevity of the carrier at risk.

As Thomas Ehrhard and Robert Work wrote in 2008, "U.S. aircraft carriers have evolved into operational strike systems with outstanding global mobility but relatively limited tactical reach and persistence." They argue that new types of unmanned naval strike aircraft might "spark a new carrier revolution – a revolution that could transform US aircraft carriers and their embarked air wings into key components of a persistent global surveillance-strike network effective across multiple 21st century security challenges."[55] Diverting savings from the F-35C program in order to accelerate the UCLASS program and field a more advanced and capable carrier-based unmanned aircraft in the 2020s would be one way to facilitate this revolution.

The rationale for this approach is straightforward. To the extent that greater range, endurance and flexibility becomes a necessity for future CVWs, the Navy may need to accelerate the development of the UCLASS and its successors and give them a much larger presence in the future carrier air wing. The current Navy plan envisages UCLASS comprising only 10 percent of the future CVN (see Table 2), although that percentage could readily be doubled or tripled if and when an unmanned carrier aircraft starts to demonstrate its operational value.[56] Testing emerging concepts of employment with a greater number of UCLASS squadrons could thus provide insights that reshape the future of naval aviation. If breakthroughs occurred, dollars earmarked for the F/A-XX could be shifted to accelerate procurement of unmanned systems.

Advantages

UCLASS provides the Navy a unique opportunity to conduct experiments on the future of unmanned and autonomous carrier–based flight systems. The results of this potentially groundbreaking effort could help the Navy leadership better understand its options for replacing the F/A-18E/Fs and the F-35C through 2030 and beyond. In any event, accelerating and expanding a move towards unmanned carrier aircraft would give the future CVW valuable assets for both ISR and strike missions, and possibly for refueling and other missions as well. With their long range and endurance, unmanned systems could play a major role in future battle networks, as they will likely be able to carry multiple sensors as well as provide some data management functions. In some situations, such aircraft are likely to provide better capabilities for operating in an A2/AD environment than any manned aircraft. Future UCAS-D and UCLASS successors would also likely enable the carrier battle group to operate from far longer ranges sooner, increasing their survivability. As enemy defenses are rolled back and the F-35C comes into play, these manned platforms might ultimately control multiple unmanned wingmen, enabling entirely new means of operations.

Several companies are already competing for the UCLASS program. Adding additional resources to this effort, where the barriers to entry are lower than with more traditional manned aircraft, may encourage more entrants into the competition and thus increase innovation and price discipline. This would help create and preserve a healthy research and development and industrial base for unmanned aerial systems. Moreover, given likely reduced training and personnel costs, a concerted shift to carrier-based unmanned systems would likely substantially reduce long-term CVW life-cycle costs.

Disadvantages

This option assumes several different types of risk. Despite the impressive advances seen in the past two decades, the scope and pace of unmanned/autonomous development still contain some degree of technological uncertainty. Although unmanned systems seem to be maturing rapidly – enabled by computer processing, advanced avionics, global positioning and, perhaps most significantly, networking – real technological risks still exist. Key issues remain unanswered, including whether man-in-the-loop controls should be established and the ethical quandaries associated with potentially autonomous lethal strikes. Risks would increase further if key technologies and employment policies fail to mature as expected.

Accelerating UCLASS and pursuing an expanded unmanned future will also be expensive during a time of shrinking budgets. Even if delaying the F-35C frees enough money to expand the UCLASS program, the Navy will still face significant challenges in protecting those funds, maintaining support for the program through uncharted technological waters and overcoming some of the cultural hostility to expanding unmanned capabilities in naval aviation.[57] Few aviators are keen to see autonomous systems replace pilots, regardless of advances in technology.

The best path ahead largely depends upon how the Navy envisions the future operating environment and whether or not the future CVW is properly configured to dominate it.

Finally, if UCLASS quickly proves more promising and can be developed more rapidly than expected, the Navy might not need to buy as many F-35Cs as currently planned, which, as discussed earlier, would drive up unit costs of all F-35 variants.

Conclusion: The Way Ahead

The Navy's leadership faces central choices about the future of its carrier air wings in the next several years. These choices are bounded by the way the Navy intends to fight in the future, the capabilities and capacities of its current and planned air wings, the pace and complexity of emerging threats, and new technological opportunities. Said another way, the best path ahead largely depends upon how the Navy envisions the future operating environment and whether or not the future CVW is properly configured to dominate it. These judgments will not be easy to make. Threats may shift or accelerate, new conflicts may suddenly emerge and strategic guidance and priorities may change. All of these uncertainties define the complexity of the environment in which these decisions about the future carrier air wing must be made.

Despite these uncertainties, the Navy has positioned itself well and given itself numerous viable options to improve the capabilities and capacities of its carrier air wings. The options presented in this paper illustrate the advantages and disadvantages of four general approaches to the problem. Realistically, however, no single option is likely to provide the right answer on its own. The Navy should seriously evaluate all of these options and more, find the best combination of choices and then make its case to the Department of Defense leadership, Congress and the nation. Navy leaders must evaluate the options through the lens of their judgment about the nature of future conflict and the Navy's global responsibilities. Ultimately, they must find the right combination of choices that best serves the Navy's and the nation's needs. Making the right choices will determine, in no small way, the future relevance of aircraft carriers and the global reach of the U.S. Navy.

ENDNOTES

1. See Adam B. Seigel, "The Intervasion of Haiti," Professional Paper 593 (Center for Naval Analyses, August 1996).

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3. Captain Henry J. Hendrix, "At What Cost a Carrier?" (Center for a New American Security, March 2013).

4. Ibid., 10.

5. There has, however, been discussion of reducing the requirement for 11 CVN/10 CVW to 10 CVN/9 CVW. In an effort to reduce costs, the Pentagon had planned to retire the *USS George Washington* early. This decision was opposed by a bipartisan group of lawmakers and later reversed, though it will have to be revisited again in 2016. See Julian E. Barnes, "Pentagon Drops Plan to Mothball USS George Washington Aircraft Carrier," *The Wall Street Journal*, February 6, 2014.

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13. Ibid., 359; and Christopher Cavas, "More Marines to fly carrier-variant JSFs," *Marine Corps Times*, March 14, 2011.

14. Tony Capaccio, "Lockheed's Troubled F-35 Unscathed in Pentagon's Budget," Bloomberg.com, March 27, 2013.

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16. "SH-60 Seahawk Helicopter," U.S. Navy, http://www.navy.mil/navydata/fact_display.asp?cid=1200&tid=500&ct=1.

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18. See, for example, Randy Huiss, *Proliferation of Precision Strike: Issues for Congress*, R42539 (Congressional Research Service, May 2012); and Nathan Freier et al., "Beyond the Last War: Balancing Ground Forces and Future Challenges Risk in USCENTCOM and USPACOM" (Center for Strategic and International Studies, 2013).

19. Jon Hemmerdinger, "Boeing remains confident in additional F/A-18 orders," Flightglobal.com, February 19, 2014.

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21. For a recent discussion of the jamming mission, see M. Thomas Davis, David Barno and Nora Bensahel, "The Enduring Need for Electronic Attack in Air Operations" (Center for a New American Security, January 2014).

22. U.S. Navy, *Naval Aviation Vision* (January 2012), 17.

23. In contrast, the combat radius of an F/A-18C/D in a strike role is 415nm. An F/A-18E/F in strike configuration has a combat radius of 490nm. See Christopher Bolkom, *Navy F/A-18E/F Super Hornet and EA-18G Growler Aircraft: Background and Issues for Congress*, RL30624 (Congressional Research Service, June 8, 2006); and Jeremiah Gertler, *F-35 Joint Strike Fighter (JSF) Program*, RL30563 (Congressional Research Service, February 16, 2012).

24. Department of Defense, *Selected Acquisition Report (SAR): F/A-18E/F*, RCS: DD-A&T(Q&A)823-549 (December 31, 2011).

25. The JSF Selective Acquisition Report shows the initial operation capability (IOC) date for the Carrier Variant (CV), or F-35C, as "TBD"; however, the Navy estimates IOC in early 2019. This date could slip for various reasons, including awaiting the complete 3F avionics package and declining budgets. See Department of Defense, *Selected Acquisition Report (SAR): F-35 Joint Strike Fighter Aircraft (F-35)*, RCS: DD-A&T(Q&A)823-198 (December 31, 2012); and Dave Majumdar, "F-35 IOC Dates Revealed," Flightglobal.com, May 31, 2013.

26. See Davis, Barno and Bensahel, "The Enduring Need for Electronic Attack in Air Operations," 1.

27. "E-2D Advanced Hawkeye," NavAir, http://www.navair.navy.mil/index.cfm?fuseaction=home.displayPlatform&key=7A0B9668-52B6-4D81-B430-A0638015EE31.

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30. Dave Majumdar, "Major Work to Replace Navy's Super Hornet to Start in 2015," *USNI News*, December 26, 2013.

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33. Majumdar, "Major Work to Replace Navy's Super Hornet to Start in 2015."

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39. Cost data vary somewhat, and are sensitive to the point in time when an aircraft is actually produced. This data comes from official documentation as shown in Department of Defense, *Fiscal Year (FY) 2014 President's Budget Submission, Justification Book, Aircraft Procurement, Navy*. Unit costs data comes from Exhibit P-5 displays for the F/A-18E/F, the EA-18G, the JSF STOVL and the Joint Strike Fighter CV.

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42. For a discussion about the potential threat of the Chinese DF-21 missile, see Andrew S. Erickson and David Yang, "On the Verge of a Game-Changer," *Proceedings Magazine*, Vol. 135, No. 3 (May 2009), 26-32.

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45. See Barnes, "Pentagon Mulls Delay to Lockheed's F-35 Program"; and Andrea Shalal-Esa, "Pentagon report cites 'lack of maturity' of Lockheed F-35 jet," *Reuters*, January 13, 2013.

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57. See Jim Hodges, "All day, all night," *Defense News*, March 1, 2009; and Mike Hoffman, "Navy plans to fund four in UCLASS development," *Defense Tech*, March 27, 2013.

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