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## THE UNMANNED COMBAT AIR SYSTEM CARRIER DEMONSTRATION PROGRAM: A NEW DAWN FOR NAVAL AVIATION?<sup>1</sup>

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### EXECUTIVE SUMMARY

Aircraft carriers are one of America's key power-projection systems. To ensure their continued operational effectiveness and survivability in the future security environment, they need to be equipped with new air platforms with **greater range** (independent reach), **greater persistence** (ability to loiter over the target area), and **improved stealth** (ability to survive in contested airspace).

In brief, this study finds:

- An important way to achieve these goals is to develop and field a low-observable and air-refuelable carrier-capable unmanned combat air system (UCAS).
- The key first step toward achieving this transformational capability is the Navy's new Unmanned Combat Air System Carrier Demonstration (UCAS-D) program and its associated technology maturation efforts to ensure these new aircraft can be safely operated as part of integrated carrier air operations.
- Congress and the Office of the Secretary of Defense should consider funding an expanded UCAS-D and technology program to improve the chances that a safe, reliable, and effective carrier-capable UCAS can be introduced into fleet service by the end of the next decade.

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<sup>1</sup> This Backgrounder is a short version of an upcoming CSBA report: Thomas P. Ehrhard, PhD, and Robert O. Work, *The Unmanned Combat Air System Carrier Demonstration Program: A New Dawn for Naval Aviation?* (Washington, DC: Center for Strategic and Budgetary Assessments, forthcoming).

## INTRODUCTION

As one of this nation's premier power-projection systems, the aircraft carrier with its embarked carrier air wing (CVW) epitomizes America's global reach and raw military power. Forming the nucleus of powerful Carrier Strike Groups (CSGs), they are respected by US allies and feared by American adversaries. It is in the nation's interest, therefore, to retain and expand the carrier's ability to influence events by simultaneously increasing its combat capability while decreasing its vulnerability.

An important way to improve the carrier's future combat capability and survivability in the emerging security environment is to develop and field a low-observable and air-refuelable carrier-capable unmanned combat air system (UCAS). The key national security challenges of the coming century are fighting the Long War against radical extremists, dealing with a world populated by a greater number of nuclear powers, and hedging against a rising China. These challenges will demand future air platforms with **greater range** (independent reach), **greater persistence** (ability to loiter over the target area), and **improved stealth** (ability to survive in contested airspace). Accordingly, in the 2006 Quadrennial Defense Review (QDR), the Department of Defense directed the Department of the Navy (DoN) to "develop an unmanned longer-range carrier-based aircraft capable of being air-refueled to provide greater standoff capability, to expand payload and launch options, and to increase naval reach and persistence."<sup>2</sup>

The logic supporting accelerated development of a carrier-based UCAS is straight-forward. Using manned aircraft, current CVWs are optimized to strike targets at ranges between 200 to 450 nautical miles (nm) from their carriers. Moreover, carrier aircraft lack persistence. That is to say, they are limited to missions no more than ten hours long, and they more typically fly missions that last only a few hours. In contrast, a carrier-based UCAS could mount strikes out to 1,500 nm from a carrier without refueling. Just as importantly, because its mission duration is not limited by human endurance, with aerial refueling a UCAS will be able to stay airborne for 50 to 100 hours—five to ten times longer than a manned aircraft. In other words, with multiple aerial refuelings, a UCAS could establish persistent *surveillance-strike combat air patrols (CAPs)* at ranges well beyond 3,000 nm, and strike point targets at far longer ranges.<sup>3</sup> For example, a carrier at Pearl Harbor ordered to respond to a developing crisis in the Taiwan Strait could immediately set sail and

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<sup>2</sup> *Quadrennial Defense Review Report* (Washington, D.C.: Office of the Secretary of Defense, February 6, 2006), p. 46. The entire report, which will be referred to hereafter as the *2006 QDR Report*, can be found online at <http://www.defenselink.mil/qdr/report/Report20060203.pdf>.

<sup>3</sup> For the purposes of this background, *long-range* strikes occur over ranges of 3,000 nautical miles or more. *Short-range* strikes, by comparison, are attacks against targets out to 1,000 nm. The *medium-range* strike envelope is between 1,500 to 2,500 nm. This is a modification of the convention developed by Barry D. Watts, in *Long Range Strike: Imperatives, Urgency, and Options* (Washington, DC: Center for Strategic and Budgetary Assessments, 2005).

launch a flight of UCASs. These aircraft would arrive over the Strait (approximately 4,450 nm distant) in just over 10 hours given a 450 knot cruising speed and two aerial refuelings. Furthermore, the aircraft could persist over the Strait, even in the face of advanced Chinese air defense systems, for over five hours before having to be refueled again. By launching and recovering successive flights of UCASs, a carrier could maintain a persistent presence over the Strait days prior to current carriers, and increase the density of its coverage as it closed the range. The strategic value of that sort of responsiveness and reach would be incalculable.

The key first step toward achieving this transformational capability is the Navy's new Unmanned Combat Air System Carrier Demonstration (UCAS-D) program and its associated technology maturation efforts. The demonstration and technology maturation program aims to prove conclusively that an unmanned aircraft can be seamlessly integrated into aircraft carrier flight deck operations. Put another way, it aims to demonstrate that a UCAS can safely and effectively operate as part of the complex and dangerous ballet associated with operating up to 70 high-performance aircraft and rotorcraft from a cramped, 4.5-acre airfield operating in the open ocean. Given the tremendous potential of naval UCASs, the UCAS-D program should therefore be accorded a high priority in the evolving Naval Aviation Master Plan.

With the many competing programs now fighting for the attention of naval aviators—not to mention the Navy's historical ambivalence regarding unmanned aircraft systems—there is a danger that the UCAS-D program will suffer in DoN budget deliberations and be progressively delayed. If this happens, the long-term operational and tactical effectiveness of the US carrier fleet may be at risk. Congress and the Office of the Secretary of Defense (OSD) should therefore take a direct interest in fostering this program and monitoring its progress. If they do, the chances will increase that the Navy will be able to transform the aircraft carrier from an operational strike system with outstanding global mobility, but relatively limited tactical reach and persistence, to a globally mobile, long-range, persistent surveillance-strike system effective across multiple 21<sup>st</sup> century security challenges.

#### **TOWARD A NAVAL UNMANNED COMBAT AIR SYSTEM**

As their name implies, unmanned aircraft, which have at times been referred to as drones, remotely piloted vehicles (RPVs), or unmanned aerial vehicles (UAVs), are robotic, fixed- or rotary-winged aircraft capable of controlled, sustained flight using onboard propulsion and aerodynamic lift, and are designed for return and re-use. An unmanned aircraft's flight can be directed remotely by a human operator located at a distant airborne, shipboard, or ground-based control station, by an autonomous flight control system, or by a hybrid of the two.<sup>4</sup> To reflect the fact that these unmanned

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<sup>4</sup> This definition excludes lighter-than-air craft such as balloons, blimps, zeppelins, and airships. It also excludes ballistic missiles, which do not employ aerodynamic lift, and one-way non-reusable aerodynamic craft such as cruise missiles. See Thomas P. Ehrhard, *Unmanned Aerial Vehicles in the United States Armed Services: A*

aircraft are part of a system of systems that includes the unmanned aircraft itself, its control station, and its dedicated communications systems and links, OSD recently announced that they would be referred to as either unmanned aircraft systems (UASs) or unmanned combat air systems.<sup>5</sup>

In this contemporary vernacular, UASs generally refer to unmanned aircraft that do not dispense weapons, while UCASs refer to those that do.<sup>6</sup> While the distinction between UASs and UCASs remains a useful one, with the recent development of *armed* surveillance UASs like the Hellfire missile-armed Predator unveiled during Operation Enduring Freedom (the operation to overthrow the Taliban government in Afghanistan), the line between the two is already beginning to blur.<sup>7</sup> Nevertheless, the UASs of various designs are increasingly substituting for manned aircraft in missions considered to be “dull” (e.g., extremely long duration), “dirty” (e.g., flying through contaminated airspace), or “dangerous” (e.g., early penetration of an integrated air defense system).<sup>8</sup>

UAS designs continue to improve as their advantages become obvious. On April 2, 2007, a new milestone in the development of US unmanned aircraft was passed. On that date, one team from Northrop Grumman and another from Boeing submitted their responses to a US Navy Request for Proposal (RFP) for an Unmanned Combat Air System Carrier Demonstration.<sup>9</sup> Specifically, the RFP calls for an operationally relevant unmanned aircraft flight demonstrator with a tail-less, low-observable (i.e., stealthy) platform that can be safely integrated into US Navy aircraft carrier flight deck operations. A successful demonstration is the prerequisite for the development

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*Comparative Study of Weapon System Innovation*, a dissertation submitted to the John Hopkins University in conformity with the requirements for the degree of Doctor of Philosophy (Washington, DC: The Johns Hopkins University, June 2000), p. viii.

<sup>5</sup> See *Unmanned Aircraft Systems Roadmap 2005-2030* (Washington, DC: Office of the Secretary of Defense, August 4, 2005), at [www.acq.osd.mil/usd/Roadmap%20Final2.pdf](http://www.acq.osd.mil/usd/Roadmap%20Final2.pdf), accessed on April 17, 2007. When only discussing the unmanned aircraft itself, it is still common to use the terms UAVs and UCAVs.

<sup>6</sup> The term UCAS derives from the UCAV Advanced Technology Demonstration (ATD) program, initiated by DARPA in the late 1990s, which is the antecedent of the current UCAS-D program. See <http://www.globalsecurity.org/military/systems/aircraft/ucav.htm>, accessed online on March 15, 2007.

<sup>7</sup> A comprehensive account of the development of the Hellfire-shooting Predator UAS is found in Sean M. Frisbee, “Weaponizing the Predator UAV: Toward a New Theory of Weapon System Innovation,” Master’s thesis (Maxwell AFB, AL: School of Advanced Air and Space Studies, 2004). The newest MQ-9 Predator B UAS has six under-wing pylons capable of carrying a variety of missiles or guided weapons, making it a deadly battlefield surveillance-strike system. See *Unmanned Aircraft Systems Roadmap 2005-2030*, p. 10.

<sup>8</sup> *Unmanned Aircraft Systems Roadmap 2005-2030*, pp. 1-2.

<sup>9</sup> Amy Butler, “Let the Race Begin,” *Aviation Week and Space Technology*, April 2, 2007, p. 34.

and acquisition of an operational naval UCAS (N-UCAS), with an initial operational capability possible around 2018.

#### WHAT'S THE BIG DEAL?

At first glance, the UCAS-D program may seem to promise “more of the same” rather than what it truly augurs: *a radical improvement in the combat effectiveness of carrier aircraft, and by extension, the aircraft carrier*. After all, unmanned aircraft of various kinds have flown since before World War II, and the United States has been a world leader in UAS and UCAS development for over 50 years.<sup>10</sup> More recently, the combination of the global positioning system (GPS), communications and flight control software advances and the increasing demand for more surveillance data from US commanders engaged in combat operations in Afghanistan and Iraq has led to a dramatic rise in the number of operational American UASs. For example, in 2002, the US armed forces operated 127 UASs of five major types, which together amassed a combined total of approximately 26,000 vehicle flight hours.<sup>11</sup> Just four years later, in 2006, 520 US UASs of 16 different types amassed over 160,000 flight hours—and these numbers do not include additional small battlefield UASs also in service.<sup>12</sup>

The 520 major UASs operated by US forces come in a wide variety of sizes and capabilities. The largest system is the 47.6-foot long Northrop Grumman RQ-4B Global Hawk, with a wingspan of 131 feet, which can fly over 35 hours at altitudes up to 60,000 feet and uses a variety of onboard sensors to survey up to 40,000 square miles of terrain per day.<sup>13</sup> More numerous are the smaller UAVs, such as the Neptune mini-UAV operated by Navy Sea-Air-Land commandoes (SEALs), which can be shipped in a 72”x30”x20” container and assembled in the field.<sup>14</sup> These American UASs join hundreds of other operational unmanned aircraft now in service in with armies, navies, and air forces around the world. Market analysts expect no fewer than 9,000 UASs

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<sup>10</sup> For a far more comprehensive overview of the history and development of US UASs and UCASs, see Ehrhard, *Unmanned Aerial Vehicles in the United States Armed Services: A Comparative Study of Weapon System Innovation*.

<sup>11</sup> From Tamar A. Mehuron, “That Giant Droning Sound,” *Air Force Magazine*, March 2007, p. 10. The five systems include the Global Hawk, Predator, Pioneer, Shadow, and Hunter UASs. Descriptions of all of these can be found in the *Unmanned Aircraft Systems Roadmap 2005-2030*.

<sup>12</sup> These systems include the five systems operating in 2002, augmented by newer UASs such as the Buster, Neptune, Tern, Mako, Sentry, Tigershark, SnowGoose, and Gnat systems. Mehuron, “That Giant Droning Sound,” p. 10.

<sup>13</sup> See Air Force Global Hawk Factsheet, accessed online at <http://www.af.mil/factsheets/factsheet.asp?fsID=175> on March 17, 2007.

<sup>14</sup> See “DRS Neptune,” accessed online at <http://www.designation-systems.net/dusrm/app4/neptune.html> on March 20, 2007.

and UCASs to be purchased worldwide between now and 2014, at a cost of nearly \$14 billion.<sup>15</sup>

However, the UCAS-D program is quite significant in that the Navy has never been an enthusiastic proponent of unmanned aircraft, despite the fact that it developed the very first US tactical UCAS: the QH-50 Drone Anti-Submarine Helicopter (DASH). In the late 1950s and early 1960s, the Navy developed and fielded DASH—a diminutive (2,100-pound) unmanned rotorcraft—for operations from a small flight deck on a frigate or destroyer. DASH was designed to take off vertically, deliver a homing torpedo on top of an enemy submarine up to 30 miles away from the ship, and then recover back aboard its host ship. However, it proved to be an idea well ahead of its technological time. While over 100 ships were eventually modified to operate the system, the Navy did not fully develop the little UCAS's flight control system, and failed to adequately train a force of competent pilots. The results were predictable: of the 746 systems built, *over half* were lost due to accident or flight control error.<sup>16</sup> It did not help that ship skippers who crashed or lost the system often received letters of caution or reprimand, leading to self-imposed flight training restrictions which exacerbated the loss rate.<sup>17</sup>

The Navy's unhappy experience with DASH helped to dampen further demand for naval unmanned aerial systems in the surface warfare community for some time. Perhaps more importantly, it also helped to sour the carrier aviation community on unmanned aircraft, for two related reasons. First, when conducting flight operations in company with their surface escorts, carrier aviators "did not want to be in the air with that crazy thing"—meaning they did not trust unmanned aircraft being operated outside the control of carrier air wing personnel.<sup>18</sup> Second, the aviators themselves had no interest in flying an unmanned system from a crowded carrier deck due to the potential disruption to closely coordinated flight deck operations.<sup>19</sup> In the end, both the surface warfare and carrier communities sought more culturally acceptable aviation systems—small manned helicopters that could operate from slightly enlarged DASH flight decks.<sup>20</sup> These helicopters were ultimately called Light

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<sup>15</sup> "UAV Market to Top \$13.6 Billion by 2014," accessed online at <http://www.defenseindustrydaily.com/2005/11/uav-market-to-top-136-billion-by-2014/index.php> on April 6, 2007.

<sup>16</sup> Norman Friedman, *US Destroyers: An Illustrated Design History*, revised edition (Annapolis, MD: Naval Institute Press, 2004), pp. 280-83.

<sup>17</sup> Interview with George Walker, Captain (US Navy, retired), conducted by Thomas P. Ehrhard, on March 23, 1999.

<sup>18</sup> Walker interview.

<sup>19</sup> For example, see Rich Worth, letter to the editor, *Proceedings*, December 1984, p. 108.

<sup>20</sup> "Manned Helicopters May Replace DASH," *Aviation Week and Space Technology*, February 3, 1964. For a more detailed story of the incorporation of helicopters onboard naval warships, see Norman Friedman, *US Naval Weapons* (London: Conway Maritime Press, 1983), p. 110.

Airborne Multipurpose Systems, or LAMPS, and they proved to be exceptionally reliable and effective in subsequent fleet operations.<sup>21</sup> They remain in fleet service today, in the form of the much larger and more capable MH-60R Sea Hawk.<sup>22</sup>

After making the decision to replace DASH with manned helicopters, it would be some time before the Navy once again began to pursue any type of unmanned aircraft for shipboard or carrier use. Most strikingly, the Navy showed little more than cursory interest in naval reconnaissance UASs, which have obvious applications in support of carrier operations, particularly for pre-strike reconnaissance of heavily defended targets. For example, between 1964 and 1973, the US Navy was fighting “the most protracted, bitter, and costly war” in the history of naval aviation off the coast of Vietnam.<sup>23</sup> Operating from as many as six aircraft carriers steaming at one time in the South China Sea, US Navy and Marine aircraft supported ground combat operations in South Vietnam and, along with the Air Force, conducted sustained attacks against targets throughout North Vietnam. Faced with the dangerous chore of conducting pre- and post-strike reconnaissance over Hanoi and Haiphong, two of the most heavily defended targets in history, the Navy relied on manned reconnaissance aircraft such as the RF-8 Crusader or the RA-5 Vigilante. Some of those pilots ended up in North Vietnam prison camps.

The Air Force, faced with the same challenge, began to augment its own manned reconnaissance fleet with reconnaissance UASs. In concert with the intelligence community, it modified the jet-powered Firebee target drone to perform penetrating reconnaissance missions over the most defended targets. The resulting Firefly UAS proved the viability of the concept, which prompted the Air Force to develop an improved system named the Lightning Bug. The Lightning Bug proved its worth as a penetrating reconnaissance system in over 3,500 combat sorties in the dangerous skies over North Vietnam (not to mention China and North Korea) between 1964 and 1973.<sup>24</sup>

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<sup>21</sup> The LAMPS I helicopter, called the Seasprite, was a relatively small two-engine helicopter with a maximum take-off weight of approximately 13,000 pounds. See Norman Polmar, *Ships and Aircraft of the US Fleet*, 14<sup>th</sup> edition (Annapolis, MD: Naval Institute Press, 1987), p. 440.

<sup>22</sup> The MH-60R Seahawk has a maximum takeoff weight of 22,500 pounds. It carries a crew of four versus the crew of three in the Seasprite, and has far more capable systems. See Norman Polmar, *Ships and Aircraft of the US Fleet*, 18<sup>th</sup> edition (Annapolis, MD: Naval Institute Press, 2005), p. 451.

<sup>23</sup> For a detailed discussion of the carrier air war over Vietnam, see Rene J. Francillon, *Tonkin Gulf Yacht Club: U.S. Carrier Operations off Vietnam* (Annapolis, MD: Naval Institute Press, 1988).

<sup>24</sup> For the history of the Lightning Bug drone, see William Wagner, *Lightning Bugs and Other Reconnaissance Drones* (Fallbrook, CA: Aero Publishers, 1982), and Ehrhard, *Unmanned Aerial Vehicles in the United States Armed Services*, chapter 8. For an online source, see “The Lightning Bug Reconnaissance Drones,” accessed online at [http://www.vectorsite.net/twuav\\_04.html](http://www.vectorsite.net/twuav_04.html) on March 18, 2007.

The Navy took note of the Air Force's success with the Lightning Bug and conducted an experiment to see if it could be modified for shipboard use. The UASs were modified to launch from carriers using a rocket-assisted take-off (RATO) booster. After RATO launch, a Lightning Bug would be guided to an initial checkpoint under radio control from a carrier-based Grumman E-2 Hawkeye airborne early warning (AEW) aircraft. From that point on, the UAS would complete its reconnaissance mission using an autonomous onboard navigation system; return to a designated location; be recovered by a helicopter, either while it descended under a parachute, or after having landed in the water; and then be returned to the carrier for mission processing and follow-on mission preparations.<sup>25</sup> However, after conducting over 30 operational Lightning Bug flights between November 1969 and May 1970, the Navy terminated the program, preferring to continue relying on carrier-based, manned reconnaissance aircraft. Despite the risks to the aircrew operating these aircraft, as William Wagner, the historian for the Lightning Bug program put it, "It was clear it would take additional time to fully integrate the drone reconnaissance capability with the fast-paced combat operations of an attack carrier strike force."<sup>26</sup>

Once again, the difficulties of integrating an unmanned aircraft system into carrier operations helped to further dampen any Navy interest in developing a naval reconnaissance UAS of its own. This was ironic, because the short-lived experiment with the Lightning Bug—a system originally designed to launch from a large, specially-modified C-130 transport aircraft—was really an evaluation program designed to help the Navy write its own unique reconnaissance UAS requirements. Given the obvious benefit of having an unmanned penetrating reconnaissance capability in support of its carrier air wings, it seems curious that the Navy never considered the wartime expedient of employing the Lightning Bug using its own considerable land-based maritime patrol aircraft fleet.

In any event, the Navy's only other attempt to develop a sea-based reconnaissance UAS during the Vietnam War was prompted by the recommissioning of the World War II battleship *USS New Jersey* for shore bombardment duties off of the coast of South Vietnam. During her single deployment in 1968, the battleship operated several modified DASH UASs equipped with video links to give its gunners a remote gunfire spotting capability. Once the battleship was again decommissioned, however, these few systems were discarded without replacement.<sup>27</sup> After giving up on the Lightning Bug and the DASH UASs, the Navy never seriously pursued any

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<sup>25</sup> Wagner, *Lightning Bugs and Other Reconnaissance Drones*, pp. 157-165.

<sup>26</sup> Wagner, *Lightning Bugs and Other Reconnaissance Drones*, p. 165.

<sup>27</sup> Norman Polmar, *Ships and Aircraft of the US Fleet*, 17<sup>th</sup> edition (Annapolis, MD: Naval Institute Press, 2001), p. 465.



further naval reconnaissance UASs (or any other type of naval UAS or UCAS except for target drones) through the 1970s and early 1980s.<sup>28</sup>

The decision to forego an unmanned reconnaissance capability came back to haunt the Navy in December 1983, when a poorly executed carrier air strike against a Syrian surface-to-air missile battery threatening US aircraft operating over Lebanon resulted in the loss of two aircraft and the capture of two aircrew. After the episode, Secretary of the Navy John Lehman concluded the strike could have been conducted using the 16-inch naval guns of the *USS New Jersey*. If the “Big J,” which had once again been recommissioned as part of the Reagan administration’s “600-ship Navy,” had been able to remotely spot its cannons’ fire, it could have destroyed the Syrian SAM site without hazarding any personnel. This prompted Secretary Lehman to launch a crash program to find a naval reconnaissance UAS capable of being used from ships by the Navy and on land by the Marines.<sup>29</sup>

This effort produced Pioneer, a modified Israeli UAS that had proven itself in combat operations against Syria over the Bekaa Valley. After a hurried development program, the Pioneer was subsequently used during the First Gulf War, Operation Desert Storm. The Marines launched and recovered the UASs from air bases on land and from the decks of amphibious assault ships. The Navy launched them from battleships using RATOs or a pneumatic catapult, and recovered them by flying the aircraft into a net erected on the ship’s fantail.<sup>30</sup> While the Department of Defense report to Congress on Operation Desert Storm declared that the “Pioneer proved to be valuable and appears to have validated the operational employment of UAVs in combat,” the Navy deactivated its own Pioneer units as soon as it decided to once again decommission its battleships. Meanwhile, the Marines continued to employ the Pioneer both from land bases and amphibious landing ships throughout the 1990s, using 16 during the invasion of Iraq in 2003.<sup>31</sup> Despite being

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<sup>28</sup> In the early 1970s, the Navy subsumed UAS development under the program manager for target drones. Paul R. Benner and Theodore C. Herring, *History of Unmanned Vehicles at NAVAIRDEVCEEN/NAVAIRWARCEN Warminster* (Patuxent River, MD: Naval Air Warfare Center, Aircraft Division, ca. 1992), p. 27. The surface Navy did pursue a program called the “over-the-horizon” (OTH) UAV in the late 1970s which would have provided targeting data to surface ships employing the Harpoon anti-ship cruise missile, but abandoned the \$1 billion program when it was in the early developmental stage. See Ehrhard, *Unmanned Aerial Vehicles in the United States Armed Services*, pp. 342-347.

<sup>29</sup> For a thorough treatment of this episode, see Ehrhard, *Unmanned Aerial Vehicles in the United States Armed Services: A Comparative Study of Weapon System Innovation*, pp. 347-59. See also “US Battlefield UAVs During the Gulf War,” accessed online at <http://www.vectorsite.net/twuav07.html#m3> on March 18, 2007.

<sup>30</sup> Ehrhard, *Unmanned Aerial Vehicles in the United States Armed Services: A Comparative Study of Weapon System Innovation*, pp. 359-81.

<sup>31</sup> The Marines employed five Pioneers on the *USS Ponce*, LPD-15, during Operation Allied Force, the NATO campaign against Serbia in the spring of 1999. “US Battlefield UAVs During the Gulf War”, and Polmar, *Ships and Aircraft of the US Fleet*, 17<sup>th</sup> edition, p. 465.

acquired in 1986 and having a designed three-year service life, thirty-three of the aircraft remain in operational service today.<sup>32</sup>

The only other Navy reconnaissance UAS programs in the 1980s or 1990s of any note were the air- and ship-launched Medium-Range UAV (MR-UAV), a joint program with the Air Force designed to replace dwindling manned tactical reconnaissance platforms; the Hunter UAV, a joint program with the Army, and the Outrider UAV, another joint program. Only the Hunter made it to active service, and then only with the Army. The other two systems were cancelled after their costs ballooned and performance failed to meet expectations. Designing a joint system that met the Navy's unique operating requirements proved to be a contributing factor to high costs and sub-par performance.<sup>33</sup>

In fairness to the Navy—and all of the other Services—the supporting technologies for early unmanned systems lagged behind the desired operational requirements. Nevertheless, it is still surprising that it took until the late 1990s—nearly three decades after its failed DASH program—for the Navy's interest in unmanned aircraft to pick up in a serious way. In late 1998, Lockheed Martin's Tactical Aircraft Systems completed a study for the Navy which offered three conceptual designs for unmanned naval aircraft. The first was a short take-off and landing (STOL) version for use on amphibious ships; the second a vertical takeoff and landing (VTOL) version for use on surface combatants; and the third for use by submarines. Note that none of the systems were designed to operate from an aircraft carrier. The Navy also began to follow closely a joint Defense Advanced Projects Research Agency (DARPA) and Air Force advanced technology demonstration program for a sophisticated, jet-powered UCAS intended to augment manned aviation platforms.<sup>34</sup>

However, with the exception of smaller air vehicles designed to support its special forces, the Navy's renewed interest in UASs and UCASs has still not yet yielded an operational unmanned aircraft system for shipboard use. The story of the RQ-8A Fire Scout is instructive in this regard. In 1999, the Navy held a competition to find a replacement for the Pioneer UAS. Consistent with the conceptual studies conducted by Lockheed Martin, the Navy called for a VTOL UAS able to carry a 200-pound sensor payload out to a range of 125 miles, and to stay on station for three hours at altitudes up to 20,000 feet. It also had to be able to land on a surface combatant or amphibious ship in winds up to about 30 miles per hour and fly 190 hours between major scheduled

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<sup>32</sup> Mehuron, "That Giant Droning Sound," p. 10.

<sup>33</sup> Ehrhard, *Unmanned Aerial Vehicles in the United States Armed Services: A Comparative Study of Weapon System Innovation*, pp. 391-98.

<sup>34</sup> Norman Polmar, *Ships and Aircraft of the US Fleet*, 17<sup>th</sup> edition, pp. 474-75.

maintenance. The winner of the competition was the Fire Scout—a small robotic helicopter.<sup>35</sup>

Despite the crash of a prototype in 2000, the Fire Scout demonstrated it could achieve the stated mission requirements and was considered a success. However, in December 2001, the Navy abruptly decided to halt production of Fire Scout at five air vehicles, citing funding concerns. However, Congress provided supplemental funds to sustain the program. Moreover, the US Army also funded Fire Scout, eventually selecting it to be the brigade-level UAS for its expansive Future Combat Systems.<sup>36</sup> The result was an improved MQ-8B UCAS, capable of carrying both sensors and weapons.<sup>37</sup>

The intervention of Congress and the Army on behalf of the Fire Scout ultimately proved to be fortuitous for the Navy. Soon after it had cancelled funding for the RQ-8A, the Navy began searching for a small UAS capable of operating off of its new, 3,000-ton Littoral Combat Ship. The Fire Scout seemed to be the logical choice, prompting the Navy to start testing the MQ-8B for shipboard use. In January 2006, Fire Scout made successful autonomous landings aboard the amphibious warship *USS Nashville* operating in Chesapeake Bay. Seven months later, in July 2006, the Navy awarded Northrop Grumman a \$135 million contract for eight MQ-8Bs (later increased to nine), with work to be completed by August 2008. In December 2006, the contract was expanded to include developing Fire Scout concepts of operations.<sup>38</sup>

At the other end of the UAS spectrum, the Navy is also exploring a large, land-based UAS as part of its Broad Area Maritime Surveillance (BAMS) program. The BAMS program calls for a large unmanned aircraft capable of flying 2,000 nautical miles to a patrol area and remaining on station for at least 24 hours. It is, in essence, a modern day and greatly improved version of the Lightning Bug. Instead of taking wet film pictures, however, a BAMS UAS will use radar and other sensors to survey large areas of open ocean or coastal areas. It will relay the data collected in real time via satellite links to land-based intelligence centers and command posts, and to deployed US naval task

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<sup>35</sup> “Northrop Grumman MQ-8 Fire Scout,” *Jane’s Unmanned Aerial Vehicles and Targets*, 7 March 2007.

<sup>36</sup> “Northrop Grumman MQ-8 Fire Scout.”

<sup>37</sup> The designation “RQ” is used to designate an unmanned (Q) reconnaissance (R) platform, like the RQ-1 Predator, RQ-2 Pioneer, RQ-4 Global Hawk, and RQ-8 Fire Scout. Arming a reconnaissance system changes its designation to “MQ,” for unmanned *multi-mission* platform. At this point, only the Predator and Fire Scout have this designation.

<sup>38</sup> The Fire Scout VTUAV Program: By Land and By Sea,” updated on October 17, 2005, accessed at <http://www.defenseindustrydaily.com/2005/10/the-fire-scout-vtuav-program-by-land-and-by-sea-updated/index.php> on March 19, 2007.

forces.<sup>39</sup> The system's requirements for extremely long range, long endurance, and large payloads necessarily demand a large, land-based UAS. The two leading competitors are the Northrop Grumman Global Hawk and the Lockheed Martin/General Atomics Mariner (a variant of the Predator). A third competitor—a modified, unmanned, Gulfstream G550 business jet built by Boeing and General Dynamics—may also enter the competition.<sup>40</sup>

Perhaps most significant of all the Navy's new unmanned aircraft programs, however, is the UCAS-D. The UCAS-D program will build and demonstrate the first unmanned aerial system of any kind specifically designed to operate as part of the Navy's premier strike platform, the aircraft carrier. As the foregoing history reveals, after its early abortive development of DASH, the Navy pursued only reconnaissance UASs, and then with little enthusiasm. Moreover, and perhaps counter-intuitively, with the exception of a short-lived experiment with the Lightning Bug, it consistently pursued these systems *for operations on ships other than aircraft carriers and for uses other than supporting carrier strike operations.*

Indeed, of all the naval warfighting communities, support for unmanned aircraft has been weakest in the carrier aviation force. This has been due primarily to widespread—and until now, perhaps justified (if largely untested)—skepticism that unmanned systems could be safely integrated into carrier flight deck operations. That said, as one naval expert has noted, "...delays, inattention, and lack of interest of the powerful aviation community have caused the Navy to lose its lead" in the development of unmanned aircraft systems.<sup>41</sup>

Regardless of the reason for the aviation community's past lack of support for unmanned systems, if the UCAS-D program proves the skeptics wrong, it will likely trigger a major advance in carrier air power that will improve the Navy's ability to fight and win in the 21<sup>st</sup> century. To understand why this is so, one has to understand the great power—and limitations—of the aircraft carrier and its embarked carrier air wing.

## **AIRCRAFT CARRIERS: THE HEART OF US NAVAL POWER**

It is impossible to overstate the pride of place that aircraft carriers have enjoyed in the Navy's operations and tactics since World War II. Although the Navy experimented with aircraft carriers for two decades during the interwar period, on December 7, 1941, the administrative and tactical structure of the US battle fleet was still built around heavily armored big-gun battleships.<sup>42</sup>

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<sup>39</sup> Congress Daily, "Navy Details Huge Unmanned Aerial Vehicle Program," accessed online at <http://www.govexec.com/dailyfed/0506/051806cdam1.htm>, on March 30, 2007.

<sup>40</sup> "Hand in Hand," *Aviation Week and Space Technology*, March 5, 2007, p. 28.

<sup>41</sup> Polmar, *Ships and Aircraft of the US Fleet*, 18<sup>th</sup> edition, p. 471.

<sup>42</sup> After over 20 years of carrier development in the Navy, the president of the Naval War College prepared a confidential study in September 1941 that included scathing

Between Pearl Harbor and 1943, however, the rapid eclipse of the battleship and the subsequent rise of the aircraft carrier as the new capital ship of the fleet resulted in the wholesale rethinking of naval tactics and the reorganization of the battle fleet around fast carrier task forces.<sup>43</sup>

In short, the carrier “revolution” greatly increased the range over which naval forces could deliver combat power. Battles between opposing surface gun lines were measured in tens of miles, while battle between carrier fleets raged over hundreds of miles. After Pearl Harbor, and based on over two decades of experimentation, the Navy quickly reorganized its fleet operations to exploit the greatly increased reconnaissance and strike range of a carrier-centered battle fleet. This reorganization helped the US Navy to defeat the Imperial Japanese Navy and spearhead the American advance across the Pacific. It also coincided with the Navy’s assumption of dominance among world naval powers. Aircraft carriers have remained atop the US naval pecking order ever since.

In contemporary terms, the rapid advancement of the aircraft carrier during the Second World War and its enduring success thereafter can be attributed to its ability to project combat power at range, as well as its modularity, reconfigurability, and operational flexibility. Aircraft carriers were among the first truly modular warships in the Navy’s battle fleet, integrating large payload capacity with interchangeable off-board systems—that is, offensive and defensive aircraft. Their large size enabled carriers to operate increasingly larger, heavier, and more capable carrier aircraft without major redesign. More importantly, the reconfigurability of the carrier’s primary payload—its embarked air wing—allowed naval commanders to easily adapt the ships to changing operational conditions. For example, during the great carrier battles at the start of the war, 75 percent of the aircraft carried were dive and torpedo bombers. By 1945, when faced by attacks from Japanese *kamikazes*—in essence, the first long-range guided cruise missiles—70 percent of a carrier’s air wing were fighters or fighter-bombers.<sup>44</sup>

Because of their modular design, easy reconfigurability, and operational flexibility—not to mention the rapidly increasing capability of their onboard air systems—aircraft carriers became the central organizing platform for US

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criticisms about carrier aviation, and an argument against building a “carrier” navy. There were many reasons why the institutional Navy was not yet ready to fully embrace the aircraft carrier. For a detailed account of them, see Thomas Hone, Norman Friedman, and Mark D. Mandeles, *American & British Aircraft Carrier Development 1919-1941* (Annapolis, MD: Naval Institute Press, 1999).

<sup>43</sup> For a great history about the Navy’s transition from the battleship to the carrier, see Clark G. Reynolds, *The Fast Carriers: The Forging of an Air Navy* (Annapolis, MD: Naval Institute Press, 1968). The definitive story of the development of US aircraft carriers is Norman Friedman, *US Aircraft Carriers: An Illustrated Design History* (Annapolis, MD: Naval Institute Press, 1983).

<sup>44</sup> Bob Kress and Rear Admiral Paul Gilcrist, USN (ret), “Battle of the Super Fighters,” *Flight Journal*, February 2002, p. 31.

fleet tactics and operations. Since the end of the Korean War, the Navy's large-deck carrier force always numbered between 12 and 16 carriers, with an average of about 13.5 ships.<sup>45</sup> They formed the nucleus of World War II fast carrier task groups, Cold War carrier battle groups (CVBGs), and contemporary Carrier Strike Groups. These powerful, self-contained groups include a carrier and its embarked air wing, accompanying surface escorts, direct support attack submarines, and logistics ships. They are supported by underway replenishment ships as well as land-based maritime patrol aircraft.<sup>46</sup>

The stability of the carrier force is all the more striking given the major changes in the total size of the fleet from the Korean War to the end of the Cold War, which fluctuated from a low of 521 ships to a high of 1,122 ships of all types.<sup>47</sup> It is often said—only slightly tongue-in-cheek—that if the Navy is ever reduced to just 12 ships, they would surely all be aircraft carriers. Indeed, the Department of the Navy (DoN) touched off a firestorm of sorts when, in early 2005, it announced its intention to retire the *USS John F. Kennedy* (CV-67) in 2006, 12 years before its previously announced retirement date.<sup>48</sup> This move, which would reduce the size of the carrier force to 11 ships, was triggered by a program budget decision that allocated hefty spending cuts across all the Services. DoN officials defended the retirement by pointing out that the move would save an immediate \$350 million in scheduled overhaul costs and an additional \$1.2 billion in operating costs over the coming future years defense plan (FYDP).<sup>49</sup> However, in April 2005, by a bipartisan vote of 58-38, the Senate blocked the move, complaining that there had “been no analysis to support reducing the Navy's carrier fleet to 11 [ships.]”<sup>50</sup> The Senate directed

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<sup>45</sup> For a brief time between the end of World War II and the start of the Korean War, the carrier force fell to seven ships, but recovered quickly during the Korean War. The ultimate Cold War carrier force necessary to support the Department of the Navy's *Maritime Strategy* in the 1980s was 15 *deployable* carriers, which required a total force structure of 16 carriers (with one always in long-term overhaul). This force level allowed the continuous forward deployment of three carriers—with one in the Mediterranean, Indian Ocean/Persian Gulf, and Western Pacific. For a discussion of Cold War carrier force levels, see Michael M. McCrae, et al., *The Offensive Navy Since World War II: How Big and Why?* (Alexandria, VA: Center for Naval Analysis, CRM 89-201, 1989), pp. 12-13.

<sup>46</sup> When two or more carriers operate together, the task force is referred to as a fast carrier task force, carrier battle force, or Carrier Strike Force.

<sup>47</sup> See “US Navy Active Ship Force Levels,” accessed online at <http://www.history.navy.mil/branches/org9-4c.htm>, on March 20, 2007.

<sup>48</sup> Dale Decamp, “Lawmakers Didn't See Carrier at Risk,” *Florida Times-Union* (Jacksonville), January 10, 2005.

<sup>49</sup> See Allison Connolly, “Navy Delays Overhaul Bids on JFK,” *Norfolk Virginia-Pilot*, January 7, 2005; and Dale Eisman, “Navy Leaders Back Plans to Retire the Kennedy,” *Norfolk Virginia-Pilot*, April 20, 2005.

<sup>50</sup> Dale Eisman, “Senate Nixes Navy Plan to Mothball *Kennedy*,” *Virginia-Pilot*, April 21, 2005.

that the final decision on the size of the carrier force be deferred until after the completion of the ongoing 2005/06 Quadrennial Defense Review.<sup>51</sup>

During the QDR, the Navy developed a new fleet target of 313 ships, including a requirement for 11 aircraft carriers—all nuclear powered. With this analysis complete, the Senate finally approved the early retirement of the conventionally-powered *Kennedy*, which made its final port call in Boston on March 1, 2007.<sup>52</sup> It is now retired, bringing the carrier fleet down to its new objective force target of 11 ships. In 2008, the *USS Kitty Hawk* (CV-63), homeported in Yokosuka, Japan, will retire after a distinguished service career of 47 years. Her retirement coincides with two events: the commissioning of the *USS George H.W. Bush* (CVN-77), which will make the US aircraft carrier fleet all-nuclear-powered; and the designation of the *USS George Washington* (CVN-73) as the new US carrier to be homeported in Japan, marking the first time a US nuclear-powered aircraft carrier has ever been permanently based in a foreign country.<sup>53</sup>

Although the Navy recently revalidated a carrier force requirement for 11 ships, if current plans hold steady, the carrier force will fall to only ten CVNs for a two-year period between 2013 and 2015, but will rebound and hold at 12 CVNs after 2019. Because one active fleet carrier is normally in long-term overhaul, a 12<sup>th</sup> carrier would provide the fleet with 11 *deployable* carriers, a distinction the Navy made in the late 1980s when building up for the “600-ship Navy.” However, there are no plans to increase the number of active carrier air wings above the ten now in the fleet, meaning the 11<sup>th</sup> carrier would be without any permanently assigned aircraft.<sup>54</sup> This point will be expanded upon later.

A comparison with other world navies highlights the great relative advantage the US Navy now enjoys in sea-based tactical aviation. Maintaining a force of large-deck carriers capable of catapult launches and arrested

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<sup>51</sup> Ron O'Rourke, “Navy Aircraft Carriers: Proposed Retirement of the *USS John F. Kennedy*—Issues and Options for Congress,” Congressional Research Service, April 7, 2005. For a synopsis of the report, see Dave Ahearn, “Retiring Carrier *Kennedy* Early Entails Risks, CRS Report Says,” *Defense Today*, January 19, 2005, p. 4.

<sup>52</sup> Joe Dwinell, “Kennedy Warship Makes Last Port of Call in Boston,” *Boston Herald.com*, accessed online at <http://news.bostonherald.com/localRegional/view.bg?articleid=185762> on March 21, 2007.

<sup>53</sup> See DefenseLink News Release No. 1250-05, “*USS George Washington* to Replace *USS Kitty Hawk* as Navy’s Forward-deployed Carrier,” dated December 2, 2005, accessed online at <http://www.defenselink.mil/releases /release.aspx?releaseid=9128> on March 21, 2007.

<sup>54</sup> When operating 12 carriers, and with one carrier always in long-term overhaul, the DoN maintained 11 carrier air wings—ten active, and one reserve. However, the reserve air wing was considered an emergency mobilization asset; in peacetime, the ten active air wings rotate among the 11 deployable carriers. Standing up an eleventh active duty CVW has long been a goal of Navy planners, but the associated costs have thwarted their plans. See David Brown, “Leaner and Meaner: The New Aviation Plan,” *Navy Times*, March 6, 2000, p. 18.

landings of fixed-wing tactical aircraft or operating large, short take-off and arrested landing (STOAL) tactical aircraft is an expensive proposition in terms of procurement, personnel, training, and operations. As a result, only a small number of navies operate them. Indeed, after the retirement of the *Kennedy*, of the 14 large-deck carriers in operation worldwide, the United States will operate 11 (79 percent).<sup>55</sup> The French, Brazilian, and Russian navies currently maintain one carrier each. Moreover, US carriers are substantially larger than the carriers found in foreign navies. The average US carrier displaces 97,605 tons at full load displacement (FLD); the comparative figure for a French, Brazilian, or Russian carrier is 44,724 tons FLD.<sup>56</sup> Additionally, as was just discussed, by next year all US carriers will have nuclear power plants, giving them essentially unlimited endurance and more magazine and aviation fuel capacity than conventionally-powered carriers. The only other nation besides the United States that now operates a nuclear carrier is France.<sup>57</sup>

The disparity in carrier size, in turn, is reflected in a disparity between the size and capability of US and foreign carrier air wings. A typical US CVW includes more than 70 aircraft, including four or five E-2C Hawkeye AEW aircraft; four or five electronic attack aircraft like the EA-6B Prowler; 40-50 “strike fighters” equipped to employ guided weapons; and approximately ten anti-submarine and multi-purpose utility helicopters. A typical foreign carrier air wing contains no more than 35 aircraft of all types, usually a mixed load of fixed and rotary-wing aircraft, and with far fewer and less capable specialized support aircraft like the aforementioned E-2C or EA-6B.<sup>58</sup>

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<sup>55</sup> These numbers do not include small carriers (CVVs), like the three small British Invincible-class carriers, or large-deck amphibious assault ships designed to support helicopters and short take-off and vertical landing (STOVL) aircraft like the AV-8B Harrier. However, including these ships is only slightly less favorable to the United States. The US Navy operates 11 large deck amphibious assault ships that can operate helicopters and STOVL aircraft. In addition to the three British CVVs (only two operational at any given time), Spain operates one; Italy one; India one, and Thailand one. Note that all of these navies are either US allies or strategic partners. Moreover, US large-deck amphibious assault ships are much larger than foreign CVVs, and carry more aircraft. Indeed, in the “carrier mode,” these ships carry STOVL air wings that rival or exceed those of the Brazilian, Russian, and French large-deck carriers. For comparisons and descriptions of world CVVs and US amphibious assault ships, see Commodore Stephen Saunders, RN, ed., *Jane's Fighting Ships, 2004-2005*, 107<sup>th</sup> edition, (Surry, England: Jane's Information Group, Ltd, 2004); and Eric Wertheim, ed., *Combat Fleets of the World 2005-2006* (Annapolis, MD: US Naval Institute Press, 2005), CD ROM version produced by ATLAS Systems, Inc., in Silver Spring, MD.

<sup>56</sup> US FLD figures come from the Naval Vessel Registry. Other sources suggest that the average US carrier FLD exceeds 100,000 tons. For example, see Polmar, *Ships and Aircraft of the US Fleet*, 18th edition, pp. 106-25.

<sup>57</sup> The French nuclear-powered aircraft carrier Charles de Gaulle, operational since 2001, is the only non-US nuclear-powered carrier in the world. See Eric Wertheim, “A Year of Compromise,” *Proceedings*, March 2005, p. 35.

<sup>58</sup> While the Russian carrier is designed to carry a maximum of 52 aircraft (18 Su-27K and 18 MiG-29K strike fighters, and 16 Ka-27 helicopters), it rarely carries this many aircraft. It more often carries just 22-24 Su-33 strike fighters and six helicopters. The



The great American lead in large-deck aircraft carriers will diminish only slightly over time. Of the three current foreign operators, the French Navy is likely the only current one that will continue to maintain and operate carriers over the long term.<sup>59</sup> The Brazilian Navy does not build carriers; it buys and operates foreign aircraft carriers that have been retired from service, and the number available on the market is declining over time. Meanwhile, the head of the Russian Navy announced in August 2003 that no new carrier construction for the Russian Navy is planned.<sup>60</sup> However, three other nations plan to join the large carrier “club”—Great Britain, India, and China.<sup>61</sup> If all planned ships are built, in 2020 the world carrier force would number 22 ships: 12 American; three Chinese; three Indian; two British; and two French. In other words, under the worst circumstances, the United States would operate between four to six times more carriers than any other world navy, and more than all of them combined.

While some outside the Navy argue that the cost of CVNs is too high and that smaller carriers are perhaps a better answer, the Navy’s commitment to large carriers remains strong and unshakable. The question for the Navy is not whether it should continue to build large-deck, nuclear-powered aircraft carriers, but how to make them more effective and to retain their operational and tactical relevance. This will best be accomplished by increasing the carrier air wing’s **range, persistence, and stealth.**

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Brazilian carrier, the former French carrier *Foch*, carries 15-18 A-4 Skyhawks and nine to 11 helicopters, for a total of 24-29 aircraft. See *Combat Fleets of the World 2005-2006*, and “Air and Sea-Supported Land Attack Operations,” Supplement, *Armada*, Issue 1/2005. The French CVW normally includes eight Rafale F-1 air superiority fighters, 12 Super Etendard strike fighters, two E-2C radar aircraft, and five helicopters, for a total of 27 aircraft. See “Charles de Gaulle and the French Carrier Air Group,” *International Airpower Review*, Vol. 15, 2005, pp. 26-33.

<sup>59</sup> The French are planning to build a second conventionally-powered carrier to complement the nuclear-powered *Charles de Gaulle*.

<sup>60</sup> Wertheim, “A Year of Compromise,” p. 32.

<sup>61</sup> The British are planning to replace their three small CVVs with two 60,000-ton CVFs designed to operate the STOVL variant of the Joint Strike Fighter. The Indian Navy is in the process of modifying a former Russian aircraft carrier to operate STOAL aircraft, and has plans to have a three-carrier force (composed ultimately of three indigenously produced Air Defense Ships (ADSs)). See AMI International, “Indian Navy Orders Three Vikrant Carriers,” *Seapower*, July 2003, p. 43. For a good overview of Chinese thinking on aircraft carriers, see You Ji, “The Debate Over China’s Aircraft Carrier Program,” *China Brief*, The Jamestown Foundation, February 15, 2005. At this point, it appears the debate has been settled; the Chinese Navy (PLAN) appears to be preparing a former Russian aircraft carrier for use, and has stated a long-term requirement for three aircraft carriers. See Keith Jacobs, “PLA-Navy Update: The People’s Liberation Army-Navy Military-Technical Developments,” *Naval Forces*, No. 1/2007, Vol. XXVIII, especially pp. 21-24.

## US CARRIER AIR WINGS: OPTIMIZED FOR SHORT-RANGE ATTACKS AGAINST FIXED LAND TARGETS

The offensive and defensive power of an aircraft carrier derives from its aircraft. Without its embarked air wing, a carrier is bereft of combat power and is little more than a large, defenseless target. As a result, the Navy has long sought to develop and field the most capable carrier aircraft possible. However, aircraft operating from a relatively small carrier deck are necessarily designed for either extremely short take-off runs or catapult launch, and are strongly built (i.e., relatively heavy) to survive the stresses and strains of repeated catapult “shots” and arrested landings. Consequently, carrier aircraft generally have a shorter unrefueled combat radius in comparison with land-based aircraft.

Operating aircraft with short “legs” did not pose a major problem during the intense carrier air battles that took place between the US and Imperial Japanese Navies in 1942 and 1943, because these clashes were between roughly symmetrical forces. Although Japanese carrier aircraft slightly outranged US carrier aircraft, the difference was small enough that carrier battles often turned on which force could find and attack the opposing carrier force first.<sup>62</sup> However, from late 1943 on, after the Navy had ravaged the Japanese carrier fleet and air wings, its own carrier force began to concentrate more and more on striking land targets—a trend that continues to this day. As indicated earlier, no navy since World War II has tried to challenge the US carrier force symmetrically by buying aircraft carriers and carrier aircraft. Instead, the Navy’s adversaries opted to take on carriers asymmetrically, primarily with submarines, or long-range, land-based maritime strike aircraft, or (as in the Soviet Union’s case) both, using heavyweight torpedoes and anti-ship cruise missiles.

Beginning in 1929, when the fleet first practiced using aircraft carriers to attack land targets, the disparity in range between aircraft that operated on ship and on land was not that great. A carrier’s great advantage in mobility thus appeared to give it a leg up against land targets, because the carrier fleet knew approximately where the targets were and could strike them at a time and from a direction of its choosing. The land-based air forces, on the other hand, had to actively search for the carrier before they could launch a strike. By the late 1930s, however, land-based aircraft began to outrange—and by a substantial margin—carrier aircraft, which increased the likelihood that a carrier would be found and attacked before its planes came into range. As a result, naval planners argued that unless the range of carrier airplanes was substantially increased, the carrier should not be used to attack well-defended land targets.<sup>63</sup>

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<sup>62</sup> For a good discussion of these carrier air battles, see Captain Wayne P. Hughes, Jr., USN (Ret.), *Fleet Tactic and Coastal Combat*, 2<sup>nd</sup> edition (Annapolis, MD: Naval Institute Press, 2000), pp. 99-107.

<sup>63</sup> Friedman, *US Aircraft Carriers: An Illustrated Design History*, p. 13.

Up through 1944, naval aviators were surprised to find that the disparity between carrier and land-based aircraft ranges did not present a major tactical problem, primarily because of an unexpected advantage in numbers. The air strikes mounted by the Japanese from the small air bases located on the outer edge of their island-based defensive perimeter proved to be too small to overwhelm the carrier's air defenses. On the other hand, the concentrated strikes of three or four carriers could easily overwhelm the local Japanese air defenses. After 1944, however, as the American westward Pacific advance reached the Philippines and other islands close to mainland Japan, the situation reversed itself. The carrier force was forced to steam in relatively confined operating areas close to US lodgments ashore, well within range of large numbers of both short-range and long-range, land-based aircraft, and US carriers were subject to intense attacks. Worse, as the Japanese introduced their *kamikazes*, the carriers found themselves confronting attacks more akin to cruise missile than aircraft strikes. The *kamikazes* proved harder to defend against than traditional naval bombing attacks.

However, by late 1944, US naval superiority was such that even concerted Japanese *kamikaze* attacks could not stop the inexorable advance of US naval forces. And so it went through most of the Cold War. From 1945 onwards, US carrier combat operations—in Korea, Vietnam, the First Gulf War, Operation Allied Force (the NATO operation against Serbia), Operation Enduring Freedom and Operation Iraqi Freedom—were all characterized by the absence of any serious counter-carrier threat. US carriers could operate from relatively restricted operating areas near the enemy's coast with little fear of attack. Indeed, since World War II, while sailors have died onboard carriers due to accidents, fires, or inadvertent explosions, none have died due to enemy action.

The only period that US carriers were seriously threatened by land and sea-based forces was in the late 1970s and 1980s, when the Navy's Maritime Strategy called for US carrier battle groups to be prepared to force their way through the Greenland-Iceland-United Kingdom (GIUK) gap, push up into the North Sea, and to attack Soviet targets located on the Kola Peninsula. The operational and tactical competition between the US carrier force and the Soviet maritime anti-access/area-denial network and its anti-carrier components was dynamic in character. It witnessed the constant development of new weapons and systems and entirely new fleet operating concepts, such as the US Navy's Outer Air Battle against attacking Soviet missile-armed strike aircraft. The Outer Air Battle severely stressed the range of the Navy's carrier air wing and restricted its offensive power. As the Cold War ended, it was not entirely clear whether the US Navy or the Soviet anti-carrier forces had the upper hand in this back-and-forth competition.<sup>64</sup>

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<sup>64</sup> For an overview of the evolution of US and Soviet naval competition during the Cold War, see Owen R. Cote Jr., *The Future of Naval Aviation* (Cambridge, MA: Massachusetts Institute of Technology Security Studies Program, 2006), pp. 33-34 and 37-41.

The point is that since the latter part of World War II, the US carrier force has only rarely had to worry about attacks from land-based forces. Thus, except for the short-lived requirement for carrier aircraft capable of launching nuclear strikes against the Soviet Union in the 1950s, there has been no demand for or reason to try to improve dramatically the range or mission endurance of US carrier aircraft.<sup>65</sup> The typical range of *unrefueled* carrier strikes has thus generally fallen within a relatively narrow band between 200 and 600 nautical miles (nm), and more generally in the lower to middle part of that band.<sup>66</sup>

Of course, naval aircraft can fly longer unrefueled missions if they carry lighter, less lethal payloads. For example the unrefueled combat radius for the A-6 Intruder medium bomber was 890 nm with a one-ton bomb load. But a more standard combat load of five tons brought the plane's range down to 450 nm.<sup>67</sup> And, with aerial refueling, even carrier aircraft with these heavier loads can mount strikes over longer ranges. During Operation Enduring Freedom (OEF), for example, naval aircraft launched from carriers operating in the Arabian Sea and flew up to 900 nm to their target areas in Afghanistan, conducting the "longest-range combat sorties ever flown by carrier-based aircraft."<sup>68</sup> However, these missions depended on land-based Air Force tankers for in-flight refueling and they lasted ten hours—the very limit of human endurance for fighter aircrew members.<sup>69</sup> Moreover, such long-

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<sup>65</sup> During the 1950s, as the Navy converted its carrier aircraft from piston-engines to jets and developed an atomic attack capability, the air wings were composed of fighters and light, medium, and heavy attack aircraft. Heavy attack aircraft like the jet-powered A3D Skywarrior were designed for nuclear strikes. The Skywarrior was the largest and heaviest airplane ever operated aboard a carrier, and had an unrefueled combat radius greater than 1,000 nm. Most of the aircraft on the carrier decks, however, operated over far shorter ranges.

<sup>66</sup> For example, the typical late-World War II CVW, consisting of the F6F Hellcat fighter-bomber, the SB2C Helldiver dive bomber, and the TBM Avenger torpedo bomber, could conduct combined strikes at ranges just over 250 nm from the carrier. See Rebecca Grant, "Cats Against the Sun," *Air Force Magazine* Online, January 2007, at <http://www.afa.org/magazine/jan2007/0107hellcat.asp>; "History of VF-11/VA-12/VA-115/VFA-117," at <http://home.att.net>; and Robert Guttman, "The SB2C Helldiver: the Last Dive Bomber," at [Historynet.com](http://Historynet.com). All were accessed online on March 21, 2007. During Vietnam, the F-4 Phantom fighter-bomber, A-7 Corsair II light attack aircraft, and the A-6 Intruder medium bomber could conduct combined unrefueled alpha strikes up to about 335 nm from the carrier. Extrapolating data from Chapter 27, "Naval Aircraft," in Norman Polmar, *Ships and Aircraft of the US Fleet*, 14<sup>th</sup> edition.

<sup>67</sup> See "A-6 Intruder," accessed online at <http://www.globalsecurity.org/military/systems/aircraft/a-6.htm> on March 30, 2007.

<sup>68</sup> A better characterization of these attacks would be "*longest* combat sorties;" for the purposes of this paper, recall that strikes less than 1,000 nm are considered short-range. Benjamin Lambeth, *American Carrier Air Power at the Dawn of a New Century* (Santa Monica, CA: RAND Corporation, 2005), p. 13.

<sup>69</sup> The longest tactical fighter sorties in the jet age were made by Air Force F-15E crews who flew a 15-hour mission during Operation Enduring Freedom, and by Air Force F-111 crews who flew an 14-hour mission during Operation El Dorado Canyon, the 1986

duration strikes—at least for a manned carrier aircraft—dramatically reduced the carrier’s maximum sortie generation rate.<sup>70</sup> Indeed, between the endurance limits of the aircrew and the reduced sortie generation rate from long range operations, a modern carrier air wing is incapable of sustaining a persistent presence over a target area, which is essential for finding and engaging mobile and “time critical” targets. For these reasons, US carrier operations generally are constrained to relatively short-range, pulsed tactical strikes against land targets and require multiple carriers in order to sustain 24-hour operations.

In fact, the carrier air wing’s tactical reach and endurance has actually *declined* since the 1980s. In the heyday of the Maritime Strategy, the F-14 Tomcat fighter and A-6E Intruder medium bomber could conduct unrefueled combined strikes out to about 600 nm. However, in the mid-1980s, the Navy began to replace both its Vietnam era F-4 Phantom fighter-bombers and A-7 Corsair II light attack aircraft with new F/A-18 Hornet “strike fighters.” The upside was the F/A-18 was more reliable and easier to maintain than the two aircraft it replaced, and could employ a wider range of guided air-to-ground weapons. The downside was that the F/A-18 offered little improvement in combat range over the F-4, and was substantially inferior in range to the A-7. Depending on the mission, with a fuel fraction of only .23, the F/A-18C has a maximum unrefueled combat radius of 320-350 nm.<sup>71</sup> However, for typical operations, the plane’s unrefueled strike radius is more often limited to between 200 and 250 nm. For example, during “Surge 97,” a firepower demonstration involving the *USS Nimitz* (CVN-68), the carrier’s embarked carrier air wing generated 771 strike sorties in 4 continuous days of flight operations against targets only 200 nm away.<sup>72</sup>

The F/A-18’s lack of “legs” may not have been so worrisome had the Navy replaced the A-6 medium bomber with the stealthy A-12 as it intended. After a disastrous development effort in the late 1980s, the A-12 was cancelled, leaving the Navy without either a suitable replacement for the A-6 or any stealthy carrier aircraft capable of penetrating modern integrated air defense systems. Moreover, during the 1990s, the Navy retired all of its KA-6D carrier-based airborne tankers (modified versions of the A-6 bomber) and is retiring

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air strike against Libya. The longest naval carrier sorties were the ten hour sorties launched during OEF. See Lambeth, *American Carrier Air Power at the Dawn of a New Century*, p. 13.

<sup>70</sup> In OEF, aircraft carriers averaged only 30-40 total sorties per day per carrier, well below a carrier’s surge sortie generation capacity. Lambeth, *American Carrier Air Power at the Dawn of a New Century*, p. 22.

<sup>71</sup> Fuel fraction indicates the percentage of an aircraft’s gross take-off weight is devoted to onboard fuel. Most tactical aircraft designs strive for fuel fractions in the range of .30-.35. From Tom Clancy, *Carrier: A Guided Tour of an Aircraft Carrier* (New York, NY: Berkley Books, 1999), p. 162.

<sup>72</sup> Angelyn Jewell and Maureen Wigge, *USS Nimitz and Carrier Air Wing Nine Surge Demonstration* (Alexandria, VA: Center for Naval Analyses, April 1998), pp. 1-3, 5.

the S-3B Viking carrier-based surveillance/tanker aircraft.<sup>73</sup> Both moves made the short range of the F/A-18C all the more problematic. As a result, an F/A-18C-equipped air wing is able to conduct unrefueled strikes to ranges no more than 300 nm from the carrier—not that much better than a World War II air wing—and longer range strikes only with the help of the Air Force’s land-based tankers.

To help redress the carrier air wing’s declining independent reach, the Navy converted the F-14 Tomcat into a fighter-bomber capable of dropping guided weapons over an unrefueled combat radius of about 500 nm (575 statute miles). At the same time, it began a development program to improve its F/A-18 Hornet fleet, an effort that resulted in the single-seat F/A-18E and dual-seat F/A-18F Super Hornets. According to the Navy, although the Super Hornets are not truly stealthy, they have 40 percent greater combat radius, 50 percent greater endurance, and a 25 percent greater weapons payload, while being more survivable than the F/A-18C.<sup>74</sup>

Although the carrier’s tactical reach declined during the 1990s, the effectiveness of the shorter-range strikes increased dramatically due to the widespread introduction of guided air-to-ground weapons. The increased emphasis on guided weapons was part of a general trend in US fixed-wing aviation after the First Gulf War, especially with the introduction of relatively cheap, all-weather guided bombs such as the Joint Direct Attack Munition (JDAM).<sup>75</sup> Because individual aircraft employing “smart” weapons capable of actively correcting their own trajectory or flight path could attack targets more effectively than larger numbers of legacy aircraft, the shift to guided weapons meant carriers could launch a greater number of smaller, more discrete strike packages against a greater number of targets. For example, a 2001 carrier air wing equipped with F/A-18Cs and F-14s could strike 683 aimpoints per day at ranges out to 200 nm. In comparison, a 1989 CVW equipped with F-14s, A-7s, and A-6s could strike only 162 targets over comparable ranges.<sup>76</sup>

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<sup>73</sup> The S-3B Viking performed in an anti-submarine warfare role until 1999 when the Navy changed it into an anti-surface ship platform. It also provided the only embarked aerial refueling capability until F/A-18E/F Super Hornet fighters assumed aerial refueling duties in 2002. In 2004 the Navy implemented an S-3 “Sundown Plan,” a phased retirement to be completed in 2009. Each wing loses its Vikings when two Super Hornet squadrons are assigned. US Navy Fact File, “S-3B Viking detection and attack of submarines aircraft,” updated 29 January 2007, accessed online at <http://www.navy.mil/navydata/factdisplay.asp?cid=1100&tid=1500&ct=1> on April 30, 2007..

<sup>74</sup> See “F/A-18E/F ‘Super Hornet,’” accessed online at <http://www.globalsecurity.org/military/systems/aircraft/f-18ef.htm> on March 20, 2007.

<sup>75</sup> For a comprehensive theoretical and historical treatment of the guided weapons warfare revolution, see Barry D. Watts, *Six Decades of Guided Munitions and Battle Networks: Progress and Prospects* (Washington, DC: Center for Strategic and Budgetary Assessments, 2007).

<sup>76</sup> The increase in US CVW striking power since 1989 is due to a combination of factors. Since 1989/90, the average number of strike aircraft in a typical CVW has increased

The Navy is increasing the carrier's already impressive short-range strike capacity in two ways: increasing the number of guided weapons carried on each aircraft; and raising the carrier's sortie generation rate.<sup>77</sup> The new F/A-18E and F/A-18F both have six wing stations capable of handling air-dropped guided weapons, compared to four on the F/A-18C. At the same time, the introduction of smaller guided weapons, such as the 500-pound JDAM and the 250-pound Small Diameter Bomb (SDB), will increase the number of weapons that can be mounted on each wing station.<sup>78</sup> The carrier's short-range strike power will thus improve substantially over the next several years. The strike component of the planned 2010 integrated carrier air wing will consist of 12 Navy two-seat F/A-18Fs, 12 Navy single-seat F/A-18Es, ten Navy single-seat F/A-18Cs, and ten USMC single-seat F/A-18Cs, for a total of 44 F/A-18 strike fighters. These will be supported by four or five electronic attack aircraft and four or five E-2C AEW air battle management aircraft. At maximum "surge" battle conditions, this air wing will be able to strike a maximum of nearly 1,080 individual aim-points per day at ranges up to 200 nm from the carrier—nearly seven times the number of a 1989 air wing, and over 1.5 times the number of a 2001 CVW.<sup>79</sup>

Over the longer term, the carrier's strike capacity will improve further as the carrier's sortie generation rate climbs. Due to the limited size of the carrier flight deck and the demands of carrier launch and recovery operations, carrier-based aircraft generally have lower sortie generation rates than aircraft operating from land bases. The Navy has thus spent much time and effort improving the sortie generation capacity of its new nuclear-powered aircraft carrier, the CVN-21, which will begin replacing the Navy's oldest legacy CVNs sometime after 2015. With a smaller island, redesigned flight deck, innovative aircraft "pit stops," and advanced weapons elevators, the CVN-21 is carefully

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from 36 to 46; the current air wing can generate more tactical air sorties per day (207 versus 162); and the F/A-18 strike fighter can strike four aimpoints per sortie compared to the one aimpoint per sortie using 1989/90 aircraft such as the A-7 Corsair II. However, the maximum number of targets hit per day represents the number of strikes at maximum surge sortie rates, in good weather, with short ranges to targets (200 nm), and no requirement to refuel. These figures should be used for analytical comparison only. Lieutenant Commander Ed Langford, *CVW Strike Sortie/Aimpoint Improvement*, unclassified point paper (Washington, DC: DoN (N8QDR), January 18, 2001). See also Dave Ahearn, "Clark Says Each Carrier Can Take Out More Targets," *Defense Today*, March 31, 2005.

<sup>77</sup> The Navy could also increase strike capacity by increasing the number of strike-capable aircraft in the CVW. However, it has settled on a CVW with 44-50 "strikers."

<sup>78</sup> The SDB Increment I is a 250-pound bomb with a wing kit and a GPS-navigation package, allowing the bomb to achieve great accuracy and hit fixed targets. The planned Increment II weapon will add a multi-mode seeker capable of characterizing and hitting moving targets—the "Holy Grail" for the next generation of weapons. See Amy Butler, "Searching for a Seeker," *Aviation Week and Space Technology*, August 15, 2005, p. 49. For a good discussion about the potential consequences of the SDB, see Joris Janssen Lok, "Small Size, Massive Consequence," *Jane's International Defense Review*, December 2004, pp. 56-59.

<sup>79</sup> See Langford, *CVW Strike Sortie/Aimpoint Improvement*.

designed to improve carrier sortie generation rates.<sup>80</sup> The standard Nimitz-class CVN in service today can sustain 120 sorties in a 12-hour flying day, and can launch 230 “surge” sorties per 24-hour flying day for four days. In contrast, a CVN-21 is designed to sustain at least 160 sorties per 12-hour flying day, and 270 surge sorties for four days—improvements of 33 and 18 per cent, respectively. The final CVN-21 surge objective is for 310 sorties per day over four days—a 35 percent improvement over today’s CVNs.<sup>81</sup>

While these are seemingly welcome improvements, neither the move to the F/A-18E/F nor increases to the carrier’s sortie generation rate will substantially improve the carrier’s reach. With two air-to-air missiles and four 1,000-pound guided bombs, the F/A-18E has an unrefueled combat radius of 475 nm. While this is better than the F/A-18C’s unrefueled radius, it is still less than that of the F-14s and A-6s flown during the 1980s. Indeed, the Navy’s focus on sortie generation rate reflects, in part, the CVW’s continued lack of reach and endurance. These limitations force the carrier to constantly launch and recover aircraft to sustain attacks or to maintain persistent surveillance-strike orbits or combat air patrols. Indeed, carrier operations revolve around successive 90-minute “deck cycles” of launching and recovering aircraft—which helps explain why comparisons of Navy strike capacity metrics continue to use a 200 nm range to target.

Being able to conduct independent carrier strikes beyond 475 nm will have to wait for the planned replacement of the CVW’s two squadrons of F/A-18Cs with the stealthy F-35 Lightning II—also known as the Joint Strike Fighter (JSF). The Navy wants to replace both of the CVW’s F/A-18C squadrons with the F-35C, the carrier variant of the JSF, which is expected to have a combat radius of about 650 nm. However, the Marines want to replace their F/A-18C squadron with the F-35B, the short take-off and vertical landing (STOVL) version of the JSF. While just as stealthy as the F-35C, the STOVL aircraft has an unrefueled combat radius of less than 500 nm—essentially that of an F/A-18E/F. If the Marines prevail, the planned 2020 carrier air wing will consist of one 12-plane Navy F/A-18F squadron; one 12-plane Navy F/A-18E squadron; one 10-plane Navy F-35C squadron; and one 10-plane Marine Corps F-35B squadron.<sup>82</sup> With this mix, the carrier will carry 34 aircraft capable of

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<sup>80</sup> Sandra I. Erwin, “Carrier Flight Decks Will have ‘Pit Stops’ for Navy Fighter Jets,” *National Defense*, November 2004; “Northrop Grumman Selects Preliminary Designers for CVN-21 Advanced Weapons Elevators,” accessed at [http://www.nn.northropgrumman.com/news/2004/040216\\_cvn21.stm](http://www.nn.northropgrumman.com/news/2004/040216_cvn21.stm) on April 23, 2007; and Hunter Keeter, “New Carrier Island Is at Heart of Higher Sortie Rates for CVN-21,” *Seapower*, June 2003, pp. 23-24.

<sup>81</sup> Lorenzo Cortes, “Navy Aims For Higher CVN-21 Sortie Rate Over Current *Nimitz*-class Aircraft Carriers,” *Defense News*, January 23, 2004; and Geoff Fein, “Navy Wants Reduced Crew Size, Lower Costs for CVN-21,” *Defense Daily*, June 3, 2005.

<sup>82</sup> The 2020 CVW will definitely have four strike-fighter squadrons. See Lambeth, *American Carrier Air Power at the Dawn of a New Century*, p. 91. As part of the Department of the Navy’s “Tac-Air Integration Plan,” the Marines agreed to provide one strike-fighter squadron for each of the Navy’s ten active CVWs. The debate over whether or not the Marines should purchase the F-35B or C version still rages on. The



conducting unrefueled strikes out to about 475 nm from the carrier, and only ten capable of conducting unrefueled strikes beyond 600 nm.

The F-35 equipped CVW will be able to deliver more strike payload out to 450 nm from the carrier than an F/A-18C-equipped air wing can deliver at 250 nm, and be able to sustain combat air patrols farther, and for longer periods, from the carrier.<sup>83</sup> Moreover, nearly half the wing will be stealthy and capable of operating in some engagement scenarios against advanced integrated air defense networks. However, the combat reach of the 2020 carrier air wing will not have improved much beyond that of the mid-1980s air wing, which had trouble dealing with 1970s Soviet land-based anti-access/area-denial technologies.<sup>84</sup>

Perhaps more significantly, the CVW's ability to establish persistent orbits at range will not have improved much beyond that of the 1950s, when the propeller-driven, non-air refuelable A-1 Skyraider provided endurances of up to ten hours. Even though new jet aircraft can be refueled in the air multiple times to extend their maximum strike *range*, their *endurance* is limited by the physical limits of the men and women in their cockpits, which remains at about ten hours.<sup>85</sup> As a result, the maximum potential strike range of the 2020 carrier and its ability to establish and sustain persistent aircraft orbits over an area of interest—even over relatively short ranges—remains inherently limited. To generate persistent 24/7 aircraft coverage, the Navy must assemble multiple carriers, some operating on “day cycles” and some on “night cycles.” Moreover, even over short ranges and with the stealthy F-35, the CVW will have difficulty sustaining orbits in the face of the most advanced integrated air systems, since persistent air operations against these systems will require even more advanced stealth in order to defeat detection from all radar frequency bands on all bearings.

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Navy believes that it would be most cost-effective if the DoN operated one version of the JSF; that the F-35C is the more capable aircraft; and that integrating a STOVL aircraft into the carrier deck cycle would be difficult. The Marines want to operate an all-STOVL fleet for maximum basing flexibility from carriers, large amphibious assault ships, and austere land bases. For a good discussion of the Tac-Air Integration Plan, see Government Accountability Office (GAO), *Department of the Navy's Tactical Aviation Plan is Reasonable, But Some Factors Could Affect Implementation* (Washington, DC: GAO, August 2004).

<sup>83</sup> David A. Perin, “Are Big Decks Still the Answer?” *Proceedings*, June 2001, p. 32.

<sup>84</sup> For a detailed account of the problems the Navy had in coping with the Soviet anti-access/area-denial threat see Norman Friedman, *Seapower and Space: From the Dawn of the Missile Age to Network Centric Warfare* (Annapolis, MD: Naval Institute Press, 2004).

<sup>85</sup> For a comprehensive analysis of manned fighter endurance limits where the author concludes that 10 hours is the maximum, albeit unsustainable limit, see Christopher J. Bowie, *Meeting the Anti-Access and Area-Denial Challenge* (Washington, DC: Center for Strategic and Budgetary Assessments, 2002), pp. 11-13.

This lack of improvement in air wing range, endurance, and persistence is somewhat ironic. The Navy has long pursued nuclear-powered aircraft carriers for three primary reasons: they have virtually unlimited range at maximum speed; they have an ability to remain on-station indefinitely without refueling; and they have greater storage capacity for combat consumables. In other words, the Navy values a CVN's *long unrefueled range* and *persistence on station*.<sup>86</sup> In contrast, the naval aviation community has put far less stock in improving the range and endurance of its carrier aircraft. As a result, unless there is a change in plans, in 2020—nearly a century after the first US aircraft carrier, the USS *Langley*, was commissioned—US aircraft carriers and their embarked air wings will continue to form operational strike systems of unequalled global mobility, but of relatively limited tactical reach and persistence.

This approach might perhaps be justified by looking *back* at the threat environment that prevailed during the past six decades of operational experience. The more relevant question, however, is can it be justified looking *forward* to the expected future security environment and potential threats? Said another way, will an operational strike system with limited tactical reach and persistence—one optimized for pulsed strikes against land targets at ranges out to about 450-475 nm—be able to tackle future operational challenges and threats that are likely to appear over the long term? The answer is: probably not.

#### **A GROWING NEED FOR LONG-RANGE, STEALTHY, AND PERSISTENT SURVEILLANCE-STRIKE SYSTEMS**

The 2006 Quadrennial Defense Review tasked the Services to organize, train, and equip their forces to meet four key 21<sup>st</sup> century security challenges: protecting the homeland from attack; fighting the ongoing Long War against radical, violent extremists; operating in a proliferated world with a larger number of regional nuclear powers, some of them hostile to the United States; and dealing with a rising China, the only country now possessing the requisite economic, technological, and educational resources to mount a serious military challenge against the American military.<sup>87</sup> When thinking about the aviation force characteristics necessary to confront the latter three challenges, three stand out above all: dramatically increased *range*, *persistence*, and *stealth*.

For example, in the Long War, the US forces are pitted against a distributed, networked enemy that can easily blend into the surrounding civil society. To deny the enemy operational sanctuaries and freedom of action and to disrupt their operations, the US military must assemble distributed and persistent (24/7) surveillance-strike networks over known enemy operating areas that can quickly identify and attack fleeting targets as they reveal themselves. As one air power analyst put it, Long War operations in Iraq and

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<sup>86</sup> Norman Polmar, *Ships and Aircraft of the US Fleet*, 18<sup>th</sup> edition, p. 109.

<sup>87</sup> See the *2006 QDR Report*, especially pp. 19-34.

Afghanistan “have seen persistence eclipse sortie generation” as the key metric for aviation effectiveness.<sup>88</sup>

These persistent surveillance-strike networks will often need to be maintained over long ranges, in many cases due to sheer geographical distances. However, an ability to assemble and operate persistent networks from long range will have the additional benefit of greatly reducing the number of foreign bases needed to conduct broad area surveillance and independent search and strike missions, or persistent surveillance-strike support of special operations forces operating against a known enemy. Moreover, it will sometimes require that the persistent networks are stealthy, especially when the United States desires to establish them over denied or unfriendly, ungoverned spaces, or when it is helpful to provide a friendly government with plausible deniability of US presence. In other words, an ability to establish persistent and stealthy airborne surveillance-strike orbits over long ranges will provide US forces with an indispensable advantage in fighting the Long War.

Range, persistence, and stealth will be equally important in a nuclear proliferated world, where the US military may be required to undertake a variety of WMD elimination operations.<sup>89</sup> Such operations might include the need to perform: persistent (24/7), stealthy surveillance of a nation’s nuclear infrastructure; persistent, covert tracking of nuclear strike systems or nuclear weapons; pre-emptive or preventive raids to seize nuclear sites or weapons; pre-emptive or preventive strikes against nuclear weapon systems; or even regime change operations against a nuclear-armed state. These operations will most likely confront integrated air defense systems, since any country with the resources and technical skills to pursue nuclear weapons will likely expend considerable resources to protect them from aerospace attack. In addition to active defenses, an enemy’s protective measures will likely involve the extensive use of decoys that put a premium on high-resolution surveillance.

In confronting a nuclear-armed, regional adversary, then, US forces will obviously require the ability to establish persistent and stealthy surveillance-strike networks in order to find, track, and, if necessary, destroy enemy nuclear forces. Once again, the capability to assemble these networks over long ranges may prove to be vitally important. Any operation against a nuclear-armed adversary may need to be conducted without local bases. Countries within striking range of an enemy’s nuclear forces will probably be unwilling to risk a nuclear attack on their own soil in order to grant US forces operational access.

Finally, although it is by no means certain that the US and the People’s Republic of China (PRC) will become hostile military competitors, PRC

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<sup>88</sup> Rebecca Grant, “Expeditionary Fighter,” *Air Force Magazine*, March 2005, p. 42.

<sup>89</sup> The 2006 QDR directs the Services to organize, train, and equip their forces for possible WMD elimination operations. See *2006 QDR Report*, pp. 51-53.

military expansion demands that the United States hedge against the possibility of a PRC attack against Taiwan or the emergence of a wider military competition against the PRC military. It is clear that the PRC armed forces are focused on this competition, as they prepare their forces for fighting a “local war under high-technology conditions” against the US military.<sup>90</sup> Central to PRC military strategy are anti-access/area-denial operations and tactics designed to disrupt or prevent US forces from mounting effective attacks on the Chinese mainland or against Chinese forces. These include, but are not limited to, attacks against US information systems, particularly the space-based components of the US global command, control, communications and intelligence (C3I) network; air and sea attacks against US supply depots and air and sea logistics forces; and, heavy aerospace attacks against US bases.<sup>91</sup>

Most significantly, at least from the US Navy’s perspective, is the emphasis PRC military writers place on neutralizing the US carrier fleet. Well aware of the limited tactical reach of US carrier air wings, the central PRC approach is to force the carriers far enough back from the Chinese coast as to take their aircraft out of the equation.<sup>92</sup> One PRC strategist argued that the PRC armed forces should develop the capability to project decisive combat power out to at least 1,600 nm from the mainland, and it appears this is now an accepted national objective.<sup>93</sup> To accomplish this goal, the PRC is developing an over-the-horizon targeting network; long-range ballistic missiles with maneuverable anti-ship warheads; medium and short-range maritime strike aircraft with advanced cruise missiles; and modern nuclear-powered and diesel-electric attack submarines with long-range anti-ship cruise missiles and torpedoes. Moreover, their combined employment doctrine will very likely be informed and shaped by Soviet experience with their Cold War maritime anti-access/area-denial network, and modern day advice from Russian military and technical advisors.<sup>94</sup> *In other words, for the first time since the 1980s, and for only the second time since the end of World War II, US carrier strike forces will be faced with a major land-based threat that outranges them.*

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<sup>90</sup> Ka Po Ng, *Interpreting China’s Military Power, Doctrine Makes Readiness* (Routledge, 2004), p. 21, accessed online at <http://books.google.com/books?id=pe1tJb2e9JIC&printsec=frontcover&dq=%22local+war+under+high+technology+conditions%22#PPP1,M1>, on March 28, 2007.

<sup>91</sup> Roger Cliff, *et al*, *Entering the Dragon’s Lair: Chinese Anti-Access Strategies and Their Implications for the United States* (Santa Monica, CA: RAND Corporation, 2007), pp. xiii-xvii.

<sup>92</sup> Cliff, *et al*, *Entering the Dragon’s Lair: Chinese Anti-Access Strategies and Their Implications for the United States*, p. 71.

<sup>93</sup> Xu Qi, “Maritime Geostrategy and the Development of the Chinese Navy in the Early Twenty-first Century,” first published in 2004 in *China Military Science* and translated by Lyle J. Goldstein and Andrew S. Erickson, *Naval War College Review*, Autumn 2006, pp. 60-61.

<sup>94</sup> Cliff, *et al*, *Entering the Dragon’s Lair: Chinese Anti-Access Strategies and Their Implications for the United States*, pp. 71-76.

If the Chinese can keep US aircraft carriers at least 600-700 nm away from their coast, they can severely constrain the carriers' effectiveness. Under these conditions, only 20 aircraft in the 2020 CVW would have the requisite range and stealth needed to operate over the Taiwan Strait in the face of Chinese advanced "double-digit" surface-to-air-missiles, and even those could not operate with meaningful persistence. These long range sorties, like those flown during Operation Enduring Freedom, would exhaust the crew members and dramatically decrease the carrier's overall sortie generation rate. A very stealthy aircraft with the unrefueled range and endurance to fly and fight from about 1,500 nm, and maintain persistent combat orbits over the Taiwan Strait in the face of China's most advanced air defenses would greatly complicate PRC military plans to keep US aircraft carriers out of any fight. In addition, with an unrefueled combat radius of 1,500 nm, such an aircraft could "top off" with fuel at a "tanker safe line" located outside the PRC air defense envelope and be able to penetrate and hold at risk PRC anti-access/area-denial targets deep inside mainland China, presenting a powerful deterrent to PRC aggression.

As this short discussion suggests, then, there is a growing strategic imperative to increase the range, persistence, and stealth of the Navy's carrier air wing. Indeed, failing to increase the CVW's reach, endurance, and survivability risks the long-term operational and tactical relevance of the US carrier fleet. The Navy would do well to stop focusing on carrier sortie rates and instead emphasize three key operational metrics to judge the effectiveness of future carrier air wings: maximum surveillance-strike range; maximum ordnance tonnage delivered per day at range; and maximum number of persistent (24/7), stealthy surveillance-strike orbits sustainable at range. Accounting for the inevitable trade-offs between system range, endurance, and payload, the goal should be to maximize all three to the greatest extent possible given the range of PRC counter-carrier threats and the requirement for persistent surveillance-strike orbits demanded by this nation's other strategic challenges. By so doing, the Navy would begin to transform the carrier and its carrier air wing from an operational strike system with outstanding global mobility and relatively limited tactical reach and persistence to a globally mobile, long-range, persistent surveillance-strike system effective across the entire range of potential 21<sup>st</sup> century security challenges.

#### **ENTER THE J-UCAS PROGRAM**

A cornerstone to this transformation is something long missing in the carrier air wing: a capable *unmanned* surveillance-strike aircraft. Why an unmanned aircraft? Because as Owen Cote has observed, "The one unambiguous advantage of separating air crews from their platforms is the increase in the latter's range and endurance that becomes possible."<sup>95</sup> Moreover, Pentagon experts in unmanned aviation make this observation:

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<sup>95</sup> Cote, *Future of Naval Aviation*, p. 29.

Aircraft with inhuman endurance bring ***persistent [orbits] at reduced sortie levels***. Fewer flight hours are “lost” due to reduced time otherwise needed for transit time in shorter range/endurance aircraft. Fewer take offs and landings mean reduced wear and tear, and exposure to historical risks of mishaps...Crew duty periods are now irrelevant to aircraft endurance since crew changes can be made on cycles based on optimum periods of sustained human performance and attention (emphasis added).<sup>96</sup>

Another advantage of unmanned systems is that carrier aircraft designers, freed from the requirements associated with a manned cockpit, can optimize a UAS or UCAS for low-observability (i.e., stealth), which equates to improved survivability. As the authors of the Office of the Secretary of Defense UAS roadmap assert, unmanned systems possess greater “potential for survivability by reducing signatures through optimal shaping not possible with traditional aircraft design.”<sup>97</sup> Why is this? From an air vehicle design standpoint, the only clear way to achieve true broad-band/all-aspect low observability is to remove all vertically-oriented elements, especially any vertical stabilizers (tails). Removing the cockpit also confers stealth advantages and improves fuel and payload storage. Thus, tail-less unmanned aircraft are inherently stealthier than manned aircraft with vertical tails like the F/A-18E/F and even the F-35. However, tail-less, flying wing-type aircraft generally require a high angle of attack while approaching the carrier for landing. At high angles of attack, human pilots would have difficulty seeing over the nose during carrier landing operations, but this is not a concern for unmanned aircraft. Thus, tail-less *unmanned* aircraft can be designed to be far more stealthy than an equivalent manned aircraft.

In other words, a UCAS provides a “three-fer” over manned aircraft: inherently greater operating range, far more combat persistence, and increased stealth/survivability. These characteristics—along with advances in flight control software—help to explain why the Air Force and the Navy began to take a serious interest in developing new unmanned air combat systems in the late 1990s. The Air Force, in conjunction with DARPA, was the first of the two Services to initiate a formal program. This work culminated with an award to Boeing to build a UCAV (“V” for vehicle vice system) demonstrator in 2000, which led to the development of the X-45A. About the same time, the Navy

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<sup>96</sup> DoD, *UAS Roadmap 2005-2030*, pp. 72-73.

<sup>97</sup> DoD, *UAS Roadmap 2005-2030*, p. A-4. Flying wing designs such as the B-2, which minimize vertical tail surfaces and decrease drag, have been pursued as far back as World War II when the German Horten brothers and American John Northrop built flying prototypes. See John K. Northrop’s 35<sup>th</sup> Wilbur Wright Memorial Lecture to the Royal Aeronautical Society of England on May 29, 1947, accessed online at [http://nurflugel.com/Nurflugel/Northrop/Northrop\\_address/body\\_northrop\\_address.html](http://nurflugel.com/Nurflugel/Northrop/Northrop_address/body_northrop_address.html) on April 2, 2007.

began work on its own unique UCAV, which it called the UCAV-N.<sup>98</sup> The Northrop Grumman Corporation (NGC) had been developing a naval UCAV demonstrator using its own funds. The Navy decided to leverage this work by awarding NGC a contract to develop an operational system concept for a carrier-based unmanned aircraft and to design a UCAV-N demonstration system, which became known as the X-47A Pegasus.<sup>99</sup> Two years later, in December 2002, an Office of the Secretary of Defense (OSD) program decision memorandum combined these two Service efforts, directing that the Air Force and the Navy join with DARPA and set up a new Joint Combat Air Systems (J-UCAS) Project Office.

At the time of this decision, the Air Force UCAS program was slightly ahead of the Navy's. Boeing's X-45A Air Force UCAS demonstrator first flew in May 2002, while Northrop Grumman's X-47A Navy UCAS demonstrator was just preparing for its first flight in February 2003. However, by the time the Joint Systems Management Office for Joint Unmanned Combat Air Systems and DARPA's J-UCAS Project Office were opened in the fall of 2003, both systems had flown and proven themselves air-worthy. Working together, the two offices quickly conducted a UCAS operational assessment, which led to increasingly more demanding J-UCAS performance specifications. The offices also crafted an ambitious seven-year plan to develop improved versions of these first "Spiral Zero" proof-of-concept vehicles, dubbed the X-45C and X-47B, respectively. This plan called for 14 Air Force and Navy UCAS prototypes to be available in time to start a two-year operational assessment in 2007. In 2010, informed by a DARPA technology assessment, OSD would then decide whether or not to pursue joint or separate operational UCAS systems. Either way, both Air Force and Navy operational UCASs were to be controlled by a common operating system.<sup>100</sup>

Whereas the Air Force envisioned its "Spiral Zero" UCAS as the ideal system for the suppression of enemy air defenses (SEAD) mission, the Navy viewed its UCAS first as an intelligence, surveillance, and reconnaissance (ISR) platform, and only later as a surveillance-strike platform. As explained by the Navy:

The initial operational role for the Navy's J-UCAS is to provide carrier based, survivable, and persistent surveillance, reconnaissance, and targeting to complement manned assets and long range precision strike weapons. But to fully exploit

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<sup>98</sup> Because the X-45 was designed for the Air Force, it was not suitable for carrier launch and recovery. In order to make the X-45 "carrier compatible," Boeing would have to make significant modifications, or even completely redesign the aircraft.

<sup>99</sup> See "Naval Unmanned Combat Air Vehicle (UCAV-N)," accessed online at <http://www.globalsecurity.org/military/systems/aircraft/ucav-n.htm> on March 30, 2007.

<sup>100</sup> See "J-UCAS Overview," accessed at the DARPA Joint Unmanned Combat Air Systems website, at <http://www.darpa.mil/j-ucas/index.htm>, on March 28, 2007.

its potential and “buy its way” onto the carrier, SEAD and strike capabilities will be designed in from the outset and fully developed in future spirals. The system will be seamlessly integrated with manned aircraft missions, carrier air traffic control, and deck operations, as well as with the carrier’s C4ISR architecture.<sup>101</sup>

Nevertheless, by designing for strike capabilities from the outset, the design performance of the X-47B is quite impressive for what is, in essence, a proof-of-concept vehicle. At just over 38 feet long, and with a wing span of about 62 feet, the unmanned aircraft will have a maximum gross take-off weight of approximately 45,000 pounds, a maximum operating altitude of 40,000 feet, and a high subsonic cruising speed. With an internal payload capacity of 4,500 pounds (equivalent to the internal payload of an F-35C when operating in its maximum stealth configuration), the X-47B’s unrefueled combat radius will be 1,400-1,500 nm (over twice that of the F-35C JSF). It is also designed to loiter over a target area for two hours at 1,000 nm with its full payload.<sup>102</sup>

The X-47B also has the space, weight, power, beyond-line-of-sight communications, and cooling necessary to allow the aircraft to operate as a flexible surveillance-strike platform. It is large enough to carry an onboard multi-sensor surveillance package and a variety of different weapons, ranging from two 2000-pound JDAMs to 12 SDBs.<sup>103</sup> Moreover, the X-47B is equipped for automated in-flight refueling. This would give the X-47B an airborne endurance of 50 to 100 hours—five to ten times that of a manned aircraft.<sup>104</sup> In other words, with aerial refueling, an X-47B-like system could establish persistent “surveillance-strike combat air patrols” at ranges well beyond 3,000 nm from the carrier, and strike point targets at even longer ranges—qualifying it as a long-range strike system.

With strong backing by the Air Force, Navy, and DARPA, the J-UCAS program continued apace. Construction of the X-47B began in June 2005. By August 2005, the Boeing X-45A had completed its 60<sup>th</sup> and final flight, and two months later DARPA awarded a \$56 million contract modification to Northrop Grumman to build two improved X-47B demonstrators (vice the three originally planned), with a new first flight date of November 2008. The revised program plan included provisions for carrier suitability testing and mission functionality demonstrations in 2011, including electronic support

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<sup>101</sup> “J-UCAS Overview,” p. 3.

<sup>102</sup> See also “J-UCAS Overview,” p. 2; and “UCAS (X-47A and X-47B) Unmanned Combat Air System,” accessed online at <http://www.northropgrumman.com/unmanned> on March 27, 2007.

<sup>103</sup> The X-47B is to have the same internal payload of the F-35C. These numbers reflect the internal bomb capacity as that aircraft.

<sup>104</sup> Butler, “Let the Race Begin,” p. 51.



measures and multi-ship operations. On November 1, management of the J-UCAS program was transferred from DARPA to a joint program office.<sup>105</sup>

#### ON TO THE UCAS-D PROGRAM

Only two months after the Air Force and Navy stood up the new J-UCAS Program Office, however, the 2006 QDR reconfigured the J-UCAS program, splitting it back into two separate Service programs. The QDR report directed the Air Force to upgrade its legacy long-range bomber force and to begin development of a new “next-generation long-range strike” (NGLRS) system, with an initial operational capability in 2018.<sup>106</sup> At the same time, the Secretary of Defense directed the Navy to “develop an unmanned longer-range carrier-based aircraft capable of being air-refueled to provide greater standoff capability, to expand payload and launch options, and to increase naval reach and persistence.”<sup>107</sup> Both moves aimed at increasing the United States military’s ability to fight over long ranges, to establish persistent, long-range airborne surveillance and strike orbits, and to survive and endure in contested airspace as the future security environment dictated.

The DoN’s plan to acquire a Navy-UCAS (N-UCAS) is split into two principal phases: first, technology maturation, and then acquisition (system design and development and introduction to the fleet).<sup>108</sup> The centerpiece of the technology maturation phase is the Navy UCAS carrier demonstration program, but it is not the only component of this effort. In addition to developing the technologies needed to integrate UCAS into carrier *flight deck* operations, the Navy must also develop the technologies necessary for UCAS to conduct *combat* operations. Indeed, Federal law requires that the Navy must reach a high level of readiness on all critical technology enablers for UCAS carrier and combat operations before the program can proceed to Milestone B (the acquisition phase).<sup>109</sup> In other words, *the technology maturation and demonstration program is the essential prerequisite if the Navy is ever to deploy an operational carrier-based UCAS.*

For the demonstration program, the Navy is holding a limited competition in which only two companies were invited to compete—Northrop Grumman and Boeing, the two companies that built the X-45 and X-47 demonstrators for the J-UCAS program. Moreover, instead of including

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<sup>105</sup> See DARPA Press Releases at the DARPA J-UCAS website, accessed online at <http://www.darpa.mil/j-ucas/index.htm> on March 31, 2007.

<sup>106</sup> *2006 QDR Report*, p. 41.

<sup>107</sup> *2006 QDR Report*, p. 46.

<sup>108</sup> The Navy now refers to the operational system as N-UCAS rather than UCAS-N. See Rear Admiral Mark Fitzgerald, quoted in Lorenzo Cortes, “Tomcat Transition to Super Hornet Complete by Fall ’06, Admiral Says,” *Defense Daily*, June 16, 2004, p. 9.

<sup>109</sup> In technical terms, this means the program must demonstrate Technology Level 6 maturity before proceeding to full-scale development. See Public Law 109-163 (Section 801), accessed online at <http://thomas.loc.gov/cgi-bin/cpquery/?&sid=cp109kh11E&refer=&rn=sr254.109&dbid=109&item=&sel=TOC714300&> on April 25, 2007.

mission functionality demonstrations including electronic support measures and multi-ship operations, competitors were expected only to demonstrate “carrier approach control operations, launch and recovery, deck operations and supportability ... no later than 2013.”<sup>110</sup> These tasks include carrier catapult launches and arrested landings; operations in carrier-controlled airspace; deck refueling and defueling; taxi, towing and maneuver on and off the carrier’s elevators; and mission planning and integration into CV information/communications systems.

The demonstration program’s focus on carrier flight deck and flight operations reflects the prudent judgment that to have a reasonable chance of success, it would first have to allay the long-held fears of many naval aviators who doubt that an UCAS could be safely integrated into carrier operations. As one senior naval aviator said, any N-UCAS will have to “earn its way onto the ship.”<sup>111</sup> Consequently, as Rear Admiral Anthony Winns recently told *Seapower* magazine, “Carrier suitability is the Navy’s primary objective for the [new UCAS-D] program.” The admiral went on to ask:

Can these vehicles take off and land on an aircraft carrier?  
We’ve never done that before with a vehicle shaped quite like these. It’s going to be a challenge, but we think that with the technology, with the full push by industry, we are going to be successful.<sup>112</sup>

Assuming the UCAS-D carrier suitability tests prove the viability of integrated manned and unmanned carrier deck and flight operations, the first operational N-UCAS capability could be operational as early as 2018.<sup>113</sup> However, the Navy’s plan to integrate a new unmanned aircraft into its future carrier air wings is relatively modest. Consistent with the Navy’s view that an operational N-UCAS should focus primarily on the stealthy and persistent surveillance, reconnaissance, and targeting mission (not strike), the planned 2020 CVW includes only four aircraft.<sup>114</sup>

## PREVENTING A MISSED OPPORTUNITY

A modern carrier flight deck is arguably one of the most dangerous workplaces in the world, and the job of spotting, fueling, arming, launching,

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<sup>110</sup> See “NAVAIR Will Release Request for Proposals for UCAS Late Next Month,” *Inside the Navy*, October 22, 2006.

<sup>111</sup> Cortes, “Tomcat Transition to Super Hornet Complete by Fall ’06, Admiral Says,” p. 9.

<sup>112</sup> Richard R. Burgess, “Mother Ship,” *Sea Power*, July 2005, accessed online at [http://findarticles.com/p/articles/mi\\_qa3738/is\\_200507/ai\\_n14687817](http://findarticles.com/p/articles/mi_qa3738/is_200507/ai_n14687817) on March 28, 2007.

<sup>113</sup> Bill Sweetman, “UCAVs Offer Fast Track to Stealth, Long Range, and Carrier Operations,” *Jane’s International Defense Review*, January 2007, p. 41; and Steven J. Zaloga, “UCAV (J-UCAS),” *World Missiles Briefing*, The Teal Group, May 2006.

<sup>114</sup> Lambeth, *American Carrier Air Power at the Dawn of a New Century*, p. 91.

and recovering aircraft is a complex evolution requiring close teamwork and timing.<sup>115</sup> The perceived difficulties in integrating an unmanned system into carrier flight deck operations have long discouraged any move toward a carrier-based unmanned aircraft of any sort. Thus, even if it were not required by law, a cautious naval UCAS demonstration and development program is warranted.

However, taking too cautious an approach may cause the Navy to miss a golden opportunity to transform its carriers into globally mobile, long-range, persistent surveillance-strike systems. In addition to removing any doubt about N-UCAS carrier suitability, a successful demonstration program needs also to allay lingering vague fears about immature technology while highlighting the system's potential to enhance carrier air wing operations. To be sure, some people will be difficult to convince. For example, Owen Cote worries about the vulnerability created by the requirement for data links that connect the N-UCAS to human operators.<sup>116</sup> But *all* next-generation combat aircraft, manned or unmanned, will require extremely high levels of connectivity to operate as components in planned future naval battle networks. In fact, high-bandwidth, jam-resistant connectivity is one of the F-35's most important capabilities. The UCAS-D program could easily be modified to demonstrate the reliability of its long-range data links.

Even if the UCAS-D program conclusively proves that UCAS can be safely operated aboard carriers and is *technically* capable of many missions, however, some will continue to doubt that "UCAVs can perform their expected missions better than manned aircraft in high-threat and high-risk environments."<sup>117</sup> To counter these doubters, the demonstration program should be structured to highlight the longer-term *multi-mission* potential of the N-UCAS through a robust technology maturation effort. Why? Some believe that N-UCAS will be most useful solely as an ISR platform. As Rear Admiral Winns makes clear,

The primary focus for developing naval UAV capabilities is centered around providing intelligence, surveillance and reconnaissance (ISR) capabilities. Our whole strategy is focused on ISR. The Navy has been very consistent with the capabilities desired [in UASs and UCASs].<sup>118</sup>

Unquestionably, having operated only non-stealthy, manned tactical reconnaissance aircraft in the past, a carrier air wing would definitely benefit from having a stealthy, long-range and persistent, penetrating ISR platform in

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<sup>115</sup> For a good, easy-to-understand discussion of carrier flight deck operations, see Clancy, *Carrier: A Guided Tour of an Aircraft Carrier*, pp. 107-115.

<sup>116</sup> Cote, *Future of Naval Aviation*, p. 29.

<sup>117</sup> Lambeth, *American Carrier Air Power at the Dawn of a New Century*, p. 93-94.

<sup>118</sup> Burgess, "Mother Ship."

the future. As one analyst notes, “Persistent surveillance, whether manned or unmanned, land or sea-based, is the foundation for success in all mission areas in the new security environment.”<sup>119</sup> However, to envision the N-UCAS as solely or even primarily a penetrating or persistent ISR platform detracts from its equally important potential as a persistent, multi-role, surveillance-strike system.

To expand on the example given at the beginning of this paper, an aircraft carrier leaving Pearl Harbor could immediately launch a flight of N-UCASs and have them in a fight over the Taiwan Strait 4,450 nm away in just over 10 hours given a 450 knot cruising speed and two aerial refuelings from land-based Air Force tankers. Furthermore, the aircraft could operate inside the PRC advanced continental air defense network for over five hours before having to be refueled again. As the carrier closed the range, it could either maintain more surveillance-strike CAPs over the Strait or send strikes deep into China, attacking PRC maritime anti-access/area-denial systems. The carrier could easily slow its advance at 1,500-1,600 nm from the Chinese mainland—at the very outer edges of the PRC anti-access/area-denial network—where it could exploit its own inherent mobility, as well as the great range and endurance of its unmanned systems, to avoid PRC targeting and attacks. From there, it could use UCASs to wage an “outer network battle,” with the intent of collapsing the PRC network from the inside out, allowing it to close the range even further, increasing its lethality and coercive presence.

As another example, carriers supporting a repeat of Operation Enduring Freedom could easily maintain *organic*, persistent surveillance-strike orbits over Afghanistan while operating their short-range manned aircraft in the Persian Gulf. Similarly, N-UCASs could be used to plant mines in harbors and deliver torpedoes against enemy submarines. They could also accompany strike fighters on fleet air defense missions, serving as remote, stealthy, air-to-air missile batteries. Demonstrating an ability to carry and launch a variety of weapons for different tactical scenarios will help to highlight the N-UCAS’s great multi-mission potential, and increase the chance that they can “earn their way aboard” the carrier.

As this discussion suggests, getting the best “bang for the buck” out of an unmanned system demands that N-UCAS be designed from the start to operate in conjunction with the Air Force’s large aerial tanker fleet. In other words, to take full advantage of the N-UCAS’s great potential mission endurance, it must demonstrate an ability to conduct automated air refueling operations. Unfortunately, demonstrating this type of capability is not a part of the current UCAS-D program. This is inconsistent with the guidance found in the 2006 QDR, which directed the Navy to “develop an unmanned longer-range carrier-based aircraft *capable of being air-refueled* to provide greater standoff capability, to expand payload and launch options, and to increase

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<sup>119</sup> Cote, *Future of Naval Aviation*, p. 12.

naval reach and persistence” (emphasis added).<sup>120</sup> At the very minimum, a demonstration of automated aerial refueling (AAR) should be restored to the UCAS-D program.

Recent developments make this a low-risk, high-payoff proposition. Consider, for example, that DARPA recently demonstrated mid-air refueling of unmanned aerial vehicles using an autonomously controlled F/A-18 Hornet, which successfully refueled using the Navy’s preferred “probe and drogue” method.<sup>121</sup> Additionally, the Air Force Research Laboratory conducted a station-keeping flight test of a surrogate UAS in November 2006 that succeeded in holding a proper refueling position behind a KC-135 Stratotanker boom for 23 consecutive minutes.<sup>122</sup> To demonstrate its full potential, the UCAS-D program should demonstrate that prospective systems are capable of being refueled by either Navy or Air Force in-flight refueling systems—and preferably both.

There are several additional candidates for technology maturation and demonstration to ensure that N-UCAS can effectively conduct combat operations, and not merely integrate into carrier operations. For example, the Navy removed the requirement to demonstrate advanced sensors originally included in the J-UCAS demonstration program. The integration of powerful, capable sensors (such as an active electronically-scanned array radar) into the relatively small airframes is necessary if an operational N-UCAS is to fulfill its essential role as a persistent surveillance-strike system. Additionally, further research into automated target recognition and automated sensor fusion will reduce the need for off-board processing and thus reduce bandwidth requirements. New miniaturized kinetic weapons and directed energy weapons would increase magazine depth, thereby enhancing combat persistence in the strike role. Lastly, an investment in advanced propulsion systems such as the Air Force Research Laboratory’s Adaptive Versatile Engine Technology (ADVENT) program would improve endurance and reduce fuel consumption.<sup>123</sup> Many of these technology research areas would benefit not merely N-UCAS but potentially all other UASs and manned aircraft.

## MOVING FORWARD

Any successful Navy UCAS technology maturation and demonstration program will demand an adequate and consistent funding stream. Unfortunately, if early returns are any indication, program funding may be a

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<sup>120</sup> 2006 QDR Report, p. 46.

<sup>121</sup> Bill Sweetman, “UCAVs Offer Fast Track to Stealth, Long Range, and Carrier Operations,” *Jane’s International Defense Review*, January 2007, p. 41.

<sup>122</sup> AFRL/XP, “AFRL Completes Automated Aerial Refueling Station-Keeping Flight Test,” accessed online at <http://www.wpafb.af.mil/news/story.asp?storyID=123034903> on March 29, 2007.

<sup>123</sup> Larine Barr, “Air Force plans to develop revolutionary engine” accessed online at <http://www.af.mil/news/story.asp?id=123046410> on May 1, 2007.

big show-stopper. For example, although the Navy asked for \$239 million in its Fiscal Year 2007 (FY 2007) budget submission for “unmanned combat aerial vehicle advanced component and prototype development,” Congress cut \$139 million from the request. This cut caused a reorientation of the program, and delayed the target date for carrier demonstrations from 2011 to 2013, setting back the start of a follow-on systems development and demonstration (SDD) program to 2014. In the most recent budget documents, the Navy asked for \$1.88 billion for UCAS from FY07 through FY13, including \$1.5 billion for the carrier demonstration and \$340 million for additional technology maturation. These amounts appear to be the bare minimum necessary to keep the program from slipping beyond 2014 and to ensure that N-UCAS is operational in the 2018-2020 timeframe.

Given the other competing requirements facing Navy planners, this represents a significant demand on DoN resources. How hard will the Navy fight for the UCAS-D program if future DoN aviation budgets are less than expected, or if it is faced with a choice of funding either the UCAS-D or other another competing priority? If history is any guide, given the inattention to and lack of interest in unmanned systems within the carrier aviation community, it seems likely that only strong OSD and congressional support will keep this new unmanned carrier surveillance-strike capability on track. Both should be prepared to encourage, prod, and, if necessary, direct the Department of the Navy to continue fully funding the carrier demonstration program and the parallel technology maturation effort, and to resist slipping the program any further.<sup>124</sup>

Indeed, given the great potential of Navy UCASs, OSD and Congress should consider *expanding and accelerating* the technology maturation and demonstration program to allow a more informed decision on the best mix of F/A-18E/Fs, F-35B/Cs, and operational N-UCASs in the Navy’s future CVW. If the rapidly improving reliability and effectiveness of UASs like the Global Hawk and Predator are any indication, it seems likely that the UCAS-D program will prove that unmanned aircraft can operate safely and effectively as part of a carrier air wing. If true, given the apparent increasing demands for range, persistence, and stealth in the future security environment, planning for just four N-UCASs in the 2020 CVW appears to undervalue the system’s great potential contribution to carrier strike operations. If the X-47B was deployed today, it would already be one of the most capable carrier aircraft ever—and it is only a *demonstrator* that uses extensive commercial-off-the-shelf technologies and a readily available engine to reduce cost and risk. An

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<sup>124</sup> In this OSD and Congress would play the same role they played in fielding the new conventional cruise missile and special operations transport submarines, now known as SSGNs. After the Nuclear Posture Review, the Ohio-class strategic ballistic missile submarine (SSBN) force was reduced from 18 to 14 boats. The “excess” Ohios had over two decades of service life remaining. OSD and Congress successfully argued that the Navy should convert the SSBNs into SSGNs, over the objections of the Navy. Now, the Navy considers these ships among the most “transformational” platforms in the fleet. See for example “SSGN: A Transformational Force for the US Navy,” accessed online at <http://www.chinfo.navy.mil/navpalib/cno/n87/usw/issue13/ssgn.htm>.

operational N-UCAS would likely have even greater range and persistence, and offer even greater combat potential. Limiting the number of N-UCASs to just four aircraft per air wing appears hard to justify.

Some may argue against an expansion or acceleration of the program by pointing out that the N-UCAS is a “paper airplane” without a single flight under its belt. But the same holds true for both the F-35B and C, and the Navy and Marines are willing to make concrete plans for their incorporation into the future carrier air wing. By robustly funding the Navy UCAS program, OSD and Congress could ensure that both the N-UCAS and JSF prove themselves and their design and cost goals at about the same time, providing an opportunity to judge the two systems more fully and equally before deciding on the appropriate mix between them.

A successful carrier demonstration program will allow the Navy to experiment with the capabilities of their new system. As mentioned earlier, although the Navy’s recently published long-term shipbuilding plan shows that the fleet will have a twelfth aircraft carrier after FY 2019, there are as yet no plans to stand up an 11<sup>th</sup> active carrier air wing to equip the ship.<sup>125</sup> The Navy might consider giving this “spare” carrier an all-N-UCAS CVW. A CVN operating over 70 N-UCASs would provide a future Carrier Strike Force consisting of two to four carriers and their escorts with a formidable surveillance-strike capability. Indeed, experiments with an all-N-UCAS wing might point the way toward smaller carriers optimized for unmanned operations, opening the way toward a more distributed unmanned aviation capability in fleet operations. The point here is that there are many potential ways to exploit N-UCASs, provided adequate development is pursued to make them reliable and effective.

The bottom line is this: the N-UCAS’s unique combination of great unrefueled range and dramatically improved endurance and stealth could transform US aircraft carriers and their embarked air wings from operational strike systems with outstanding global mobility and relatively limited tactical reach and persistence into globally mobile, long-range persistent surveillance-strike systems effective across multiple 21<sup>st</sup> century security challenges. To make this potentially revolutionary transformation possible, Congress, OSD, and the Navy must take the necessary first step and support both an expanded N-UCAS carrier demonstration program and technology maturation effort to safely integrate these unmanned surveillance/strike systems into carrier flight deck and strike operations.

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<sup>125</sup> OPNAV N8F, “Report to Congress on Annual Long-Range Plan for Construction of Naval Vessels for FY 2008,” (Washington, DC: Office of the Chief of Naval Operations, February 2007), p. 6.