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RED ALERT:
The Growing Threat to U.S. Aircraft Carriers

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The views expressed in this report are solely those of the author, who is responsible for any error of fact, analysis, or omission.

Cover Photo: In light of the evolving threat landscape and the global proliferation of A2/AD capabilities, the United States must re-examine the relevance of the carrier and its air wing. The aircraft carrier USS *George H.W. Bush* (CVN 77) transits the Gulf of Aden in October 2014 while returning to Naval Station Norfolk after supporting maritime security operations, strike operations in Iraq and Syria as directed, and theater security cooperation efforts in the U.S. 5th Fleet area of responsibility.
(U.S. Navy/Mass Communication Specialist 2nd Class Abe McNatt)

Introduction

While the U.S. Navy has long enjoyed freedom of action throughout the world's oceans, the days of its unchallenged primacy may be coming to a close. In recent years, a number of countries, including China, Russia, and Iran, have accelerated investments in anti-access/area denial (A2/AD) capabilities such as advanced air defense systems, anti-ship cruise and ballistic missiles, submarines, and aircraft carriers. These capabilities are likely to proliferate in the coming years, placing greater constraints on U.S. carrier operations than ever before.

For decades, aircraft carriers and their associated air wings (CVWs) have represented a potent symbol of American military might, serving as persistent reminders of the country's forward presence and ability to project power globally. Today, the United States operates 10 carriers,[1] each displacing more than 100,000 tons and hosting over 70 aircraft.[2] At any given time, two to four of these carriers are deployed abroad.[3] But as A2/AD capabilities continue to proliferate, the United States will be faced with a choice: operate its carriers at ever-increasing ranges – likely beyond the unrefueled combat radii of their tactical aircraft – or assume high levels of risk in both blood and treasure.

This state of affairs will impact carrier operations in all theaters; however, in the near term, it will be particularly relevant in the Asia Pacific, where carriers and their air wings play an essential role in mitigating the tyranny of distance and where A2/AD capabilities are most mature. In order to examine the implications of these capabilities, this paper will assess the threats to U.S. aircraft carriers posed by Chinese systems. While China does not represent the sole threat to the carrier air wing – indeed, many of its systems are Russian-origin – Beijing's technological sophistication and emphasis on long-range anti-ship missile procurement qualify it as the pacing threat. For organizational purposes, this paper will categorize threats to the carrier and its air wing at three distances: short-, medium-, and long-range.[4]

AS A2/AD CAPABILITIES CONTINUE TO PROLIFERATE, THE UNITED STATES WILL BE FACED WITH A CHOICE: OPERATE ITS CARRIERS AT EVER-INCREASING RANGES – LIKELY BEYOND THE UNREFUELED COMBAT RADII OF THEIR TACTICAL AIRCRAFT – OR ASSUME HIGH LEVELS OF RISK IN BOTH BLOOD AND TREASURE.

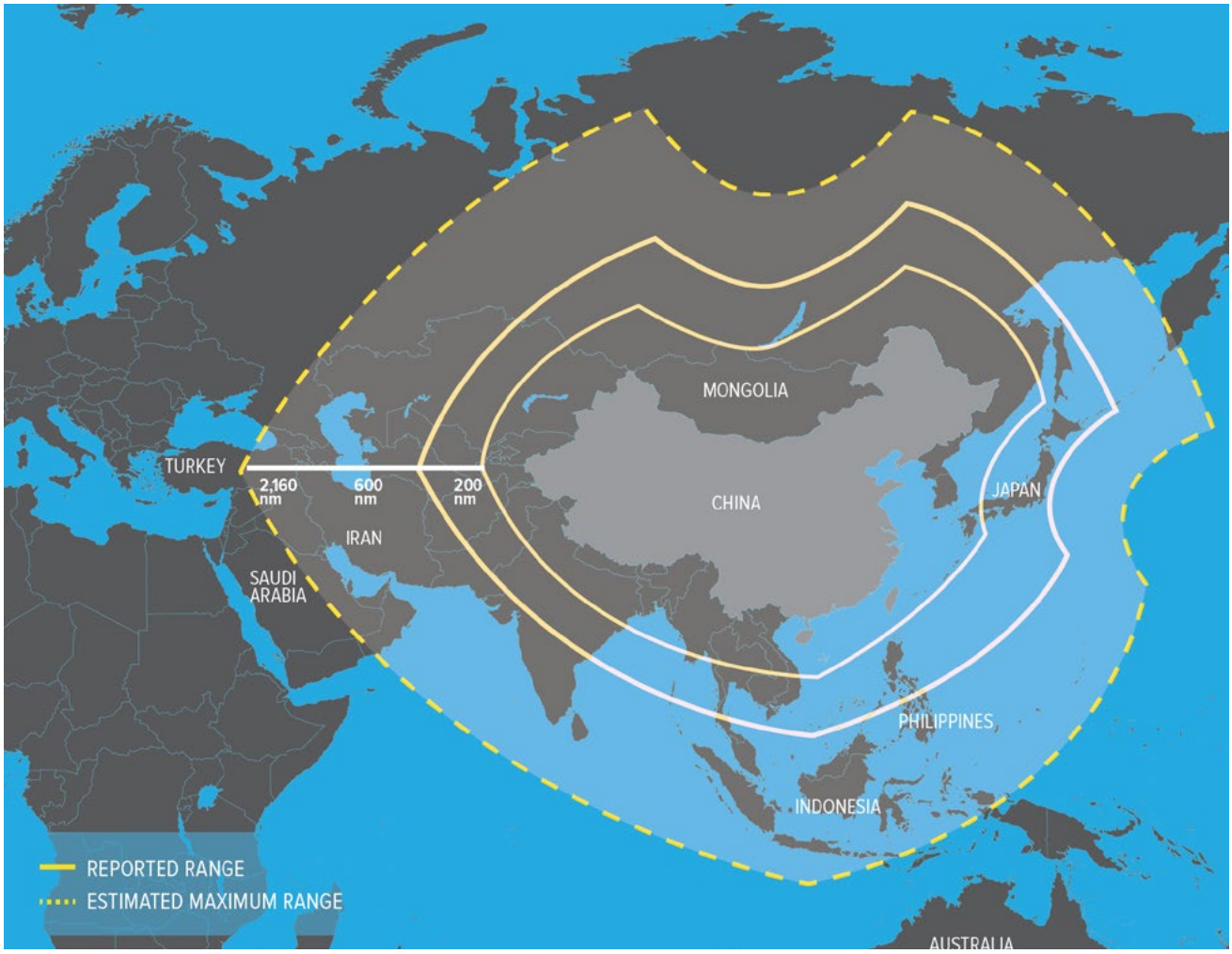
Short-range threats include systems capable of operating within China's 200-nautical-mile (nm) exclusive economic zone (EEZ), or the area in which a given country enjoys sovereign rights over natural resources. These systems – such as surface-to-air missiles (SAMs), anti-ship cruise missiles (ASCMs), and tactical unmanned aerial vehicles (UAVs) – are additionally capable of reaching Taiwan.

Medium-range threats include systems capable of operating at ranges of up to 600 nm, such as ASCMs delivered by submarines, land-based fighter aircraft and bombers, and larger surface vessels. In the event of a conflict, these systems could be used throughout the East and South China Seas and could reach the first island chain that extends from Japan in the north to the Philippines in the south.

Long-range threats include systems capable of operating beyond 600 nm, such as anti-ship ballistic missiles (ASBMs) and submarine- and bomber-delivered ASCMs. These systems could extend as far as the U.S. territory of Guam and additionally cover the entirety of the Bay of Bengal and most, if not all, of the Arabian Sea. Select land-based fighter aircraft may also threaten the carrier – without aerial refueling – at distances greater than 600 nm.

Growing international interest in A2/AD capabilities occurs at a time when the U.S. Navy is particularly ill-equipped to operate at distance. Since the end of the Cold War, the service has steadily retreated from its prior emphasis on long-range carrier-based assets and the deep strike mission, instead focusing on short-range assets intended to improve

THREAT DISTANCE FROM MAINLAND CHINA



sortie generation rates.[5] During this time, the average unrefueled combat radius of the carrier air wing plummeted over 300 nm – from 800 nm in 1996 to only 500 nm in 2006 – bringing it well within the range of a number of states' A2/AD capabilities.[6] This was largely the result of the decision to replace the A-6 attack aircraft, which featured a combat radius of 1,000 nm, with the comparatively low-cost but short-legged F/A-18 fighter jet. Limitations on the CVW's range were further exacerbated by the retirement of the KA-6 tanker and the resultant decline in the carrier's organic tanking capabilities.[7] The convergence of these factors could present new challenges for the U.S. carrier and its air wing and foreshadow the end of unrivaled U.S. domination of the world's oceans.

Short-Range Threats

Throughout its history, the carrier has been forced to assume risk at short ranges, operating within the threat envelope of surface combatants, SAMs, and land-based aircraft. However, advancements in precision and lethality have amplified this risk at all ranges and will continue to do so in the years to come. China, in particular, is acquiring a robust portfolio of A2/AD capabilities that could be used to constrain adversary operations within its EEZ. These capabilities could additionally be brought to bear in a conflict with Taiwan, which lies less than 100 nm from mainland China.

At this short range, China operates approximately 40 Russian-built S-300 SAM batteries in addition to 60

indigenous HQ-9 models, which together form what the U.S. Department of Defense has termed "one of the largest forces of advanced long-range SAM systems in the world."[8] Deployed on mobile launchers, these systems are highly survivable in combat. Existing batteries are capable of striking incoming cruise missiles and nonstealthy aircraft at a range of 80 nm[9] and may also have limited abilities to strike ballistic missiles.[10] Furthermore, when China receives delivery of the upgraded S-400 system, its ability to strike incoming targets will extend to 215 nm – a range large enough to cover the entirety of its EEZ.[11]

Throughout its EEZ, China additionally operates a wide range of surface combatants – including destroyers, frigates, corvettes, and fast-attack craft – equipped with anti-ship cruise missiles. Over 100 of these vessels are capable of carrying the YJ-83, an ASCM that employs inertial and active radar guidance and that can receive in-flight target updates.[12] Difficult to defend against due to its speed (Mach .9) and flight altitude (20 to 30 meters), the YJ-83 delivers a 165 kg semi-armor-piercing warhead – large enough to disable destroyers and frigates – at ranges of approximately 65 nm.[13] China is also capable of delivering this missile from a range of land-based fighter aircraft and bombers and, in the event of a conflict, would be likely to attempt a saturation attack that would overwhelm U.S. defenses.[14]

CHINA IS ACQUIRING A ROBUST PORTFOLIO OF A2/AD CAPABILITIES THAT COULD BE USED TO CONSTRAIN ADVERSARY OPERATIONS WITHIN ITS EEZ.

China's four Russian-built *Sovremenny* guided missile destroyers also operate an advanced anti-ship cruise missile – the SS-N-22 Sunburn, alternatively known as the 3M80ME Moskit – with each ship capable of launching eight missiles. Like the YJ-83, the Sunburn employs inertial and active radar guidance. It is designed to evade the United States' advanced SM-2 missile interceptors as well as the defenses of the Aegis Combat System, reaching speeds of Mach 2.5 and conducting 15G maneuvers.[15] It is additionally capable of striking targets with a 300 kg semi-armor-piercing warhead at a range of 65 to 130 nm (depending on variant).[16]

Similarly, China deploys the SS-N-27 Sizzler, or 3M-54 Klub, ASCM aboard eight of the country's 12 Kilo-class diesel submarines.[17] This system operates in variable flight mode, shifting from subsonic flight in phases one and two to supersonic flight (Mach 2.2) in the terminal phase, which begins 10 to 35 nm from the target. During the terminal phase, the Sizzler additionally operates in sea skimming mode at an altitude of five to 10 meters, following a "zig-zag flight path."[18] This approach both prevents the defender from detecting the missile until it breaks the defender's radar horizon and complicates fire control calculations. At such altitudes, detection occurs at a distance of less than 18 nm, leaving the defender less than one minute to respond.[19] While the Sizzler has an overall range of 120 nm, the B variant eliminates the terminal phase sprint vehicle to achieve an extended range of over 160 nm. Both variants are thus capable of operating throughout China's EEZ.

Finally, China could deploy its fleet of over 100 Israeli-built Harpy UAVs in the event of a conflict within its EEZ. These systems, which have a range of approximately 215 nm, essentially function as loitering anti-radiation missiles equipped with a 32 kg explosive warhead.[20] While a single munition of this size could disable a ship's radar, it would be highly unlikely to achieve a mission kill. It is possible that China could, however, swarm its Harpys in a saturation attack against the carrier. An attack of this nature could overwhelm U.S. defenses and ultimately result in the neutralization or loss of the carrier.

Medium-Range Threats

In addition to its short-range A2/AD capabilities, China operates a number of systems that could be used at medium ranges, throughout the East and South China Seas and the first island chain extending from Japan in the north to the Philippines in the south. At this distance, ASCMs – including those delivered by submarines, land-based fighter aircraft, bombers, and large surface vessels – will continue to pose a threat to the carrier due to the range of their associated platforms. For example, one major delivery platform for the 65 nm-range YJ-83, the J-10A/S fighter jet, has a combat radius in excess of 540 nm, bringing the platform's effective reach to around 600 nm.[21] In the event of a conflict, these capabilities could limit U.S. freedom of operation in contested areas and push U.S. aircraft carriers to – or even beyond – the maximum unrefueled range of their tactical aircraft. Indeed, the most recent estimate of the F-35C's combat radius is 610 nm,[22] while the combat radius for the U.S. Navy's existing fleet of F/A-18 E/F Super Hornets is less than 500 nm.[23] These limitations would likely pull the carrier well inside the threat envelope.

While China's ability to track and target the carrier degrades as a function of distance and could be limited at such ranges, it appears to be developing high-altitude, long-endurance UAVs that could assist in over-the-horizon targeting for ASCMs and ASBMs. In particular, the design characteristics of the Soar Dragon suggest that it may be capable of carrying a sensor suite that could be used in support of an emerging reconnaissance-strike complex.[24]

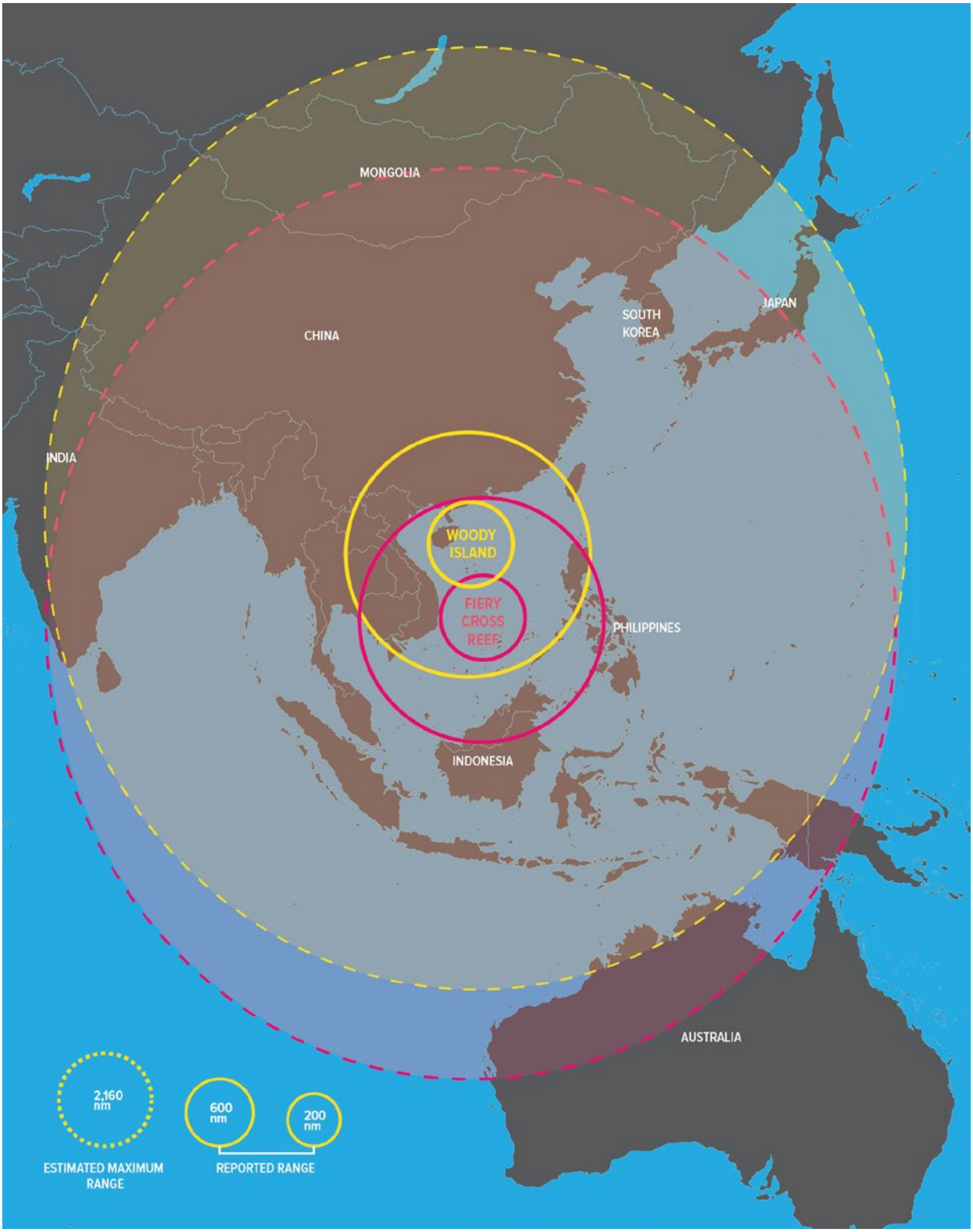
WHILE CHINA'S ABILITY TO TRACK AND TARGET THE CARRIER DEGRADES AS A FUNCTION OF DISTANCE AND COULD BE LIMITED AT SUCH RANGES, IT APPEARS TO BE DEVELOPING HIGH-ALTITUDE, LONG-ENDURANCE UAVS THAT COULD ASSIST IN OVER-THE-HORIZON TARGETING FOR ASCMS AND ASBMS.

CHINESE ISLAND-BUILDING

One development that complicates efforts to determine the threat to the carrier air wing at various distances stems from China's recent island-building campaign in the South China Sea. Beginning in early 2014, China accelerated its efforts to construct artificial landmasses capable of hosting an array of port facilities, airstrips, and other military structures in the contested Paracel and Spratly Islands.[25] In the event of a conflict, China could deploy A2/AD capabilities from a number of islands in this region – two of which, Woody Island in the Paracels and Fiery Cross Reef in the Spratlys, feature runways that can accommodate UAVs, fighter aircraft, and bombers. Indeed, China has already demonstrated both the interest and the ability to deploy such capabilities on the islands, moving advanced J-11 fighter aircraft to Woody Island in late October 2015 and HQ-9 SAMs in February 2016.[26]

While deploying A2/AD capabilities from the islands would significantly extend their reach – potentially enabling China to strike targets as far as Australia – it would additionally provide a clear targeting opportunity for U.S. forces and likely present only a brief threat to the carrier. If paired with the construction of hardened aircraft shelters and the permanent deployment of SAMs, however, these capabilities could present a more survivable and enduring threat.

THREAT DISTANCE FROM WOODY ISLAND AND FIERY CROSS REEF



Long-Range Threats

Beyond the 600 nm range, the number of China's A2/AD systems begins to taper. Many of its land-based fighter aircraft could continue to deliver ASCMs at this range only with the assistance of aerial refueling, a task that could expose the fleet to a high level of threat from U.S. carrier-based aircraft. China's approximately 250 land-based Su-27 Flankers and J-11s (the Su-27's indigenously produced counterpart) and over 100 land-based Su-30MKK/2 Flankers are notable exceptions to this limitation, featuring combat radii of over 750 nm.[27] China is also developing two stealthy, fifth-generation fighters, the J-20 and J-31, each of which is expected to have a combat radius of over 1,000 nm.[28] If paired with long-range ASCMs, these aircraft could be capable of targeting the carrier at distances of over 1,200 nm[29] – a range that could be extended to over 1,600 nm if China were to assume the risk of aerial refueling. As China becomes increasingly proficient in conducting its own carrier operations, it may also deploy YJ-83s and other ASCMs from carrier-based aircraft.[30]

In addition to ASCMs, China could use ASBMs to strike aircraft carriers at distances greater than 600 nm.[31] China currently deploys the solid-fuel DF-21D ASBM on highly survivable land-based mobile launchers capable of operating in off-road conditions.[32] Further complicating defensive measures, the DF-21D – which travels at speeds of Mach 10 – features a maneuverable warhead guided by inertial and GPS navigation and may additionally incorporate cluster *fléchettes* designed to neutralize carrier flight decks and radar and communications equipment.[33] While open-source details of the system's operating parameters vary, the DF-21D reportedly has a circular error probable[34] of 20 meters and is capable of striking "slow-moving targets" at a range of around 810 nm.[35]

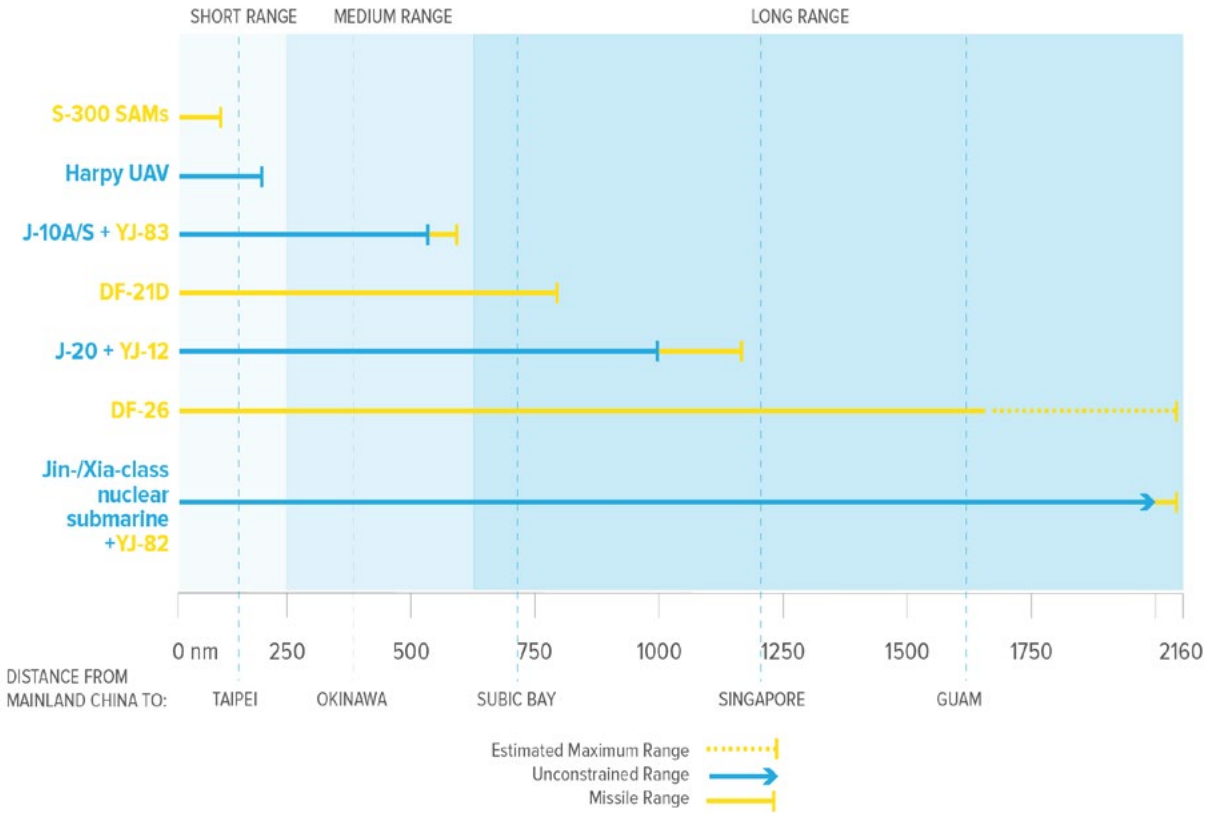
China appears intent upon increasing its ASBM capabilities further and, at a recent military parade commemorating the end of World War II, revealed that it may have an ASBM variant of a substantially longer-range missile – the DF-26. As with the DF-21D, estimates of the capabilities of the DF-26 vary widely; however, it is thought to have a range of 1,620 to 2,160 nm and to have both conventional and nuclear warheads.[36] If accurate and operational, this system would give China the ability to strike targets within the second island chain – including those in and around the U.S. territory of Guam – as well as those throughout the entirety of the Bay of Bengal.[37] In the event of a wider conflict, these systems could also reach targets throughout much, if not all, of the Arabian Sea.

BEYOND THE 600 NM RANGE, THE NUMBER OF CHINA'S A2/AD SYSTEMS BEGINS TO TAPER. MANY OF ITS LAND-BASED FIGHTER AIRCRAFT COULD CONTINUE TO DELIVER ASCMS AT THIS RANGE ONLY WITH THE ASSISTANCE OF AERIAL REFUELING, A TASK THAT COULD EXPOSE THE FLEET TO A HIGH LEVEL OF THREAT FROM U.S. CARRIER-BASED AIRCRAFT.

While both the DF-21D and the DF-26 represent a significant threat to the carrier, China's ability to successfully track and target adversary assets at such distances is unclear and there is no evidence that China has tested its ASBMs in a realistic operating environment.[38] Nonetheless, China is actively growing its reconnaissance-strike complex, integrating UAVs – such as the Soar Dragon – into an existing suite of over-the-horizon radars and overhead satellites, and additionally improving its ability to coordinate and cue intelligence, surveillance, and reconnaissance (ISR) assets capable of providing more precise targeting data.[39]

Finally, Chinese submarines and bombers will continue to pose a threat to the carrier throughout much of the Western Pacific.[40] In the event of an attack, China would likely launch a large number of A2/AD systems – including ASBMs and submarine- and bomber-delivered ASCMs – along a variety of azimuths. Doing so would increase the difficulty of

RANGE OF SELECT CHINESE A2/AD CAPABILITIES



defense and almost certainly result in significant damage to U.S. carriers within range, even assuming a high degree of Chinese attrition.[41]

CHINA APPEARS INTENT UPON INCREASING ITS ASBM CAPABILITIES.

U.S. Countermeasures

In the event of a near-term conflict, there are a number of countermeasures – including jamming; spoofing; dazzling; kinetic strike;[42] passive avoidance;[43] and, potentially, hacking – that the United States could undertake in order to attempt to mitigate the missile threat.[44] An assessment of the effectiveness of these measures is unavailable in the open source; however, it is highly unlikely that they could wholly neutralize a saturation attack against U.S. forces. Furthermore, as China continues to develop and mature its reconnaissance-strike complex, the threat to the carrier will grow increasingly resilient.[45]

Over the long term, the United States may have access to additional countermeasures such as railguns, which could fire projectiles at speeds as high as Mach 7 and ranges of 50 to 100 nm.[46] The Navy is evaluating early-stage prototypes of these systems, but if they become operational at some point – a prospect far from guaranteed – they will significantly increase the depth of ships' magazines while simultaneously decreasing the cost[47] of defending against missile salvos. These factors would greatly strengthen the defense of U.S. surface assets.

Conclusion

No longer will aircraft carriers and their associated air wings be able to operate with impunity. Instead, they will face a dense and growing threat across their full range of operations as A2/AD systems continue to proliferate. Operating the carrier in the face of increasingly lethal and precise munitions will thus require the United States to expose a multibillion-dollar asset[48] to high levels of risk in the event of a conflict.[49] Indeed, under such circumstances, an adversary with A2/AD capabilities would likely launch a saturation attack against the carrier from a variety of platforms and directions. Such an attack would be difficult – if not impossible – to defend against.

There are a number of options for addressing this problem. First, the United States could significantly increase the range of the carrier air wing, such that the carrier could operate beyond the 1,000 to 1,500 nm distance at which the threat landscape is most intense.[50] This could be accomplished if requirements for the Navy's unmanned carrier-based system include a significant strike capability.[51] Given the range of emerging ASBMs, however, this would not wholly remove the risk to the carrier and would dramatically reduce sortie rates.

Second, the United States could shift its emphasis from supercarriers such as the Ford-class to undersea assets such as submarines and unmanned undersea vehicles that are capable of operating within a dense A2/AD threat environment. While a shift of this nature would result in a reduction in combat airpower, it would preserve some degree of strike capability and likely increase the survivability of the fleet as a whole.

As an alternative, the United States could adopt a combination of these options, both increasing the range of the aircraft operating from existing carriers and shifting future investments from Ford-class supercarriers to undersea assets. At this time, the optimal choice among these three options is unclear and will require further study to assess tradeoffs in strike capacity, survivability, and affordability.

Even in the face of major changes to U.S. force structure, however, the risk posed by submarine-delivered ASCMs to U.S. surface assets will remain. For this reason, it will be essential to invest in long-range anti-submarine warfare capabilities. Similarly, the continued ASBM threat will require sustained investments in emerging technologies, such as railguns, that hold the potential to shift the offense-defense balance in favor of the U.S. military.

As the United States considers the nature of the evolving threat landscape and confronts the global proliferation of A2/AD capabilities, it must re-examine the relevance of the carrier and its air wing and explore innovative options for future operations and force structure. If the United States is to maintain its military superiority well into the future, it cannot afford to do otherwise.

THE CONTINUED ASBM THREAT WILL REQUIRE SUSTAINED INVESTMENTS IN EMERGING TECHNOLOGIES, SUCH AS RAILGUNS, THAT HOLD THE POTENTIAL TO SHIFT THE OFFENSE-DEFENSE BALANCE IN FAVOR OF THE U.S. MILITARY.

Endnotes

1. Although the U.S. Navy is required by law to operate no fewer than 11 aircraft carriers, it received a waiver to operate only 10 between the 2012 inactivation of the USS *Enterprise* (CVN-65) and the commissioning of the USS *Ford* (CVN-78) –currently slated for March 2016. Ronald O'Rourke, "Navy Ford (CVN-78) Class Aircraft Carrier Program: Background and Issues for Congress," RS20643 (Congressional Research Service, December 17, 2015), https://www.fas.org/sgp/crs/weapons/RS20643.pdf.

2. Norman Polmar, *The Naval Institute Guide to the Ships and Aircraft of the U.S. Fleet* (Annapolis, MD: Naval Institute Press, 2013), 349. Beginning in 2018, some of the carrier's fourth-generation F/A-18s will be replaced by fifth-generation F-35Cs.

3. Carrier presence in the Asia Pacific is occasionally "gapped" for maintenance, budgetary, or operational reasons, leaving the region without a carrier. See, for example, Kristina Wong, "Navy shuffles up aircraft carrier fleet," TheHill.com, August 12, 2015, http://thehill.com/policy/defense/250938-navy-begins-swap-of-three-aircraft-carriers.

4. The following discussion is intended to be representative of the types of threats the carrier air wing will face, rather than an exhaustive catalog of Chinese weapon systems.

5. For more on the history of the carrier air wing, see Jerry Hendrix, "Retreat From Range: The Rise and Fall of Carrier Aviation" (Center for a New American Security, October 2015).

6. Ibid.

7. Ibid.

8. Catherine Putz, "Sold: Russian S-400 Missile Defense Systems to China," *The Diplomat* (April 14, 2015), http://thediplomat.com/2015/04/sold-russian-s-400-missile-defense-systems-to-china/; and Office of the Secretary of Defense, *Annual Report to Congress: Military and Security Developments Involving the People's Republic of China 2015*, D-117FA69 (April 7, 2015).

9. Michael Stephens and Justin Bronk, "Why the Iranian Purchase of the S-300 Should Worry the Gulf States," *RUSI Defence Systems* (May 1, 2015), https://rusi.org/publication/rusi-defence-systems/why-iranian-purchase-s-300-should-worry-gulf-states. While some observers suggest that the system may have modest abilities against stealth aircraft, this appears unlikely.

10. Open-source estimates of the single-shot hit probability of the HQ-9 are as high as .9 for aircraft and .3 for ballistic missiles. "HQ-9: Specifications," GlobalSecurity.org, http://www.globalsecurity.org/military/world/china/hq-9-specs.htm.

11. Putz, "Sold: Russian S-400 Missile Defense Systems to China."

12. International Institute for Strategic Studies, *The Military Balance 2014: The Annual Assessment of Global Military Capabilities and Defence Economics* (London: Routledge, 2014); and "YJ-83/C-803," GlobalSecurity.org, http://www.globalsecurity.org/military/world/china/c-803.htm.

13. Dennis M. Gormley, Andrew S. Erickson, and Jingdong Yuan, *A Low-Visibility Force Multiplier: Assessing China's Cruise Missile Ambitions* (Washington: National Defense University Press, 2014), 16.

14. Robert Haddick, "China's Most Dangerous Missile (So Far)," WarOnTheRocks.com, July 2, 2014, http://warontherocks.com/2014/07/chinas-most-dangerous-missile-so-far/.

15. Bernard D. Cole, "The modernization of the PLAN and Taiwan's Security," in *Taiwan's Maritime Security*, eds. Martin Edmonds and Michael M. Tsai (New York: RoutledgeCurzon, 2003), 56; Dylan B. Ross and Jimmy A. Harmon, *New Navy Fighting Machine in the South China Sea* (Monterey, CA: Naval Postgraduate School, June 2012), 12; and "Moskit SS-N-22 Sunburn," GlobalSecurity.org, http://www.globalsecurity.org/military/world/russia/moskit.htm.

16. Gormley et al., *A Low-Visibility Force Multiplier*.

17. Ibid.

18. Ross and Harmon, *New Navy Fighting Machine in the South China Sea*; and Gormley et al., *A Low-Visibility Force Multiplier*, 50.

19. Gormley et al., *A Low-Visibility Force Multiplier*.

20. Ibid.

21. China operates approximately 240 J-10A/S jets. Ibid.

22. U.S. Department of Defense, "Selected Acquisition Report (SAR): F-35 Joint Strike Fighter Aircraft (F-35) As of FY 2015 President's Budget," http://breakingdefense.com/wp-content/uploads/sites/3/2014/04/F-35-2013-SAR.pdf.

23. U.S. Department of Defense, "Selected Acquisition Report (SAR): F/A-18E/F Super Hornet Aircraft (F/A-18E/F) As of December 31, 2012," http://www.globalsecurity.org/military//library/budget/fy2012/sar/f-a-18e-f_december_2012_sar.pdf. It should be noted that the U.S. Navy is developing standoff weapons – such as the JSOW C-1, which features a range of 70 nm – that will effectively extend these platforms' ability to target adversary surface assets. The JSOW C-1 is expected to achieve initial operational capability in 2016. "Joint Standoff Weapon (JSOW)," Naval Air Systems Command, http://www.navair.navy.mil/index.cfm?fuseaction=home.displayPlatform&key=9097785F-B258-46B6-8474-20A48B820898.

24. While the range of the Soar Dragon is unknown, it is similar in size and weight to Northrop Grumman's RQ-4 Global Hawk. The Block 10 Global Hawk has a listed range of 12,000 nm. Bill

Sweetman, "New Chinese UAVs Could Support Anti-Carrier Missile," *Aviation Week & Space Technology* (September 28, 2015); and "RQ-4 Global Hawk Fact Sheet," NorthropGrumman.com, May 2008, http://www.northropgrumman.com/Capabilities/RQ4Block20GlobalHawk/Documents/HALE_Factsheet.pdf.

25. Asia Maritime Transparency Initiative, Center for Strategic and International Studies, http://amti.csis.org/island-tracker/; and Derek Watkins, "What China Has Been Building in the South China Sea," *The New York Times*, October 27, 2015, http://www.nytimes.com/interactive/2015/07/30/world/asia/what-china-has-been-building-in-the-south-china-sea.html?_r=0.

26. Wendell Minnick, "China Expands Presence With Fighters on Woody Island," *Defense News*, November 8, 2015, http://www.defensenews.com/story/defense/air-space/strike/2015/11/08/china-expands-presence-fighters-woody-island/75147522/; Christopher Bodeen, "New China airstrips a potential headache for neighbors, US," The Associated Press, December 6, 2015, http://bigstory.ap.org/article/8188c920b826442cb5b4dcd7543be43b/new-china-airstrips-potential-headache-neighbors-us; and Michael Forsythe, "China Deployed Missiles on Disputed Island, U.S. Says," *New York Times*, February 16, 2016, http://www.nytimes.com/2016/02/17/world/asia/china-is-arming-south-china-sea-island-us-says.html?ref=world&_r=0.

27. Gormley et al., *A Low-Visibility Force Multiplier*; and Richard D. Fisher Jr., "PLAAF Equipment Trends" (International Assessment and Strategy Center, October 30, 2001), http://www.strategycenter.net/research/pubID.8/pub_detail.asp.

28. "Chinese Stealth Fighter J-X / J-XX / XXJ (Jianjiji - Fighter aircraft)," GlobalSecurity.org, http://www.globalsecurity.org/military/world/china/j-xx.htm.

29. This distance assumes the pairing of fifth-generation fighters with the YJ-12 ASCM, which features a range of approximately 215 nm. Haddick, "China's Most Dangerous Missile (So Far)."

30. David Cenciotti, "No match for a U.S. Hornet: 'China's Navy J-15 more a flopping fish than a flying shark' Chinese media say," TheAviationist.com, September 30, 2013, http://theaviationist.com/2013/09/30/j-15-critics/.

31. While ASBMs could pose a threat to the carrier at lesser ranges, China's deep inventory of ASCMs – and comparatively limited inventory of ASBMs – as well as the lesser cost of ASCMs suggest that the country would hold its ASBMs in reserve for use at greater distances, at which it has fewer strike options. Gormley et al., *A Low-Visibility Force Multiplier*, 1.

32. "WU-14 Dong Feng-21D (DF–21D)/CSS-5 Mod 5: Anti-Ship Ballistic Missile (ASBM)," GlobalSecurity.org, http://www.globalsecurity.org/wmd/world/china/df-21d.htm; and Robert Haddick, "Stopping Mobile Missiles: Top Picks For Offset Strategy," BreakingDefense.com, January 23, 2015, http://breakingdefense.com/2015/01/stopping-mobile-missiles-top-picks-for-offset-strategy/.

33. A successful strike would thus achieve a "mission kill" against an aircraft carrier. Ross and Harmon, *New Navy Fighting Machine in the South China Sea*.

34. Circular error probable is a measure of accuracy, denoting the radial distance at which 50 percent of a given weapon system can be expected to fall. In this instance, 50 percent of launched DF-21Ds can be expected to fall within 20 meters of their aim point. For context, the dimensions of the flight deck of a Ford-class aircraft carrier are 78 meters x 332.8 meters. "Aircraft carriers – CVN," Navy.mil, http://www.navy.mil/navydata/fact_display.asp?cid=4200&tid=200&ct=4.

35. Office of the Secretary of Defense, *Annual Report to Congress: Military and Security Developments Involving the People's Republic of China 2015*; Andrew S. Erickson, *Chinese Anti-Ship Ballistic Missile (ASBM) Development: Drivers, Trajectories, and Strategic Implications* (Washington: Jamestown Foundation, 2013); and Ross and Harmon, *New Navy Fighting Machine in the South China Sea*.

36. Andrew S. Erickson, "Showtime: China Reveals Two 'Carrier-Killer' Missiles," *The National Interest* (September 3, 2015), http://nationalinterest.org/feature/showtime-china-reveals-two-carrier-killer-missiles-13769.

37. Richard D. Fisher Jr., "DF-26 IRBM may have ASM variant, China reveals at 3 September parade," Janes.com, September 2, 2015, http://www.janes.com/article/53994/df-26-irbm-may-have-asm-variant-china-reveals-at-3-september-parade.

38. For a more detailed discussion of targeting accuracy and the corresponding number of ASBMs needed to achieve a mission kill against a surface ship, see Eric Heginbotham et al., *The U.S.-China Military Scorecard: Forces, Geography, and the Evolving Balance of Power, 1996–2017* (Santa Monica, CA: RAND Corporation, 2015), 168.

39. Erickson, *Chinese Anti-Ship Ballistic Missile (ASBM) Development*; and Heginbotham et al., *The U.S.-China Military Scorecard*.

40. China's fleet of approximately 20 H-6K bombers could deliver anti-ship cruise missiles at distances of around 2,100 nm, although this would require the bombers to fly beyond the range of their fighter escorts. As an alternative, China's nine nuclear submarines could deliver ASCMs at unconstrained ranges.

41. Ross and Harmon, *New Navy Fighting Machine in the South China Sea*, 31; and Haddick, "China's Most Dangerous Missile (So Far)."

42. As Deputy Secretary of Defense Robert O. Work has noted, nonkinetic options are preferable to current kinetic strike, given the high cost of missile interceptors and the large number of

interceptors that would be needed to neutralize a mass attack on U.S. forces. Sydney J. Freedberg Jr., "Cyber, EW Are Secret Missile Defense Weapons Too Secret To Use," BreakingDefense.com, December 4, 2015, http://breakingdefense.com/2015/12/cyber-ew-are-secret-missile-defense-weapons-too-secret-to-use/.

43. Passive avoidance entails operating surface assets in such a way as to increase the difficulty of detection or tracking by an adversary (e.g., "avoid[ing] impending satellite passes by maximizing speeds with east-west headings.") Heginbotham et al., *The U.S.-China Military Scorecard*, 164.

44. Heginbotham et al., *The U.S.-China Military Scorecard*, 164-165; and Freedberg , "Cyber, EW Are Secret Missile Defense Weapons Too Secret To Use."

45. Heginbotham et al., *The U.S.-China Military Scorecard*, 164-165.

46. Ronald O'Rourke, "Navy Lasers, Railgun, and Hypervelocity Projectile: Background and Issues for Congress," R44175 (Congressional Research Service, November 6, 2015), https://www.fas.org/sgp/crs/weapons/R44175.pdf.

47. Estimates suggest that railguns would cost $25,000 per shot. In contrast, the SM-3 Block IB missile interceptor carried by USS Arleigh Burke-class guided missile destroyers has an estimated procurement cost of approximately $10 million. Ronald O'Rourke, "Navy Lasers, Railgun, and Hypervelocity Projectile"; and Ronald O'Rourke, "Navy Aegis Ballistic Missile Defense (BMD) Program: Background and Issues for Congress," RL33745 (Congressional Research Service, December 11, 2015), https://www.fas.org/sgp/crs/weapons/RL33745.pdf.

48. The unit cost of the Ford-class carrier – excluding air assets – is expected to be approximately $12.1 billion in 2015 dollars. Government Accountability Office, Defense Acquisitions: Assessments of Selected Weapons Programs (March 2015), http://www.gao.gov/assets/670/668986.pdf#page=113.

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

50. For an in-depth discussion of the potential options for increasing the range of the carrier air wing, see Hendrix, "Retreat from Range."

51. There has been significant, ongoing disagreement over the requirements for an unmanned carrier-based system, which recently shifted in emphasis from ISR to aerial refueling. For a history of the changes to the system's requirements, see Jeremiah Gertler, "History of the Navy UCLASS Program Requirements: In Brief," R44131 (Congressional Research Service, August 3, 2015), https://www.fas.org/sgp/crs/weapons/R44131.pdf; and Sam LaGrone, "Pentagon to Navy: Convert UCLASS Program Into Unmanned Aerial Tanker, Accelerate F-35 Development, Buy More Super Hornets," USNI News, February 1, 2016, http://news.usni.org/2016/02/01/pentagon-to-navy-convert-uclass-program-into-unmanned-aerial-tanker-accelerate-f-35-development-buy-more-super-hornets.

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