

Correspondence

How Good Are China's Antiaccess/ Area-Denial Capabilities?

Andrew S. Erickson

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To the Editors (Andrew S. Erickson writes):

I commend Stephen Biddle and Ivan Oelrich for elucidating a vital topic: China's antiaccess/area-denial (A2/AD) development and potential U.S. responses.¹ Biddle and Oelrich document China's growing ability to threaten Taiwan with a blockade; the high cost and risks of any U.S. planning predicated on finding and kinetically striking mobile mainland targets; and the value in the United States, Taiwan, and regional allies enhancing their own countermeasures. Geography, technology, and physics matter—and interact powerfully, requiring sober consideration. However, mistaken assumptions and oversimplifications in describing these interactions risk underestimating how far China could extend credible combat power offshore. Emerging anti-ship ballistic missile (ASBM) capabilities aside, China's current sea- and air-launched anti-ship cruise missile (ASCM) capability already exceeds the seaward limits asserted by Biddle and Oelrich. Thus, contrary to their article's optimistic projections, the United States and its regional allies already face a more challenging and uncertain military situation.

Part of the problem is conceptual: Biddle and Oelrich conflate A2/AD with outright military control, when it is actually a more easily operationalized concept of sowing doubt through growing risk of denial. Most fundamentally, in categorically dismissing the possibility of China achieving A2/AD beyond 400–600 kilometers seaward by 2040, they not only ignore capabilities that China has already achieved—or is close to achieving, per its Near Seas Active Defense strategy—but, worse, dismiss nearly two and a half decades of potential future Chinese improvement, powered by what is already the world's second-largest economy and defense budget. Few analysts in 1992 imagined

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1. Stephen Biddle and Ivan Oelrich, "Future Warfare in the Western Pacific: Chinese Antiaccess/Area Denial, U.S. AirSea Battle, and Command of the Commons in East Asia," *International Security*, Vol. 41, No. 1 (Summer 2016), pp. 7–48. Further references to this article appear parenthetically in the text.

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how serious Chinese capabilities could become by 2017; Biddle and Oelrich provide little rationale or evidence that their straight-line projection will hold nearly a quarter-century hence.

Biddle and Oelrich also make more specific errors. Based on limitations they ascribe to targeting radars, they underestimate the distance from shore to which China can target missiles. Over-the-horizon (OTH) radar is not as restricted in detection range and accuracy as they suggest. The Russian Mineral-ME targeting system, or its Chinese counterpart, is fitted to the vast majority of China's major surface combatants. Mineral-ME is a fourth-generation tactical OTH system that reportedly offers up to 250 kilometers active range and 450 kilometers passive range, allowing effective ASCM targeting with multi-ship triangulation, even absent other targeting data.² Chinese warships, increasingly armed with anti-surface and anti-air defenses, are hardly restricted to operating only 400–600 kilometers from shore. These dedicated targeting systems are designed to exploit the significant electromagnetic signatures of U.S. naval vessels: consider the tremendous energy transmitted by high-powered air-search radars such as the U.S. AN/SPS-49(V) or AN/SPY-1 series, the latter absolutely critical for air-space surveillance and long-range surface-to-air missile guidance. OTH radar need only provide locating information sufficiently accurate for one or more ASCMs' seeker(s) to effectively search a target's area of uncertainty.

Moreover, if China cannot target beyond 600 kilometers now or in the near future, one must question why it has developed both the 1,500-kilometer DF-21D (deployed since 2010) and the 3,000-kilometer DF-26 (close to deployment) ASBMs. These long ranges strongly suggest that China has some confidence that it will be able to develop suitable targeting methods. Moreover, Chinese ASBMs likely have multiple seekers—both active and passive—and sufficient maneuverability to hit a target within a terminal seeker's effective area. Properly designed ballistic missiles can be quite maneuverable.³

Continentalism compounds this oversight. Biddle and Oelrich apparently assume that China could fire ASCMs against U.S. warships only from its mainland. Yet China has rapidly deployed medium-to-long-range ASCMs on surface ships, submarines, aircraft, and South China Sea features well capable of covering the area within the First Island Chain with targeting radars and weapons. Furthermore, China is on the cusp of fielding its next generation of long-range (out to 300 kilometers) supersonic ASCMs on its newest classes of warships, submarines, and aircraft. The First Island Chain is precisely where U.S. naval forces, lacking long-range strike aircraft and limited in Tomahawk loadout, would have to enter in numerous contingencies. Even within the narrow land-based radar capabilities Biddle and Oelrich posit, these platforms' mobility can credibly challenge opposing forces with the prospect of accurately delivering lethal firepower well beyond 600 kilometers from China's shores.

Regarding submarines, Biddle and Oelrich may overestimate the effectiveness of U.S. anti-submarine warfare through 2040. Long backward in this area, China is striv-

2. "The Multifunctional Target Designation Radar Complex 'Mineral Me'" (Kyiv: SpetsTechnoExport, Ukraine State Foreign Trade Enterprise, n.d.), <http://spetstechnoexport.com/catalogues/9>.

3. Tony Lin, "Development of U.S. Air Force Intercontinental Ballistic Missile Weapon Systems," *Journal of Spacecraft and Rockets*, Vol. 40, No. 4 (July/August 2003), p. 507.

ing to reduce its undersea vulnerabilities. Its nuclear-powered submarines remain noisy, but its newer conventional submarines are already very quiet, and the Type 039A/B class benefits from air-independent power. Once these platforms are fitted with the YJ-18 ASCM, they will have the ability to pose a significant challenge well beyond 400 kilometers from China's coast. Currently undergoing at-sea testing, the YJ-18 can be expected to join China's fleet within a few years at most.

In addition, Biddle and Oelrich are strangely sanguine regarding U.S. prospects for maintaining airfield access and sorties within range of the conflicts they posit. This optimism contradicts analysis by manifold academic and government-related organizations and think tanks, most recently a leading RAND Corporation study.⁴ It is also puzzling in light of their assertion that "long-range, high-speed, guided [surface-to-surface missiles] . . . will eventually achieve true intercontinental range from mobile launchers beyond the reach of effective preemption" (p. 43).

Finally, Biddle and Oelrich overestimate the willingness of China and the United States to destroy each other's space systems. The disparity of interests in conceivable Taiwan, East China Sea, and South China Sea scenarios and the U.S. Department of Defense's near-total dependence on space systems weigh heavily against the United States willingly trading them away. Even if such an exchange occurred, China retains the advantages of proximity, with much shorter communications lines and an extensive redundant network. It would still be able to employ its land, ship, and airborne systems. Beijing might thus not be deterred by the threat of retaliation in space; in a worst-case scenario, restricting access thereto could in fact advantage China. Fear of retaliation is thus unlikely to sustain deterrence (or strategic stability) in such circumstances. Biddle and Oelrich also underestimate the rate of debris proliferation. Finally, they discuss military low-earth-orbit satellites specifically, but by 2040 China could well have manifold means to target medium-earth-orbit and geosynchronous satellites, with serious implications for nuclear early warning, intelligence collection, and command and control.

A truly comprehensive net assessment requires considering all elements of a complex, multivariate force-on-force campaign. This includes information currently unavailable from open sources. While scholarship and public debate demand unclassified analysis, researchers should acknowledge its limitations explicitly. Making sweeping projections beyond two decades is fundamentally problematic to begin with, and intentionally limiting one's view only compounds matters. In their commendable effort to provide useful insights, Biddle and Oelrich imply an authority of findings that their methodology and evidence cannot substantiate, and they make questionable assumptions that further undermine some of their core conclusions. The result: a useful opening salvo in a debate that remains far from complete.

—Andrew S. Erickson
Newport, Rhode Island

4. Eric Heginbotham et al., *The U.S.-China Military Scorecard: Forces, Geography, and the Evolving Balance of Power, 1996–2017* (Santa Monica, Calif.: RAND Corporation, 2015), http://www.rand.org/content/dam/rand/pubs/research_reports/RR300/RR392/RAND_RR392.pdf.

To the Editors (Evan Braden Montgomery writes):

In "Future Warfare in the Western Pacific," Stephen Biddle and Ivan Oelrich offer an unusual take on China's antiaccess/area-denial (A2/AD) capabilities, which many analysts consider a significant security challenge for the United States and its frontline allies.¹ On the one hand, Biddle and Oelrich note that China is developing the means to launch a debilitating conventional assault on U.S. military assets and infrastructure across the region. On the other hand, they see little cause for concern and no need for major changes in U.S. operational concepts or force structure (pp. 12–13, 29). How do they reconcile these conclusions? Ultimately, Biddle and Oelrich consider only scenarios in which China never actually attacks the United States. In other words, they assume that it would not take advantage of the very weaknesses that its A2/AD capabilities are designed to exploit, such as the concentration of U.S. combat power in a handful of theater airbases that are hard to defend given their fixed positions and aircraft carriers that are difficult to hide given their high signatures.

The crux of Biddle and Oelrich's analysis is a simple but important assertion: that China's optimal strategy in a conflict with U.S. allies is an "A2/AD blockade." This would entail the use of ground-launched anti-ship missiles against commercial vessels to isolate opponents from the global economy (pp. 16–18). To date, most assessments of China's A2/AD capabilities have emphasized the danger they pose to military targets, including U.S. military targets. Yet Biddle and Oelrich do not see this as a serious concern. In their view, attacks against U.S. armed forces "are means, not ends," and could not make local nations concede (p. 15). Threats to military targets should not be dismissed so easily, however, for several reasons.

First, successful attacks on U.S. forces and facilities would almost certainly influence the political calculations of allied nations, irrespective of the issues at stake. The United States is the principal security provider for these nations; therefore, any losses it suffered would only heighten their own vulnerability. That, in turn, could influence whether allies choose to stand firm or stand down. Second, because control of the air enables maneuver in other domains, attacks against military targets such as airbases and aircraft carriers would be a critical enabler for other lines of effort, to include seizing disputed territory and even blockading a rival. For example, the authors dismiss the value of Chinese submarines as commerce raiders because concentrating near ports would put them at risk from airborne anti-submarine warfare assets (p. 31). These undersea platforms would be much more survivable if opposing air and sea bases were degraded, however, giving China another means of interdiction and increasing the like-

1. Stephen Biddle and Ivan Oelrich, "Future Warfare in the Western Pacific: Chinese Antiaccess/Area Denial, U.S. AirSea Battle, and Command of the Commons in East Asia," *International Security*, Vol. 41, No. 1 (Summer 2016), pp. 7–48. Additional references to this article appear parenthetically in the text. On the potential dangers of China's A2/AD capabilities, see Evan Braden Montgomery, "Contested Primacy in the Western Pacific: China's Rise and the Future of U.S. Power Projection," *International Security*, Vol. 38, No. 4 (Spring 2014), pp. 115–149; Eric Heginbotham et al., *The U.S.-China Military Scorecard: Forces, Geography, and the Evolving Balance of Power, 1996–2017* (Santa Monica, Calif.: RAND Corporation, 2015), http://www.rand.org/content/dam/rand/pubs/research_reports/RR300/RAND_RR392.pdf; and Office of the Secretary of Defense, *Annual Report to Congress: Military and Security Developments Involving the People's Republic of China, 2016* (Washington, D.C.: U.S. Department of Defense, 2016).

likelihood that an economic warfare campaign might succeed. Third, Biddle and Oelrich suggest that imposing economic pain alone is more effective than alternate forms of coercion. This is a puzzling claim. As they note, the bombardment of civilian targets is unlikely to work for China given this strategy's poor historical track record (p. 16). But civilian bombardment and maritime blockade rely on the same underlying mechanism: collective punishment. And if history suggests that populations can endure massive air campaigns, it stands to reason they could tolerate slow economic strangulation.

While an exclusive focus on standoff attacks against civilian shipping is difficult to justify on strategic or operational grounds, it also leads Biddle and Oelrich to overestimate the likely demands of A2/AD operations and underestimate the potential scope of China's military power. Perhaps their most significant empirical finding is that the "effective reach" of land-based A2/AD systems will not extend more than 400–600 kilometers beyond the Chinese coastline, which would put Taiwan at great risk but would leave other U.S. allies mostly out of range (pp. 13–14, 28, quote at p. 33). Yet this ostensible upper bound applies only under extremely narrow conditions. To execute its A2/AD blockade, China would need to continuously monitor wide areas, track a huge number of mobile targets in a cluttered environment, and maintain this intelligence, surveillance, and reconnaissance (ISR) posture over a long period of time. Further complicating matters, Biddle and Oelrich assume that China would lose all access to space-based imagery and have no viable alternatives except large airborne radars. Consequently, they predict that it would operate high-value ISR assets only behind a protective umbrella of land-based surface-to-air missiles, which would severely limit their field of view (pp. 22–30). It is important to note, however, that distant fixed targets would still be at risk in these circumstances. Moreover, many naval forces could be as well, even without access to space. If China had military rather than civilian ships in its crosshairs, its surveillance requirements might be less demanding, its force employment concepts less conservative, and its military reach much greater. Simply put, opposing aircraft carriers, surface combatants, and support vessels would make up a far smaller and more valuable set of targets than commercial ships. That could encourage China to push its ISR assets forward despite the risks to their safety, for instance by conducting reconnaissance raids with airborne sensors and defensive escorts that receive queuing from ground-based early-warning systems.

In the end, "Future Warfare in the Western Pacific" is an important contribution to a pressing debate. Nevertheless, by dismissing contingencies in which the United States is directly threatened and depending on the forbearance of an emerging competitor, it is also a problematic guide to regional security challenges and a risky foundation for U.S. defense policy.

—*Evan Braden Montgomery*
Washington, D.C.

To the Editors (Craig Neuman writes):

In "Future Warfare in the Western Pacific," Stephen Biddle and Ivan Oelrich argue that the physics of radar and properties of the land, sea, and air will produce a defense-dominant region, though one where Taiwan remains susceptible to Chinese blockade.¹ Given the vulnerability of satellites, Biddle and Oelrich postulate that U.S. and Chinese surveillance aircraft will fly up to 20 kilometers high, using their radars to extend antiaccess/area-denial zones 400–600 kilometers from the shores of U.S. allies and China (p. 24). Enemy missiles will destroy fixed air bases, so these aircraft must survive and operate from "austere airfields or even long stretches of highway" (p. 33). I argue that these assumptions overlook four key limitations and that these factors make Biddle and Oelrich's blockade scenario ineffective.

First, Biddle and Oelrich cite precedence for smaller aircraft (up to a C-130) landing on highways, but many dedicated surveillance platforms (e.g., the E-3 AWACS or E-8 JSTARS) are modified commercial airliners that are too heavy to continuously operate on normal highway concrete. The Chinese Ministry of Defense recognizes that "not any section of the highway is suitable for the aircraft to land . . . [and] the regular highway has risks of collapse."² Interestingly, the Chinese fret over damage to highways from a Su-27 (with a maximum takeoff weight of 66,000 pounds), let alone aircraft such as the E-3 (347,000 pounds) or the KC-10 aerial refueler (590,000 pounds).³

Second, efforts to prepare highway sections for heavy use run the risk of pre-crisis discovery by foreign intelligence, particularly satellites searching for the distinctive patterns and signatures of runways and support facilities.⁴ These highway sections would then be destroyed alongside traditional airfields.

Third, aircraft designed to endure at high altitudes require specialized airframes (with low weight and long, slender wings), which make these aircraft poor candidates for austere airfield operations. Aircraft such as the U-2 are notoriously difficult to land even on normal runways,⁵ and they are unlikely to lift the weight of large surveillance systems. For example, the U-2 and Global Hawk can carry only 5,000 and 3,000 pounds, respectively; the E-8's payload is probably around 20,000 pounds.⁶ High-altitude en-

1. Stephen Biddle and Ivan Oelrich, "Future Warfare in the Western Pacific: Chinese Antiaccess/Area Denial, U.S. AirSea Battle, and Command of the Commons in East Asia," *International Security*, Vol. 41, No. 1 (Summer 2016), pp. 7–48. Subsequent references to this article appear parenthetically in the text.

2. Ministry of National Defense, People's Republic of China, "Backgrounder: Difference between Regular Highway and Highway Runway for Airplanes" (Beijing: Ministry of National Defense, May 27, 2014), http://eng.mod.gov.cn/DefenseNews/2014-05/27/content_4512191.htm.

3. These weight problems also affect high-altitude bombers. Unless otherwise noted, weights and performance characteristics come from publicly available fact sheets.

4. See, for example, Ugur Zongur et al., "Airport Runway Detection in Satellite Images by Adaboost Learning," *Proceedings of SPIE—The International Society for Optical Engineering*, Vol. 7477 (September 2009), https://www.researchgate.net/profile/Ilkay_Ulusoy/publication/228358459_Airport_runway_detection_in_satellite_images_by_Adaboost_Learning/links/0912f50ae9c2c8e90e000000.pdf?origin=publication_list.

5. A car races behind the U-2, radioing updates to assist the pilot in descending the last several feet onto the runway. The U-2's wingtips also dip to the ground, so the aircraft uses removable wheels for support during taxi and wingtip skids for the landing itself.

6. The empty weight difference between the E-8 and a basic 707 is around 22,000 pounds.

gines are also smaller and produce less power,⁷ which is a significant problem given that required transmitter power increases to the fourth power with distance.

Fourth, aircraft that could operate from surviving highways or austere airfields would fail to reach the altitudes that Biddle and Oelrich assume. The E-2D (lighter than a C-130) has a service ceiling of 11 kilometers. China's KJ-2000 is based on an Il-76, which is designed to accommodate unimproved airstrips, but has a maximum altitude of 12 kilometers.⁸

These limitations directly affect China's ability to blockade Taiwan. A 12-kilometer maximum altitude limits China's A2/AD zone to 390 kilometers,⁹ and allows Taiwan's Chungyang mountains to "terrain mask" shipping approaches from the east and southeast.¹⁰ In southeast Taiwan, these mountains rise approximately 2.5 kilometers above sea level and sit 310 kilometers from the closest point on mainland China. For Chinese aircraft flying at this distance, these mountains cast a radar "shadow" 81 kilometers beyond them, shielding surface ships to the edge of the radar's horizon (390 kilometers). Chinese aircraft flying further south would look over lower mountains, but the increased distance to these obstacles results in a similar radar blind spot.

Biddle and Oelrich provide a compelling account of the future of antiaccess/area denial in the Pacific, but the above limitations would prevent China from seeing and targeting the ships necessary to sustain a blockade. Aircraft optimized to endure at high altitudes would not be able to operate from austere airfields, while aircraft that can would fail to reach the altitudes that Biddle and Oelrich assume. Chinese radars will surely close the airspace over the island, but their efforts to implement a blockade would likely fail.

—Craig Neuman
Hurlburt Field, Florida

7. The generator on the Global Hawk's single AE 3007 engine produces 25 kilovolt amps of power, whereas each of the E-2D's engines produce 170 kilovolt amps. Bill Kinzig, *Global Hawk Systems Engineering Case Study* (Wright-Patterson Air Force Base, Ohio: Air Force Center for Systems Engineering, 2010). See also Stephen Trimble, "Cutaway Technical Description: E-2D May Not Look Pretty, But Packs Big New Bunch," *FlightGlobal.com*, July 30, 2010, <https://www.flightglobal.com/news/articles/cutaway-technical-description-e-2d-may-not-look-pretty-but-packs-big-new-344539/>.

8. Some fighter aircraft reach altitudes around 15 kilometers, but their radars (designed to fit in the aircraft's nose) lack the range, versatility, and search azimuth of dedicated surveillance radars. The radar for the Su-30MK2 reportedly detects an aircraft carrier at 350 kilometers, but this range rapidly decreases with ship size (it detects a destroyer at 250 kilometers) and probably sea state. A flotilla of smaller ships southeast of Taiwan (more than 330 kilometers from the mainland) will likely remain undetected for the foreseeable future. Tikhomirov Scientific Research Institute of Instrument Design, "Su-30 Weapons Control System SUV-VEP 'Sword' Series of Fighter Su-27" (Zhukovsky, Russia: Tikhomirov Scientific Research Institute of Instrument Design, n.d.), http://www.niip.ru/index.php?option=com_content&view=article&id=13:-l-r-l-r-lr&catid=8:2011-07-06-06-33-26&Itemid=8. Furthermore, the lack of aerial refuelers would require a large number of constantly rotating fighters (that survived the initial attack) to coordinate continuous coverage from a considerable number of small and widely dispersed austere airstrips—all while their communications are under attack.

9. Aircraft typically operate below their service ceiling during operations and maneuvering (reportedly 7.6 kilometers for the E-2D); therefore 12 kilometers is a conservative assumption. Trimble, "Cutaway Technical Description."

10. As Biddle and Oelrich note, Chinese aircraft could fly closer beyond the shoreline, but Taiwan could respond with land-based radar jammers drawing on large, powerful generators. Further-

Stephen Biddle and Ivan Oelrich Reply:

We welcome the opportunity to respond to Evan Braden Montgomery's, Andrew Erickson's, and Craig Neuman's comments on "Future Warfare in the Western Pacific."¹ Montgomery and Erickson argue that we underestimate China's future capabilities; Neuman claims that we overestimate them. In fact, we get them about right. To explain why, we address each critique in turn.

ON MONTGOMERY

Much of Montgomery's letter chides us for ignoring things that we actually discuss, often in considerable length. He opens with the claim that we ignore the prospect that China would attack U.S. forces. Yet, most of the article comprises an extended analysis of two-sided military interactions between U.S. and Chinese forces, in which each attacks the other. Whereas Montgomery asserts that "Biddle and Oelrich consider only scenarios in which China never actually attacks the United States," nothing in our article addresses such a scenario, which would be, well, a curious expectation for a major war between China and the United States. A little later, he implies that we ignore the issue of U.S. airbase vulnerability, yet we discuss this explicitly on page 29. Perhaps he disagrees with our assessment, but as he gives no reason why, it is difficult to respond beyond the basic point that we do not actually ignore this.

Much of the rest of Montgomery's critique is an elaboration on logical problems that would arise if one ignored the possibility that China might attack U.S. forces. As we did not ignore this possibility, much of this discussion is moot. Parts of it, however, are worth further comment.

In particular, whereas Montgomery sees strategic bombing and blockade as analytically indistinguishable because they are both coercive, we see important differences due to their different escalatory potential and collateral damage prognosis, as we argue in detail on pages 16–19. None of this means that blockade will always succeed, but its features make it a stronger option for China and hence worthy of special attention.

Curiously, given Montgomery's primary concern that we underestimate the Chinese threat, he claims that we overestimate China's antiaccess/area-denial (A2AD) blockade threat because this requires China to master a variety of complex tasks. We agree that this mission is complex, and we argue that further analysis is warranted to shed more light on China's likely capacity to master military complexity by 2040 (pp. 43, 47–48). But if China cannot master this, the natural implication would be a more benign assessment of the Chinese threat, not its opposite—our findings are robust to this assumption.

more, western Taiwan rests well inside China's A2/AD sphere. Taiwanese missiles would have a shorter flight time to Chinese aircraft than missiles fired from outside the A2/AD bubble. This reduces the reaction time of Chinese defensive missile interceptors, drawing the surveillance aircraft back inland. See Biddle and Oelrich's appendix at <http://dx.doi.org/10.7910/DVN/GK6PR2>. For simplicity, I assume that there is no jamming and that Chinese aircraft remain at the shoreline.

1. Stephen Biddle and Ivan Oelrich, "Future Warfare in the Western Pacific: Chinese Antiaccess/Area Denial, U.S. AirSea Battle, and Command of the Commons in East Asia," *International Security*, Vol. 41, No. 1 (Summer 2016), pp. 7–48. Subsequent references to this article appear parenthetically in the text.

Montgomery notes that fixed targets would be vulnerable even if China cannot master a blockade. We agree, of course, as we argue, at some length, on pages 20–22 and 43 and highlight in our findings. The vulnerability of fixed targets hardly contradicts our argument.

After hypothesizing that China might not be skilled enough to master blockade, Montgomery hypothesizes that it might be skilled enough—and risk acceptant enough—to sally intelligence, surveillance, and reconnaissance (ISR) assets forward “despite the risk to their safety” to hunt U.S. warships at ranges beyond those we consider viable. As we point out on page 29, forward-deployed U.S. warships or aircraft caught within reach of a Chinese preemptive attack at the outset of a war can be destroyed, but those withheld in a mobile posture beyond this range are far less vulnerable. Sallies of the kind Montgomery considers could be made arbitrarily expensive simply by moving naval combatants further away until China has sacrificed its ISR capability in fruitless raids flown into the teeth of the opposite, U.S., mobile land-based A2/AD system. In a two-sided, mutually adaptive, long-run contest between economic peers, as our article posits, it is far from clear that this approach would be the best use of China’s capabilities.

ON ERICKSON

Erickson is at once a pessimist and an optimist on the utility of long-term projections. He does not believe one can support our 2040 projection given the future’s uncertainty, but he does believe one should support his own, more pessimistic, projection because he sees current Chinese capability as already superior to what we expect for 2040. We disagree on both counts.

As for the latter, in a two-sided competition between adaptive peers such as China and the United States, all current capabilities, on both sides, are subject to countermeasures. There is no particular reason to assume that, say, a missile that can strike targets 1,500 kilometers away today will be able to do so in twenty years after its enemies have deployed systems to destroy the RSTA (reconnaissance, surveillance, and target acquisition) capabilities that the missile needs to find targets. In fact, we expect that both sides would target the other’s RSTA, given the enormous military incentive to do so and its clear technical feasibility. Nor does the mere fact that China deploys a weapon imply that it must be effective. Military history offers too many counter-examples for exhaustive enumeration (The Davy Crocket nuclear recoilless rifle round? The Model 1913 cavalry saber? The F-105 Thunderchief?). Suffice to say that assessment requires more than just an assumption that if China deploys a weapon then it must be a good idea. Either way, no snapshot of 2017 capabilities can logically sustain any particular expectation for 2040, and China can be denied any meaningful capability against mobile targets 1,500 kilometers away in 2040 whether or not it has this capability in 2017.

This is why we base our projection not on 2017 systems, or some linear, straight-line projection from these, but on the constraints of physics in interaction with the trajectories of trends that have been unfolding for decades. Erickson is uncomfortable with any long-term projection, but there is no real alternative when designing navies and aircraft with service lives that routinely exceed thirty years. The lead vessel of today’s first-line U.S. aircraft carrier class, the USS *Nimitz*, was launched in 1972 and will serve until at least 2025; today’s F-16 was first fielded in 1978, and variants will serve until 2025; B-52s are now older than most of their pilots. Analysts in the 1970s surely failed to fully

anticipate today's world when designing these systems, but that does not excuse a failure to try. Acquisition decisions have to be made, and some assessment of the future operating environment and its exigencies has to be provided lest these decisions be mere guesses in the dark. As we argue on pages 10–11, this makes long-run projection mandatory for such decisions—a focus on today when planning navies that may sail for another half a century is not sound analytical practice.

Part of the reason we emphasize underlying physics in such projections is our belief that physical laws are more stable than engineering particulars, and thus offer a more robust way to bound future capabilities. In particular, we see the physics of radio waves as a limiter on radar's ability to provide targeting information beyond the horizon.

Erickson disagrees, and offers the Russian Mineral-ME radar as evidence. There are several problems here, however. First, the source he cites (a sales brochure from the Russian manufacturer, whose advertised specifications have changed several times in recent weeks) now claims a normal active range of only 35 kilometers, or roughly the expected horizon for a surface-ship-based radar—this is not an over-the-horizon (OTH) capability.² Longer ranges require either super refraction, whose atmospheric prerequisites are unreliable, or passive collection, which can detect only ships actively broadcasting strong radar signals. Even so, neither option advertises more than a 450-kilometer maximum range, which is less than our 600-kilometer bound. Nor can passive collection detect targets at any range when the targeted radars cycle off (as they commonly do for security against such techniques). It cannot detect warships that rely on, say, airborne radar for surveillance while not turning on their own large shipboard radars. Nor can it detect the merchant ships that are the primary target of any blockade unless these ships operate large military surveillance radars, for purposes unknown. Mineral-ME is hardly a solution for extending Chinese A2/AD beyond the limit of 400 to 600 kilometers that we cite. Second, the physics of OTH radar make it unlikely that some future system will overcome Mineral-ME's shortcomings. Frequencies low enough for consistent refraction off the ionosphere (as OTH surveillance requires) have intrinsically poor resolution. An antenna small enough to fit on a ship (most OTH radars have antennas multiple kilometers long) and operating at an OTH range of, say, 800 kilometers would illuminate over 1,000 square kilometers of ocean surface. Even if searchers triangulate using multiple ships with time-of-arrival methods to compensate for poor resolution and Doppler filtering of the vast background clutter, the enormous illuminated area creates inherent vulnerability to mainbeam jamming—the weak signal-to-noise ratios created by the huge illumination spot make even low-power jammers sufficient, and the huge mainbeam offers enormous deployment areas wherein many jammers can be located without the radar's being able to resolve their location for counterattack. These problems are inherent in the physics of the frequency band required for OTH refraction—even if future engineers overcome all the problems of meteorological variability and other complications that prevent today's systems from serving as viable targeting devices, the physics of resolution at these frequencies will remain. This is why we see conventional, line-of-sight radar as the only viable long-

2. For one archived iteration, see "Mineral-Me" (Kyiv: SpetsTechnoExport, Ukraine State Foreign Trade Enterprise, n.d.), <https://web.archive.org/web/20170227184244/http://spetstechnoexport.com/catalogues/423>.

term solution—and this is what creates a limit in the neighborhood of 600 kilometers for feasible targeting. Neither Mineral-ME nor any plausible successor offers any escape from this limit.

Erickson sees several other “specific errors”; again, we disagree. He claims that we overlook the possibility that warships could venture further from the Chinese coast, extending A2/AD accordingly. Fundamental to our analysis, however, is the premise that both sides will pursue A2/AD in a dynamic competition—hence Chinese warships would have to sail into a U.S. A2/AD capability to accomplish this. We discuss the possibility (pp. 21 n. 30, 27), but reject it because such ships would be unable to survive once they leave the coverage of land-based mobile surface-to-air missiles (which enjoy the asymmetric survivability advantage of operation against a more complex background than either ships or aircraft can). Airborne radars operating within such missiles’ protection radius enjoy a much longer horizon than would surface ships, hence our emphasis on the former. (Nor would Chinese submarine quieting change this, as Erickson suggests. Our treatment of undersea warfare, on pages 30–32, is premised on the structural requirements of commerce raiding against escorted convoys where submarines must approach their quarries, not an assessment of future Chinese submarine design.)

Erickson finds us “strangely sanguine” about U.S. airbase access, apparently because we contradict a 2015 RAND study that looks out only to 2017. But, again, our analysis extends to 2040 and posits a two-sided competition between adaptive rivals wherein threats to runways will be an obvious challenge that both will strive to overcome. We discuss this on pages 29 and 33–34, reaching findings different than Erickson’s. As he does not engage our discussion beyond a reference to 2017 capabilities, we thus stand by our conclusions.

Erickson asserts that we overestimate both sides’ willingness to destroy space systems. The crux here is U.S. willingness to target Chinese satellites. We do not simply assume this. We present an extended argument finding potentially grave consequences if the United States allows sanctuary for Chinese satellites, and we argue that the United States should therefore seriously consider attacking them in wartime—even if China retaliates in kind (pp. 44–46). Erickson seems to expect mutual deterrence in space, but if the United States enjoys a net advantage in space-based communications and surveillance, as Erickson believes, then why would China grant Americans wartime sanctuary? We see two-sided space access as favoring China, because only this could enable its A2/AD to seriously threaten most U.S. allies in the region. But if we are wrong, this would undermine Erickson’s deterrence expectation, not reinforce it. (Erickson also claims that we underestimate debris from anti-satellite use, but we present a detailed supporting analysis on p. 7 of the online appendix that Erickson ignores; it is unclear what part of this, if any, he would challenge.)

ON NEUMAN

Whereas Montgomery and Erickson argue that we underestimate China, Neuman asserts we give China too much credit. We see Taiwan as vulnerable to a Chinese A2/AD blockade, but Neuman argues that the Chungyang mountains create a radar shadow shielding Taiwan-bound shipping from Chinese RSTA. Airborne radars can see over the mountains but require specialized runways that are vulnerable to preemp-

tive destruction, he argues, enabling the U.S. to ground such aircraft and blind the Chinese threat.

We agree that radar aircraft the size of today's E-3 AWACS or E-8 JSTARS are too large for survivable basing, but our assessment is for 2040, not today. The E-3 and E-8 were designed in an era when the electronics and crew members needed to process radar signals had to be carried in the airplane itself. Ongoing progress in microelectronics and secure, high-bandwidth communications are reducing this need every year. By 2040, it will be possible to offload much of this processing payload to mobile ground stations, enabling far smaller aircraft to carry viable antennas to the necessary altitudes. The Learjet 24F, for example, has a service ceiling of 15.5 kilometers (higher than the E-8) and a payload of more than three tons,³ sufficient to carry an antenna about the size of today's E-8 with its minimum essential electronics. Aircraft this size can operate from unimproved highways; their modest runway-length requirements also open a large number of small airports to sustained operations. China now has more than 350 airports sufficient to operate Learjet 24s, for example.⁴ U.S. missiles could certainly cut 350 runways, but all great powers invest in rapid runway repair, so additional strikes would be needed to keep them closed; if both sides destroy the other's satellites, as they will be able to do, then battle damage assessment to identify repaired runways for further strikes will be impossible, and the United States would have to strike them all on perhaps a daily basis for the duration of the war to ensure that they stay closed. By contrast, China could repair only a few, on a rotating basis, and still maintain adequate basing even without relying on highways. As many of these runways are deep in the Chinese mainland, requiring expensive, long-range missiles to reach, the cost-exchange ratio is very likely to favor China in a sustained campaign of runway closure versus repair. (Of course, the same logic applies in reverse for Chinese efforts to ground U.S. RSTA aircraft in a sustained campaign—with appropriate adaptation, both sides can ensure survivable basing.)

Montgomery's and Erickson's pessimism is thus excessive, but Neuman's optimism is also overstated. We stand by our original findings: by 2040, competing spheres of influence are more likely than either Chinese or U.S. military hegemony in the Western Pacific.

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3. "Gates Learjet 24F Performance Specs" (Fort Myers, Fla.: Premier Jet Aviation, n.d.), <http://jetav.com/gates-learjet-24f-performance-specs/>.

4. Central Intelligence Agency, *The World Factbook* (Washington, D.C.: Central Intelligence Agency, 2016), <https://www.cia.gov/library/publications/the-world-factbook/fields/2030.html>.