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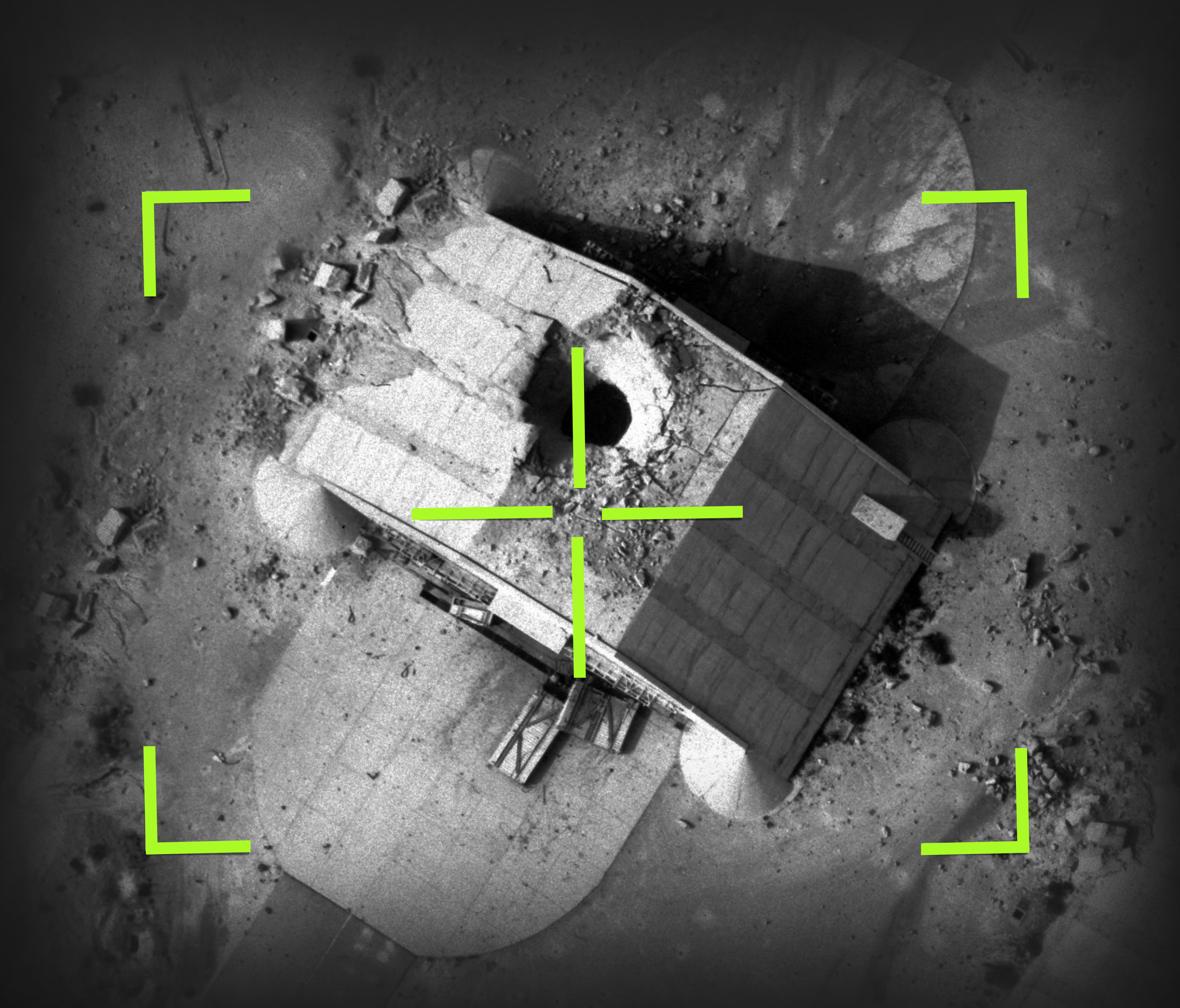
THE EVOLUTION OF PRECISION STRIKE



Barry D. Watts

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BY BARRY D. WATTS

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Mr. Watts has written on a wide variety of military topics, including a number of CSBA monographs: *Nuclear-Conventional Firebreaks and the Nuclear Taboo* (2013), *The Defense Industrial Base* (2011, co-authored with Todd Harrison); *The Revolution in Military Affairs* (2011); *Regaining Strategic Competence* (2008, co-authored with Andrew Krepinevich); *The Case for Long-Range Strike* (2008); *The Past and Future of the Defense Industrial Base* (2008); *U.S. Combat Training, Operational Art, and Strategic Competence: Problems and Opportunities* (2008); *Six Decades of Guided Munitions and Battle Networks* (2007); *U.S. Fighter Modernization* (2007, co-authored with Steve Kosiak); *Long-Range Strike: Imperatives, Urgency and Options* (2005); and *The Military Use of Space: A Diagnostic Assessment* (2001).

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INTRODUCTION

This paper endeavors to address how the spread of non-nuclear (or conventional) precision munitions, along with associated sensors and targeting networks, may alter the conduct of war over the next decade or two. Suggesting, even tentatively, what a mature precision-strike regime might look like ten or twenty years from now is an uncertain business because of the inherent unpredictability of the future. To recall a classic Arab proverb, *He who predicts the future lies, even if he tells the truth*. Or, stated more precisely, "There is no algorithmic process to determine the future—whether it's the future of a computer program, a thought process of the human mind, or the universe as a whole."[1]

Nevertheless, some aspects of the future—for example, demographic trends and economic growth rates—are more amenable to prediction than others, and any attempt to describe the principal features of a mature precision-strike regime in the years ahead must take advantage of these sorts of more predictable trends and factors.[2] That said, Nassim Taleb is right to caution that the occurrence of "black swans"—highly improbable, unpredictable events that have extreme impact—is severely underestimated most of the time and severely overestimated the rest of the time.[3] The use of precision weapons, advanced sensors, and targeting networks is emerging in a number of countries. But exactly how their proliferation may alter the conduct of future war or America's role in world is far less certain.

Perhaps the most striking feature of the evolution of non-nuclear (or conventional) precision strike since the Cold War ended in 1991 has been what has not happened. In the early 1990s, there was growing anticipation that for major powers such as the United States and Russia, "long-range precision strike" would become "the dominant operational approach."[4] The rate at which this

[1] Charles Petzold, "Turing Machines That Run Forever," May 18, 2008, available at http://www.charlespetzold.com/blog/2008/05/Turing-Machines-That-Run-Forever.html, accessed on October 8,

[2] Andrew W. Marshall, "Strategy as a Profession in the Future Security Environment," in Robert Zarate and Henry Sokolski, eds., *Nuclear Heuristics: Selected Writings of Albert and Roberta Wohlstetter* (Carlisle, PA: Strategic Studies Institute, 2009), p. 625.

[3] Nassim Nicholas Taleb, *The Black Swan: The Impact of the Highly Improbable* (New York: Random House, 2007), pp. xvii-xviii, 141-142. Al Qaeda's 9/11 attacks on the World Trade Center and the Pentagon were black swan events that nobody could have predicted.

[4] A. W. Marshall, "Some Thoughts on Military Revolutions—Second Version," Office of Net Assessment memorandum for the record, August 23, 1993, p. 3.

transformation might occur was anyone's guess but many American observers presumed that this emerging form of warfare would proliferate rather quickly. Not widely foreseen in the mid-1990s was that nearly two decades later long-range precision strike would still be a virtual monopoly of the U.S. military.

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The country most likely to begin catching up with the United States in exploiting long-range precision strike is the People's Republic of China (PRC). The People's Liberation Army (PLA) is developing precision-strike capabilities, including very accurate ballistic missiles with maneuverable reentry vehicles and conventional warheads. The PLA's Second Artillery Corps' short-range ballistic missiles (SRBMs) already threaten Taiwan. Looking ahead, Second Artillery Corps' medium-range ballistic missiles (MRBMs) will be able to hold American forward bases in East Asia at risk and may, one day, even pose a credible threat to U.S. carrier strike groups operating inside the "second island chain" running from southern Japan through Guam and Palau to eastern Indonesia and Australia. Moreover, China is not the only country investing in precision strike. Vladimir Putin stated during his 2012 campaign for president that Russia's prospects of catching up with the United States in this area were good and vowed that Russia would do so.[5] And, on a more modest scale, the Iranians and other prospective U.S. competitors are also pursuing precision-strike capabilities. Still, the principal fact about precision strike remains that over the last two decades the United States alone has been able to bring reconnaissance strike to bear in distant theaters around the globe.

[5] Pavel Feigenhauer, "Putin Declares His Defense Agenda for the Next Decade," *Eurasian Daily Monitor*, 38, Issue 9, February 23, 2012, available at http://www.jamestown.org/programs/edm/single/?tx_ttnews%5Btt_news%5D=39051&cHash=5ccec28ca8c50c06309e2ee0749774a9 accessed on March 13, 2013.

A DISTINCTION BETWEEN LONG AND SHORT-RANGE PRECISION STRIKE

The observation that even today the U.S. military still enjoys a near monopoly in *long-range* precision strike is not intended to exclude the proliferation of short-range precision strike: guided rockets, artillery, mortars, and missiles (G-RAMM). But how is *short-range* precision strike to be distinguished from *long-range* precision strike? The natural inclination is to utilize the range from the target at which precision weapons can be launched or released to differentiate one from the other. Unfortunately, advancing technology has undermined any clear distinction based on range to the target. In the last year of American combat operations in Vietnam, especially during Operation Linebacker I (May to October 1972), unpowered laser-guided bombs (LGBs) produced "spectacularly good" results.[6] Because the vast majority of these weapons (78 percent) were employed by F-4Ds using dive-bomb deliveries, LGBs were exceedingly short-range: aircrews had to acquire their targets visually to illuminate them with laser energy and LGBs were released with the front seat pilot looking at the target through the aircraft's gun sight.[7] By contrast, an F-22 cruising at Mach 1.5 and 50,000 feet can release a small diameter bomb (SDB) as far away from the target as 70 nautical miles (nm). Yet neither Paveway LGBs nor SDBs are powered weapons (although the SDB is equipped with a diamondback wing that opens after release to extend its range). To further muddy the situation, the Martin Marietta T-16 and Vought T-22 missiles developed during the Defense Advanced Research Projects Agency's (DARPA's) Assault Breaker program in late 1970s (see Figures 1 and 2) were considered "long-range" or "deep-attack" at the time. Yet neither the T-16 nor the T-22 could quite match the maximum range of SDBs.[8] Range to the target from weapon launch

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[6] R. L. Blachly, P. A. Conine, and E. H. Sharkey, "Laser and Electro-Optical Guided Bomb Performance in Southeast Asia (LINEBACKER 1): A Briefing," RAND R-1326-PR, October 1973, Confidential (declassified September 12, 1991), p. 1 of summary. From February 1, 1972 to February 28, 1973 the U.S. Air Force expended nearly 10,500 LGBs, of which over 5,100 were direct hits with an additional 4,000 achieving a circular error probable of 25 feet. Major Donald L. Ockerman, "An Analysis of Laser Guided Bombs in SEA (U)," Headquarters 7th Air Force, Thailand, June 28, 1973, SECRET (declassified December 31, 1981), p. ii.

[7] Ockerman, "An Analysis of Laser Guided Bombs in SEA (U)," pp. 5, 9.

[8] Martin Marietta's T-16 and Vought's T-22 missiles had ranges of 100 and 120 kilometers (54 and 65 nm), respectively. In terms of what was later actually fielded, the Block IA version of the Army Tactical Missile System (ATACMS), which used GPS/INS (Global Positioning System/Inertial Navigation System) and delivered 275 M74 sub-munitions, had a range of 165 kilometers (89 nm).

or release, then, does not provide a satisfactory basis for distinguishing short- and long-range precision strike as these concepts are generally understood today.

A better way of distinguishing long- from short-range precision strike may be to focus on whether a near-real-time targeting network is required. Assault Breaker depended on the Pave Mover MTI/SAR (moving target indicator/synthetic aperture radar) to detect armored vehicles advancing "deep" behind enemy lines and attack them within minutes using guided sub-munitions delivered by tactical missiles. Using this distinction, the F-117 that struck the AT&T telephone exchange in downtown Baghdad on the first night of the 1991 Persian Gulf War with a single LGB would fall into the "short-range" category. After all, intelligence sources had identified the target, which was a fixed facility; the air tasking order assigned the mission to an F-117; and the F-117 pilot used the aircraft's infrared acquisition and designation system to locate the target, illuminate it with laser energy, and guide the LGB to the desired aim point. In other words, the F-117 strike used essentially the same targeting process American bombers had used against Germany and Japan during World War II. Since G-RAMM weapons can generally be employed—especially against fixed facilities like overseas U.S. bases and ports—without the need for sophisticated, real-time targeting networks, they too fall into the "short-range" category.

By contrast, a strike against a Taliban leader in Pakistan's ungoverned areas with a laser-guided bomb or AGM-114 Hellfire missile released from an MQ-9 Reaper unmanned aerial vehicle (UAV) qualifies as "long-range" reconnaissance strike because of the dependence of its human operators, located in Nevada, on satellite communications for command and control (C2) even though the LGB itself is fundamentally a short-range guided weapon.[9] Similarly, ongoing PLA efforts to evolve the DongFeng-21 (DF-21) into an anti-ship ballistic missile (ASBM) to strike a U.S. aircraft carrier operating 1,000 kilometers or more from China's coast epitomizes "long-range" precision strike because of the need for target updates during the ASBM's brief time of flight. Battle networks able to find and strike targets in near-real time, then, provide a more flexible, functional way of distinguishing long- from short-range precision strike than picking an arbitrary range to the target.

[9] If range from launch or weapon release to the target is used to distinguish "short-range" from "long-range," then the Reaper example will be short-range. On the other hand, if the distinction is based on the use of a battle network able to respond in practically real time, then the Reaper example qualifies as "long-range" reconnaissance strike because of the short range of the munitions involved.

RECONNAISSANCE STRIKE AND THE REVOLUTION IN MILITARY AFFAIRS

By the early 1980s, Soviet military authorities and theorists were growing concerned that emerging military technologies—specifically a "new family of highly accurate, precision-guided delivery systems for non-nuclear munitions"—would give rise to a late 20th century revolution in military affairs (RMA) that would transform the conduct of war.[10] The main reason for the Soviets' concern stemmed from their assessment of how this RMA might affect the conventional force balance in Central Europe. Starting in the late 1960s, the Union of Soviet Socialist Republics (USSR) began investing in traditional types of conventional forces (tanks, armored fighting vehicles, tactical aircraft, etc.) and, by the late 1970s, authorities such as Marshal N. V. Ogarkov had concluded that the threat of aggression from the North Atlantic Treaty Organization (NATO) "had been significantly curtailed."[11] Looking ahead, however, this favorable situation did not appear likely to last. The prospective emergence of U.S. precision-strike capabilities promised to begin shifting the European balance in NATO's favor by obviating the investments the Soviets had made during the previous decade in traditional conventional forces.

At the heart of this possibility was what Soviet theorists termed a "reconnaissance-strike complex" (or "RUK" from the Russian рекогносцировочно-ударный комплекс). The RUK had three basic elements: precision munitions, advanced sensors with wide-area coverage, and automated command and control (C2) for near-real-time responses. The MQ-9 example mentioned above did not automate the decision to attack. But a battle network was clearly needed for the decision to be made in one side of the globe and the attack itself to be immediately carried out on the other. The U.S. development of reconnaissance strike has retained human oversight of attack decisions. But the reliance on battle networks suggests that "long-range precision strike" and "reconnaissance strike" can be used more or less synonymously.

[10] Notra Trulock, III, "Emerging Technologies and Future War: A Soviet View," in Andrew W. Marshall and Charles Wolf, Jr., *The Future Security Environment*, Report of the Future Security Environment Working Group submitted to the Commission on Integrated Long-Term Strategy, (Washington, DC: Pentagon, October 1988), pp. 97-98. For an historical overview of Soviet thinking on RMAs in general, see William E. Odom, "Soviet Force Posture: Dilemmas and Directions," *Problems of Communism*, July-August 1985, pp. 1-14.

[11] Trulock, "Emerging Technologies and Future War: A Soviet View," p. 97.

FIGURE 1: ASSAULT BREAKER TEST, WHITE SANDS MISSILE TEST RANGE[12]

By the early 1980s, Soviet military authors were writing extensively about the probable implications of RUKs for future warfare. Long-range precision strike systems would extend the depth of destruction ten times deeper than had been possible during the Great Patriotic War (that is, during World War II on the Eastern Front) and the single-shot kill probabilities of precision weapons would range from 0.6 to 0.9 for both fixed and mobile targets.[13] RUKs would be able to carry out reconnaissance and destruction "practically in real time."[14] Against many targets, they would also approach the destructiveness of low-yield nuclear weapons. As Marshal Ogarkov wrote in May 1984, developments in non-nuclear means of destruction, which included everything from precision munitions to fuel-air explosives, would "make it possible to sharply increase (by at least an order of magnitude) the destructive potential of conventional weapons, bringing them closer . . . to weapons of mass destruction in terms of effectiveness."[15]

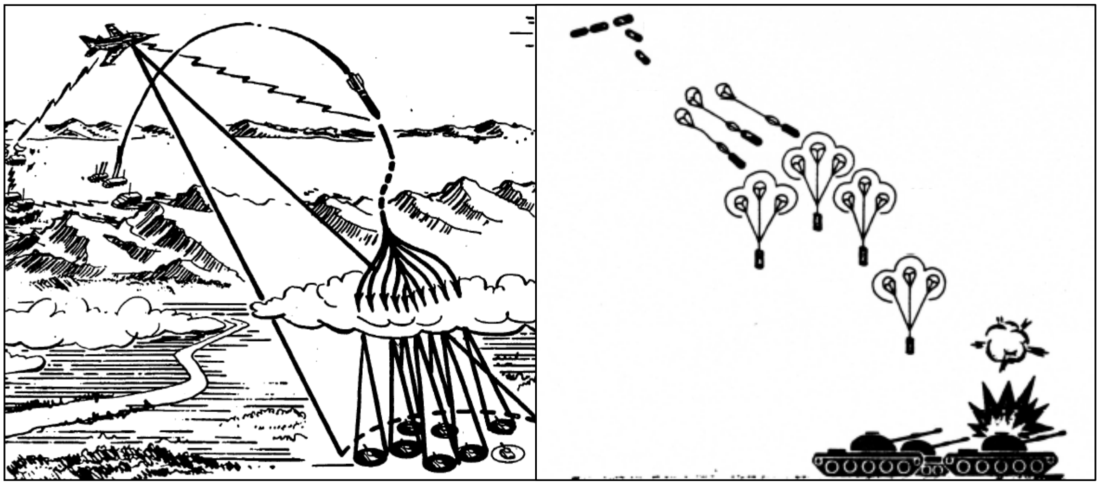
[12] Texton image, used with permission.

[13] Trulock, "Emerging Technologies and Future War: A Soviet View," pp. 105, 107.

[14] Vasiliy G. Reznichenko, Ivan N. Vorobyev, and Nickolay F. Miroshnichenko, *Tactics* (Moscow: Voyenizdat, 1987), trans. Foreign Broadcast Information Service (FBIS), JPRS-UMA-88-008-L-1, June 29, 1988, pp. 8-9.

[15] Marshal N. V. Ogarkov, "The Defense of Socialism: Experience of History and the Present Day," *Red Star*, May 9, 1984, trans. FBIS, *Daily Report: Soviet Union*, Vol. III, No. 091, Annex No. 054, May 9, 1984, p. R19. Chinese military theorists have reached the same conclusion. The application of non-nuclear RUK technologies in high-tech conventional war "has the strategic effect similar to nuclear weapons while avoiding the huge political risk of stepping over the nuclear threshold." Peng Guangqian and Yao Youzhi, eds., *Science of Strategy* (Beijing: Military Science Press, 2001), p. 21. China's Military Science Publishing House published an English translation of this book in 2005.

FIGURE 2: SOVIET DEPICTIONS OF AN ASSAULT BREAKER RUK AND PRECISION-GUIDED SUBMUNITIONS[16]



This observation suggested that conventional precision munitions could, in many cases, be substituted for nuclear ones, thereby achieving the required levels of destruction without the collateral damage and escalatory risks inherent in nuclear weapons.[17] This idea was not new. In fact, it had occurred to American defense specialists in the aftermath of the Vietnam War. In 1975, the final report of the Long Range Research and Development Planning Program (LRRDPP) argued that "near zero miss" conventional munitions could substitute for nuclear weapons in "a wide range of circumstances."[18] While U.S. officials did not formally embrace this idea for another quarter century, the Pentagon's 2001 Nuclear Posture Review's new strategic triad explicitly included non-nuclear strike capabilities along with nuclear ones.[19] The more immediate result of the LRRDPP's examination of emerging technologies was the DARPA's Assault Breaker program. DARPA initiated Assault Breaker in 1978; by December 1982, tests at the White Sands Missile Range had demonstrated the feasibility of using reconnaissance-strike systems to attack Soviet follow-on forces "deep" behind the front lines in the event of a Warsaw Pact attempt to overrun Western Europe.

Soviet concerns about the force balance in Central Europe were undoubtedly reinforced in 1986 when NATO's military committee endorsed Assault Breaker-like capabilities under the label "Follow-On Forces Attack (FOFA)." FOFA's aim was to bolster the Alliance's conventional capabilities, thereby reducing the chance that defending Western Europe against a Warsaw Pact conventional attack would require an early NATO decision to resort to nuclear weapons.[20] By then the Soviet economy was well

[16] Colonel A. Sergeyev, "Reconnaissance-Strike Complexes," *Красная звезда [Red Star]*, February 1985; and S. Davydov and V. Chervonobab, "Conventional, But No Less Dangerous," *Energy: Economics, Engineering, Ecology*, No. 7, 1987, Soviet Press Selected Translations, Department of the Air Force.

[17] Trulock, "Emerging Technologies and Future War: A Soviet View," p. 110.

[18] Dominic A. Paolucci, *Summary Report of the Long Range Research and Development Planning Program* (Falls Church, VA: Lulejian and Associates, February 7, 1975), p. 45.

[19] J. D. Crouch, "Special Briefing on the Nuclear Posture Review," January 9, 2002, comments on Slide 9, available at http://www.defense.gov/transcripts/transcript.aspx?transcriptid=1108, accessed on February 1, 2013.

[20] Alan Shaw (project director) et al., Office of Technology Assessment, *Technologies for NATO's Follow-On Forces Attack Concept—Special Report* (Washington, DC: U.S. Government Printing Office, July 1986), OTA-ISC-312, p. 1.

on the way to outright collapse, and the USSR was as much as a decade behind the United States in the digital computer technologies so essential to reconnaissance strike.[21] As a result, Mikhail Gorbachev, who had become the USSR's leader in 1985, opted to back down from the strategic competition with the United States in order to restructure the failing Soviet economy.

In December 1988, Gorbachev announced at the United Nations that the Soviet Union would begin withdrawing forces from Eastern Europe and allow Soviet satellite states to go their own way.[22] By October 1989, the promised withdrawals were underway and the East German leader Erich Honecker had been forced to resign.[23] On November 9, 1989, the Berlin Wall came down. In light of such developments, the Pentagon's Director of Net Assessment, Andrew W. Marshall, directed Andrew Krepinevich in December 1990 to set aside his work on the military balance in Europe and instead examine the emerging military-technical revolution (MTR) that Soviet theorists had been discussing since the 1970s.

Even before Krepinevich was able to complete his MTR assessment, the first trial of emerging U.S. precision-strike capabilities came in the 1991 Persian Gulf War (Operation Desert Storm). Soviet observers concluded that the "integration of control, communications, reconnaissance, electronic combat, and delivery of conventional fires into a single whole was realized for the first time."[24] Certainly Soviet observers were correct in highlighting the impact of precision munitions and low observable technologies (stealth) during Operation Desert Storm (ODS). For example, the F-117 flew only two percent of the sorties during the 43-day campaign but struck 40 percent of the strategic targets and recorded a hit rate of 80 percent.[25] Further, U.S. post-war analysis found that "a ton of PGMs [precision-guided munitions] typically replaced 12-20 tons of unguided munitions on a tonnage per target kill[ed] basis as well as saving as much as 35-40 tons of fuel per ton of PGMs delivered."[26] More broadly, the combination of reconnaissance systems, precision munitions, and stealthy F-117s "worked brilliantly" in 1991, giving U.S. forces "the ability to win quickly, decisively, and with remarkably few casualties."[27] Nevertheless, a more careful assessment would be that while most of the components of RUKs were present during Desert Storm, they had not yet been fully integrated into a true reconnaissance-strike complex able to find fleeting or time-sensitive targets and strike them in near-real time.

In July 1992 Marshall's office began circulating Krepinevich's MTR assessment. This document initiated the American RMA debate of the 1990s. Krepinevich's assessment hypothesized that a

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[21] Central Intelligence Agency (CIA), Office of Scientific and Weapons Research, "Soviet Computer Technology: Little Prospect for Catching Up," SW 83-10038, March 1985. pp. iv, 4.

[22] "Excerpts of Address by Mikhail Gorbachev," Forty-third United Nations General Assembly Session, December 7, 1988, available at http://isc.temple.edu/hist249/course/Documents/gorbachev_speech_to_UN.htm, accessed on February 3, 2013.

[23] Les Aspin, "As Gorbachev's Troops Pull Out . . ." *The New York Times*, October 1989, available at http://www.nytimes.com/1989/10/13/opinion/as-gorbachev-s-troops-pull-out.html, accessed on February 3, 2013.

[24] Defense Intelligence Agency, "Soviet Analysis of Operation Desert Storm and Operation Desert Shield," translation LN 006-92, October 28, 1991, p. 32.

[25] Thomas A. Keaney and Eliot A. Cohen, *Revolution in Military Warfare? Air Power in the Persian Gulf* (Annapolis, MD: Naval Institute Press, 1995), pp. 190, 293.

[26] Alexander H. Flax and John S. Foster, Jr. (co-chairmen), "Report of the Defense Science Board Task Force on Tactical Air Warfare," Office of the Under Secretary of Defense for Acquisition and Technology, Washington, DC, November 1993, p. 17.

[27] "Perry on Precision Strike," April 1997, *AIR FORCE Magazine*, p. 76.

military revolution was underway that would alter "the character and conduct of military operations" as fundamentally as the emergence of *Blitzkrieg*, strategic bombing, and carrier aviation had changed the character and conduct of warfare between 1918 and 1939.[28] Krepinevich compared Desert Storm to the initial large-scale use of tanks by the British in the November 1917 battle of Cambrai.[29] In Marshall's judgment, Desert Storm witnessed the "first trial of new technology and new ways of operating."[30] He also speculated that long-range precision strike might become "the dominant operational approach" as the RMA matured.[31]

From this perspective it was natural to assume that future wars between major powers would be "increasingly dominated by the application of force at extended ranges to exploit the advantages of information dominance," and that the forces conducting these operations would closely approximate Soviet RUKs.[32] The July 1993 update of the Office of Net Assessment's MTR paper, however, also speculated that low-intensity or unconventional warfare would continue to be the "most prevalent form of conflict," just as it had been since World War II.[33] If so, then one possible future threat the United States might face would be a non-peer state that, while unable to compete seriously in U.S. extended range reconnaissance strike, was willing to absorb disproportionate punishment in pursuit of its strategic objectives. Such a "street fighter state" could combine some of the advances in precision weaponry with "unconventional approaches" such as fighting in complex terrain or attacking civilian populations and national infrastructure.[34]

While China is certainly endeavoring to field RUKs tailored to the PRC's security needs and objectives, the PLA must still surmount some formidable barriers before it can approach U.S. reconnaissance-strike capabilities.

As prescient as this speculation about street-fighter opponents was, the majority of the DoD's analysis and war-gaming of the RMA during the 1990s concentrated on a peer competitor armed with extended-range RUKs.[35] Yet, as of 2013, U.S. military forces have yet to confront such an opponent. While China is certainly endeavoring to field RUKs tailored to the PRC's security needs and objectives, the PLA must still surmount some formidable barriers before it can approach U.S. reconnaissance-strike capabilities. The protracted wars in Afghanistan and Iraq have more closely resembled unconventional operations against street-fighter states and non-state organizations. Indeed, the U.S. military has not even faced an opponent with G-RAMM, much less with comparable long-range precision-strike capabilities. Consequently, the precision-strike regime has not yet matured. When Germany introduced *Blitzkrieg*, for example, its forces quickly overran Poland in 1939 and France in 1940. But Germany's enemies soon began to close the gap. German forces were fought to a

[28] Andrew F. Krepinevich, Jr., *The Military-Technical Revolution: A Preliminary Assessment* (Washington, DC: Center for Strategic and Budgetary Assessments (CSBA), 2002), p. 3. This version of the Office of Net Assessment, Office of the Secretary of Defense's (OSD/NA's) 1992 MTR paper contains retrospective observations by Marshall and Krepinevich.

[29] Krepinevich, *The Military-Technical Revolution: A Preliminary Assessment*, p. 9.

[30] Marshall, "Some Thoughts on Military Revolutions—Second Version," p. 3. See also, Andrew F. Krepinevich, Jr., "The Military-Technical Revolution: A Preliminary Assessment," OSD/NA, July 1993, pp. 7-8.

[31] Marshall, "Some Thoughts on Military Revolutions—Second Version," p. 3.

[32] Krepinevich, "The Military-Technical Revolution: A Preliminary Assessment," July 1993, p. 36.

[33] Krepinevich, "The Military-Technical Revolution: A Preliminary Assessment," July 1993, p. 33.

[34] Krepinevich, "The Military-Technical Revolution: A Preliminary Assessment," July 1993, pp. 56-59.

[35] Commander Jan van Tol, "Brief on Early RMA Gaming Insights," OSD/NA, July 1995, text for slides 8, 9, 10, 12; William J. Hurley, Dennis J. Gleeson, Jr., Colonel Stephen J. McNamara, and Joel B. Resnick, "Summaries of Recent Futures Wargames," Institute for Defense Analyses, October 21, 1998, pp. 7-8, 15. 16, 17, 19, 26, 31, 36; Michael Vickers and Robert Martinage, *Future Warfare 20XX Wargame Series: Lessons Learned Report* (Washington, DC: CSBA, December 2001), pp. 1-3, 5-6.

standstill by Soviet armored forces in 1943, especially at the Battle of Kursk. By 1944 the U.S. Army had a higher density of motorized forces operating with tactical air forces than did Germany's *Wehrmacht*.

WHY HAS THE DIFFUSION OF RECONNAISSANCE STRIKE BEEN SO SLOW?

That the U.S. military would still enjoy an overwhelming lead in reconnaissance strike two full decades after the American RMA debate began has been something of a surprise, an outcome that was not widely anticipated. While it was natural to hope that the United States could sustain its early lead, military history has no shortage of nations that were overtaken by competitors who adopted the new ways of fighting. During World War I, the Royal Navy invented carrier aviation, but by the late 1930s the British had been overtaken by both the United States and Japan. Similarly, the American monopoly on atomic weapons was broken in 1949, and by the early 1970s the USSR had achieved parity in intercontinental nuclear arms. Such examples tend to support the international relations theory that competition between nations creates "a powerful incentive for states to emulate the military practices of the more successful states."[36] Yet, although the People's Liberation Army is certainly developing long-range precision-strike capabilities, no other nation has yet come close to approaching the capacity of the American military to mount high-volume reconnaissance-strike operations in distant or overseas theaters.

Why? There appear to be at least two reasons. First, even considering China and Iran, the militaries of other nations have not had the U.S. military's compelling need to develop reconnaissance strike. The United States has global commitments, including assuring the access to the global commons on which the global economy depends. And in the aftermath of al Qaeda's attacks on the World Trade Center and the Pentagon on September 11, 2001 (9/11), the U.S. military has waged two protracted unconventional conflicts in Afghanistan and Iraq. Undoubtedly the Russians possess the technical capability to field extended range RUKs. But since the Cold War ended, the Russians have neither had the resources to invest heavily in reconnaissance strike nor, in the case of operations in Chechnya, Estonia and Georgia, a compelling military need to do so. European countries such as France and Great Britain have long possessed the technical ability to pursue extended range reconnaissance strike, but they have been unwilling to make the necessary resource investments.[37]

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[36] Emily O. Goldman and Leslie C. Eliason, eds., *The Diffusion of Military Technology and Ideas* (Stanford, CA: Stanford University Press, 2003), p. 5.

[37] According to recent research, the defense budgets of NATO allies are "unlikely to return to 2 percent of gross domestic product even after the financial crisis, short of an overt military threat, yet the cost of military systems will continue to grow dramatically." See Charles Barry and Hans Binnendijk, "Widening Gaps in U.S. and European Defense Capabilities and Cooperation," *Transatlantic Current*, No. 6, July 2012, p. 2.

Eventually American special operations forces developed a real-time reconnaissance-strike capability against al Qaeda and Taliban commanders as well as those of their affiliates outside Iraq and Afghanistan.

The second reason why the diffusion of reconnaissance strike has been so slow stems from the sheer complexities and inherent difficulties of fielding and integrating the various guided munitions; wide-area sensors; positioning, navigation, and timing (PNT) capabilities; and networked C2 needed to prosecute mobile, emergent, or other time-sensitive targets. In the case of fixed targets, such as bases or ports, accurate cruise or ballistic missiles with sufficient range can generally suffice. Sophisticated battle networks are not needed. But in the case of emergent, fleeting, mobile, moving, or other time-sensitive targets, battle networks able to find targets and strike in near-real time are essential, and effective battle networks have proven extraordinarily difficult to establish and sustain under actual combat conditions. Part of the reason has been the elusiveness of certain classes of targets. Assault Breaker originally focused on attacking tanks and armored fighting vehicles behind Warsaw Pact lines in Europe, and the Joint Surveillance Target Attack Radar System (JSTARS) was developed by the Air Force to find and track these targets. Nevertheless, in Desert Storm U.S. forces had virtually no success killing mobile launchers for Iraq's modified "Scuds," even after they had revealed themselves to nearby aircrews by firing a missile.[38] Later, in Iraq and Afghanistan, U.S. reconnaissance-strike operations focused increasingly on an even more elusive target category: individual terrorist leaders. Eventually American special operations forces developed a real-time reconnaissance-strike capability against al Qaeda and Taliban commanders as well as those of their affiliates outside Iraq and Afghanistan. But this capability arose in response to the war-fighting demands of America's post-9/11 operations against insurgents and terrorists, demands that most other countries have not experienced on a long-term basis. The elusiveness of mobile missile launchers and the demands of global man-hunting operations have pushed the U.S. military to address some of the most difficult challenges of reconnaissance-strike operations, whereas other countries have had neither the resources nor imperatives to do so. This history supports Krepinevich's 1993 judgment that joint operations and network integration at progressively higher levels would prove to be the most difficult aspect of reconnaissance strike.[39] These very difficulties go far to explain why the diffusion of extended-range reconnaissance strike has been so slow.

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[38] Barry D. Watts and Thomas A. Keaney, *Effects and Effectiveness*, Part II, in Gulf War Air Power Survey (GWAPS), Vol. II, *Operations and Effects and Effectiveness* (Washington, DC: U.S. Government Printing Office, 1993), pp. 317-322, 330-340.

[39] Krepinevich, "The Military-Technical Revolution: A Preliminary Assessment," July 1993, p. 10.

INCENTIVES FOR G-RAMM PROLIFERATION

Besides their relatively short ranges, G-RAMM can also be categorized as short-range precision munitions because they do not necessarily require advanced targeting or battle networks to be employed effectively, especially against fixed targets or high-signature ground forces in known locations. Many of these munitions use inertial guidance aided by satellite PNT constellations such as the U.S. Global Positioning System (GPS) to achieve accuracy. GPS, however, is not the only PNT system such weapons could utilize. In 2011 Russia finally succeeded in once again fully populating its GLONASS satellite navigation system; China is working on the second generation of a third PNT system, *Běidǒu*; and the Europeans plan to have a fourth PNT constellation, Galileo, fully populated by 2019. It appears, therefore, that the PNT data many G-RAMM munitions require is rapidly becoming ubiquitous, and other guidance technologies—laser illumination, infrared sensors, millimeter wave, ladar (light detection and ranging), etc.—offer other means of achieving precision.

G-RAMM PGMs offer states (and even non-state actors) the possibility of acquiring relatively affordable weaponry for precision attacks on known aim points. In the case of U.S. adversaries, these munitions could be used to attack U.S. overseas ports and bases, large troop concentrations, logistics facilities, embassies, or even the lead elements of American expeditionary forces moving ashore from the sea. They could do so with considerable success. To cite a current example illustrating how affordable some G-RAMM munitions can be, the U.S. Army is developing a GPS-aided precision guidance kit (PGK) for 155-millimeter (mm) and 105-mm artillery shells that can be screwed into the noses of the “dumb” artillery rounds in place of the burster fuze. The target price for a PGK is under $3,000. Its 30-meter circular error probable (CEP) is within the 50-meter lethal radius of a 155-mm artillery shell. Thus, a PGK offers nearly an order-of-magnitude improvement over the 260-meter CEP of an unguided 155-mm round at a range of 30 kilometers. And compared to PGMs such as the Tactical Tomahawk and the Joint Air-to-Surface Standoff Missile (JASSM) at over $1 million per round (see Table 1 on page 18), PGKs are quite cheap.

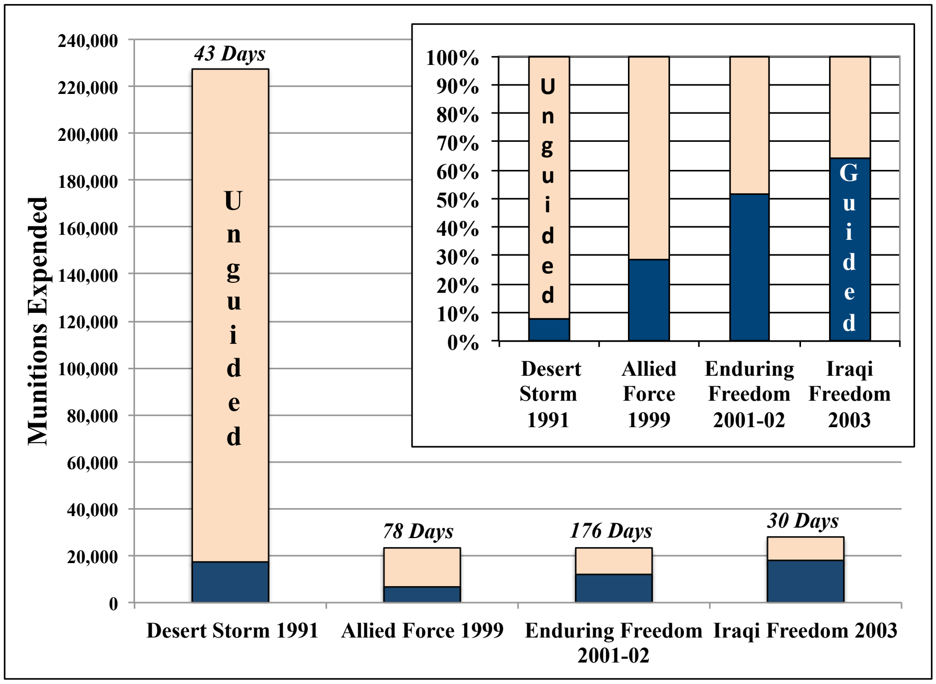
A number of countries are producing G-RAMM PGMs. They include the United States, China, Russia, France, Great Britain, Sweden, South Korea, Israel, India, and Iran. Many of these countries are willing to sell precision weapons to any state or group able to pay for them. Ease of use, low unit prices, and availability from many sources all suggest that short-range G-RAMM weapons will proliferate widely and rapidly during the next decade, even to countries unable to produce these munitions themselves. It also seems likely that some of these weapons will eventually fall into the hands of terrorist organizations such as Hezbollah and al Qaeda.

TRENDS TOWARD PRECISION-CENTRIC OPERATIONS

The expenditure data in Figure 3 shows the growing U.S. preference for guided munitions over the course of the major air campaigns in 1991, 1999, 2001-2002, and 2003. The most dramatic change in expenditures evident in the three campaigns of 1999, 2001-2002, and 2003 is the large reduction in unguided munitions such as Mark-82 general-purpose bombs. In Desert Storm, American air forces expended over 210,000 unguided munitions. In Operation Iraqi Freedom (OIF) in 2003, the number of unguided weapons expended by the air campaign was under 10,000—less than five percent of the total expended in 1991. As a result, while less than eight percent of the munitions expended in the 1991 air campaign were guided, during OIF in 2003 the percentage of guided munitions was over 60 percent, thereby confirming the American military's transition to predominately precision air campaigns.[40] Insofar as Air Force, Navy, and Marine Corps strike aviation is concerned, the trend toward precision is clear and unmistakable.

[40] In 1991, U.S. attack helicopters fired over 3,050 AGM-114 "Hellfire" missiles, and in OIF they expended another 562. These guided munitions are not included in Figure 2, nor are the 293 tube launched, optically tracked, wire guided "TOW" BGM-71 missiles expended in ODS.

FIGURE 3: U.S. UNGUIDED VERSUS GUIDED MUNITIONS EXPENDITURES IN FOUR AIR CAMPAIGNS[41]



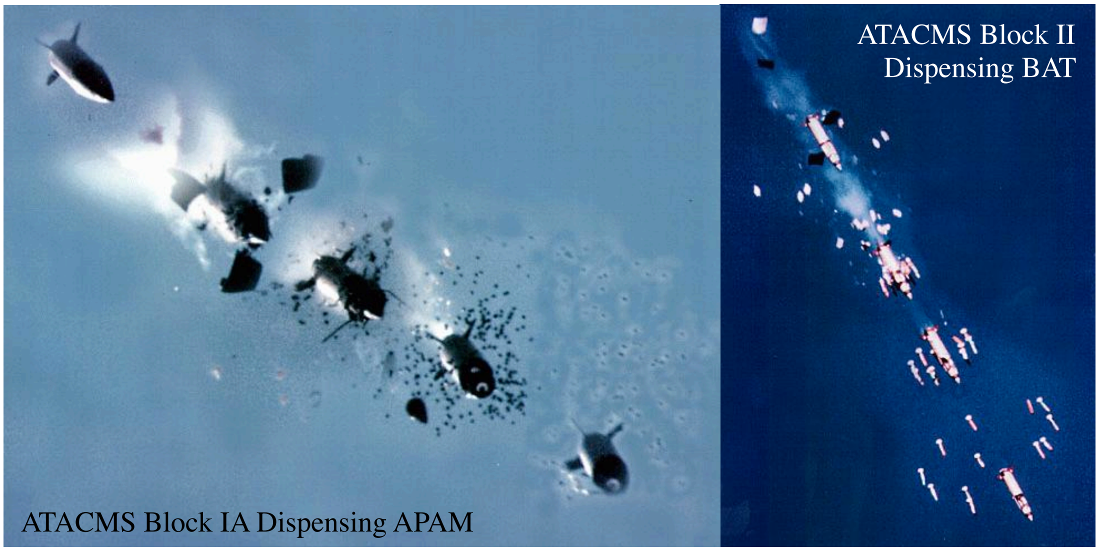
A similar trend toward precision munitions has also emerged, if somewhat belatedly, in the operational preferences of the Army and the Marine Corps.

What about U.S. ground forces? A similar trend toward precision munitions has also emerged, if somewhat belatedly, in the operational preferences of the Army and the Marine Corps. The most obvious example is the Army's evolution of the Multiple Launch Rocket System (MLRS) from an area weapon using unguided rockets into a precision-attack system. MLRS consists of the M270 self-propelled loader-launcher and a family of rocket munitions. In the 1991 Persian Gulf War, 189 M270s were deployed to the theater and they fired over 9,600 unguided M26 rockets, each containing over 600 Dual Purpose Improved Conventional Munition (DPICM) M77 grenades.[42] MLRS launchers also fired some 30 Block I M39 (MGM-140A) Army Tactical Missile System (ATACMS) rockets, each containing 950 M74 submunitions. Given the fact that the Block I ATACMS missile had only inertial guidance, it was not very accurate, especially at its maximum range of 165 kilometers. As a rocket system, therefore, MLRS was essentially an imprecise area weapon in 1991.

[41] Principal sources: Lewis D. Hill, Doris Cook, and Aron Pinker, *A Statistical Compendium*, Part I, in GWAPS, Vol. V, *A Statistical Compendium and Chronology* (Washington, DC: U.S. Government Printing Office, 1993), pp. 553-554; USAF, "Air War over Serbia (AWOS) Fact Sheet," January 31, 2000; Headquarters USAF/XOOC (Checkmate), "ISO Joint Staff 'Quick Look' After-Action Review Panel," PowerPoint slides, December 15, 1999; William Arkin, "Weapons Total from Afghanistan Includes Large Amount of Cannon Fire," Defense Daily, Vol. 213, No. 42, March 5, 2002; and, Lieutenant General T. Michael Moseley, *Operation IRAQI FREEDOM—By the Numbers* (CENTAF-PSAB, Kingdom of Saudi Arabia: US Central Command Air Forces, April 30, 2003).

[42] Department of Defense (DoD), *Final Report to Congress: Conduct of the Persian Gulf War* (Washington, DC: U.S. Government Printing Office, April 1992), p. 753.

FIGURE 4: ATACMS DISPENSING SUBMUNITIONS[43]



Starting in 1997, the U.S. Army began producing the Block IA version of ATACMS. Aside from the longer range (up to 300 kilometers) achieved by reducing the payload to 300 M74 Anti-Personnel, Anti-Material (APAM) sub-munitions, the Block IA's accuracy was improved by the addition of GPS-aided inertial guidance.[44] The unit acquisition cost of these missiles, however, had grown to roughly $1 million a round; the U.S. Army eventually judged them to be only marginally effective; and the planned production run that at one point exceeded 2,300 missiles was halted at around 500.[45] The Block II ATACMS was armed with thirteen Brilliant Anti-Tank (BAT) submunitions. Each BAT used acoustics to identify the vehicles in moving armored formations and terminal guidance to attack the weakest points of vehicles identified acoustically. ATACMS Block II's main drawbacks were its intelligence requirements and its unit cost. ATACMS with BAT was even more expensive than the Block IA.[46] As of April 2007, there were only 75 ATACMS-BAT rounds in the Army's inventory as compared with 1,076 Block I rounds.[47] Years before that, however, the Army had begun developing a unitary warhead version of ATACMS with improved inertial/GPS guidance. The first successful test of the unitary ATACMS Block IA occurred in 2001.

ATACMS usage in 2003 was more than an order of magnitude greater than it had been in 1991. Over 450 rounds were fired: 371 Block I, 69 Block IA, and 13 Block IA Quick Reaction Unitary (QRU)

[43] "M39 Army Tactical Missile System (Army TACMS)," Federation of American Scientists, available at http://www.fas.org/man/dod-101/sys/land/atacms.htm, accessed on February 10, 2013.

[44] Lieutenant Colonel Mark Pincoski, "Precision Guided Missiles and Rockets Program Review," PowerPoint slides, April 24, 2007, slide 19.

[45] Pincoski, "Precision Guided Missiles and Rockets Program Review," April 24, 2007, slide 19; and DoD, Office of the Under Secretary of Defense for Acquisition, Technology, and Logistics (OUSD(AT&L)), "Selected Acquisition Report (SAR) Summary Tables: As of Date: December 31, 1998," March 29, 1999, p. 8.

[46] As of December 2002, the unit acquisition cost of ATACMS-BAT was nearly $1.7 million per round. DoD, OUSD(AT&L), "Selected Acquisition Report (SAR) Summary Tables: As of Date: December 31, 2002," April 4, 2003, p. 9.

[47] Pincoski, "Precision Guided Missiles and Rockets Program Review," April 24, 2007, slide 19.

rockets.[48] Only the thirteen ATACMS-QRU rounds were categorized as precision munitions capable of dealing with harder point targets such as enemy troops fighting from buildings or bunkers. The U.S. Army assesses the Block I and IA ATACMS rockets as area weapons for use against personnel and soft targets. On the one hand, the development of the ATACMS-QRU round reflected a desire for an organic precision-attack capability, which Army doctrine asserted to be as important in stability missions as the application of overwhelming force.[49] On the other hand, the mounting costs of ATACMS variants were reflected in declining production runs from Block I through Block II. Nevertheless, by 2008 the Army's view was that ATACMS had evolved from an area to a precision weapon.[50]

The same trend toward precision-centric operations is evident in the evolution of the U.S. Army's Guided MLRS (GMLRS) rocket. Whether armed with DPICM grenades or unitary warheads, the unit production cost is currently about $133,000 per round (compared to $725,000 for ATACMS-QRU).[51] With a range of seventy kilometers and a CEP of less than five meters, GMLRS rockets with unitary warheads have enabled M270 launchers, as well as the wheeled M142 High-Mobility Artillery Rocket System (HIMARS) launcher, to engage hard stationary point targets with a high probability of kill.[52] The U.S. Army began using GMLRS rockets in Iraq in September 2005. The 200-pound unitary warhead proved small enough for the weapon to be employed in urban areas against individual buildings without appreciable collateral damage. As of March 2008, some 670 GMLRS-U rockets had been fired, achieving a 98.6 percent reliability rate.[53] By this time ATACMS-QRU was enjoying similar success (albeit at over five times the cost per round). By March 2008, 44 ATACMS-QRU rockets had been employed with only a single failure.[54] Thus, while it has taken U.S. ground forces longer to migrate to precision-centric operations than American fixed-wing air and naval forces, the U.S. Army and Marine Corps appear to be well down this path.

One other development in precision strike merits mention: the emergence of armed, remotely controlled UAVs during the U.S. wars in Afghanistan and Iraq. The United States began developing remotely piloted vehicles (RPVs) for national intelligence collection in the early 1960s. Early RPVs such as the Ryan Fire Fly arose from collaboration between the U.S. Air Force and the then-secret National Reconnaissance Office.[55] In 1975 the idea of arming RPVs for strike operations was discussed in the final report of the Long Range Research and Development Planning Program. The LRRDPP's employment concept was that armed RPVs would employ standoff precision munitions to penetrate enemy air defenses and, then, in the case of a major target such as an oil refinery, make a

[48] Pincoski, "Precision Guided Missiles and Rockets Program Review," April 24, 2007, slide 22.

[49] Department of the Army, *Operations*, FM 3-0, February 2008, p. 3-16. The same emphasis on precision in stability missions can be found in FM 3-0, C1, February 22, 2011, p. 3-15.

[50] Lieutenant Colonel Mark Pincoski, "Precision Guided Missiles and Rockets Program Review," PowerPoint slides, April 15, 2008, slide 14.

[51] Department of the Army, "Justification Book: Missile Procurement, Army," February 2012, p. 4 of 9 (Exhibit P1). $133,000 is the unit price for the planned procurement of 1,749 GMLRS missiles during fiscal year 2013.

[52] Pincoski, "Precision Guided Missiles and Rockets Program Review," April 24, 2007, slides 5, 8.

[53] Pincoski, "Precision Guided Missiles and Rockets Program Review," April 15, 2008, slide 10.

[54] Pincoski, "Precision Guided Missiles and Rockets Program Review," April 15, 2008, slide 17.

[55] Thomas P. Ehrhard, *Air Force UAVs: The Secret History*, (Portland, ME: Mitchell Institute Press, July 2010), pp. 5-13.

kamikaze strike against the facility.[56] The first American UAV to be armed was the Tier II "tactical endurance UAV" developed in the mid-1990s and later known as the RQ-1/MQ-1 Predator. It carried a synthetic aperture radar (SAR) that could image the ground through cloud cover. By utilizing GPS, the Predator provided a high degree of position accuracy at relatively low cost. It was the first UAV to provide "true beyond line-of-sight control" through satellite data links.[57]

Based on UAV experience in Bosnia, in 1996 the Air Force stood up the 15th Reconnaissance Squadron at Indian Springs in Nevada to conduct Predator operations.[58] Developmental work on arming Predator UAVs with the AGM-114 Hellfire missiles began prior to 9/11, but actual employment did not begin until after al Qaeda's attacks on 9/11. In 2007, the Air Force introduced the larger, faster MQ-9 Reaper. The MQ-9 can carry a payload of as many as fourteen Hellfire missiles. Alternatively it can carry either two 500-pound GBU-12 Paveway II LGBs or two 500-pound GPS-aided GBU-38 Joint Direction Attack Munitions (JDAMs) along with four Hellfire missiles. As of December 2011, the Air Force had 57 available Predator and Reaper orbits serving U.S. and allied warfighters.[59]

While armed RPVs with human oversight have emerged as an element of American precision-centric operations, kamikaze weapons that both find targets and sacrifice themselves to destroy them have not gotten beyond the development stage. The joint DARPA and Air Force Low Cost Autonomous Attack System (LOCAAS) aimed at developing a small (~100-pound) lethal robotic air vehicle. The powered version of LOCAAS used a ladar seeker to search for, identify, and attack high-value targets within an area of 50 to 100 square kilometers depending on the standoff distance. Given the lack of success in 1991 destroying fleeing Iraqi "Scud" launchers at night even after they had fired, LOCAAS promised to provide a better capability against these sorts of imprecisely located targets. In the end, however, the Air Force chose not to produce LOCAAS because of qualms about the loss of real-time human oversight inherent in unleashing lethal robots even within areas as small as 100 square kilometers.[60] The LOCAAS missile then became the Loitering Attack Munition (LAM) in the Army's Non Line of Sight-Launch System (NLOS-LS) program. But in 2010 the Army cancelled NLOS-LS.

Armed Predator and Reaper UAVs have emerged as the leading edge of the U.S. military's capability to conduct real-time reconnaissance strike over global distances. Organizationally, the Air Force has instituted flight ratings for unmanned aviation system (UAS) sensor operators and pilots.[61] Weapons like ATACMS and GMLRS provide U.S. ground forces with RUK-like capabilities over shorter distances. For surveillance and strike over longer ranges the Army began deploying its first company

Armed Predator and Reaper UAVs have emerged as the leading edge of the U.S. military's capability to conduct real-time reconnaissance strike over global distances.

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[56] Paolucci, *Summary Report of the Long Range Research and Development Planning Program*, p. 30.

[57] Ehrhard, *Air Force UAVs: The Secret History*, pp. 22, 49.

[58] Ehrhard, *Air Force UAVs: The Secret History*, p. 51. The Air Force had dismantled its drone squadrons in 1979. Ibid.

[59] DoD, OUSD(AT&L), "MQ-9 UAS Reaper: Selected Acquisition Report (SAR)," RCS DD-A&T(Q&A)823-424, December 31, 2011, p. 5. "GBU" stands for guided bomb unit. The Air Force has flown two prototypes of a jet-powered Predator C, which includes reduced signature features, a retractable electro-optical/infrared (EO/IR) gimbal, and an internal stores capability.

[60] LOCAAS search areas were quite small. One hundred square kilometers has the same area as a circle with a radius of 3.05 nautical miles.

[61] 1st Lieutenant Kinder Blacke, "Tinker Airman Graduates in First Class of UAV Operators," October 29, 2009, available at http://www.tinker.af.mil/news/story.asp?id=123175180, accessed on September 30, 2012. The Reaper UAV is a component of the Reaper unmanned aviation system (UAS).

of 12 Gray Eagle UAVs (a Predator variant) in January 2013.[62] Without question, then, the American military services have increasingly embraced a precision-centric way of war. One thing they have not done, however, is to field autonomous lethal robots despite the progress of the LOCAAS program in developing automated target recognition using ladar sensors. Whether potential adversaries will have similar qualms about employing such systems remains to be seen. Regardless, the key fact regarding the maturation of the evolving precision-strike regime is that American military forces have yet to be confronted by an adversary with a comparable suite of precision weapons and battle networks. But there is reason to anticipate that in the years ahead at least some other nations—including China, Russia, and Iran—will endeavor to either begin catching up with or erode the U.S. lead in reconnaissance strike.

[62] "First Gray Eagle Company Deployed to Afghanistan," February 6, 2013, available at http://www.unmanned.co.uk/unmanned-vehicles-news/unmanned-aerial-vehicles-uav-news/first-gray-eagle-company-deployed-to-afghanistan/, accessed on February 11, 2013.

RESOURCE CONSTRAINTS

Prior to the emergence of modern precision-guided weapons, range to the target from firing positions or weapon release was a significant constraint on accuracy. Recall the difference between the 260-meter CEP of an unguided 155-mm artillery shell at a range of 30 kilometers and the 50-meter CEP goal (now reduced to 30 meters in light of promising test results) of a PGK at the same range. Precision guidance removed distance to the target as a constraint on accuracy. Accuracy, in other words, became independent of the expendable PGM's range to the target at launch, firing, or release.

The unit costs of modern precision munitions, however, are not independent of range to the target. Long-range cruise missiles such as the Air Force's JASSM Extended Range (499 nm) and the Navy's Tactical Tomahawk (900 nm) are considerably more expensive than the unpowered SDB and, especially, the Joint Direct Attack Munition. The average unit acquisition cost for the planned buy of 2,531 JASSM Extended Range (ER) missiles is over 50 times greater than the average unit acquisition cost for the planned JDAM procurement.[63]

TABLE 1: COSTS AND QUANTITIES OF SELECTED PRECISION MUNITIONS[64]

Precision Munition	Unit Cost in Then-Year $	Planned Quantity
Joint Air-to-Surface Standoff Missile Extended Range	$1,481,825	2,531
Tactical Tomahawk Land Attack Missile	$1,448,277	4,961
Small Diamter Bomb II	$245,441	17,163
Excalibur XM182 (Artillery Round)	$223,322	7,508
GMLRS/GMLRS AW (Alternative Warhead)	$145,928	43,936
Joint Direct Attack Munition	$26,641	232,875

[63] DoD, OUSD(AT&L) ARA/AM, "Selected Acquisition Report (SAR) Summary Tables: As of December 31, 2011," March 29, 2012, pp. 8, 10-11. The unit acquisition price of the baseline JASSM is $1.43 million; the planned inventory is 2,487. Similarly, Table 1 also omits the earlier Tomahawk Land Attack Missile (TLAM) program that preceded the Tactical Tomahawk. The buy of TLAM was 4,201 missiles of which at least 1,800 had been expended in operations from 1991 through 2003.

[64] DoD, OUSD(AT&L) ARA/AM, "Selected Acquisition Report (SAR) Summary Tables: As of December 31, 2011," March 29, 2012, pp. 8, 10, 11. The unit costs in Table 1 include RDT&E (research, development, testing and evaluation) as well as procurement.

Cost differentials this large have implications for procurement quantities. What Table 1 suggests is that the more expensive a given expendable munition is, the smaller the quantity actually procured is likely to be. True, the relationship between unit costs and quantities is not a physical law. For example, the SDB is slightly more expensive than the Excalibur guided artillery round but the planned SDB procurement is more than twice Excalibur's. Different military services have different priorities and missions and, hence, reach different judgments about the quantities of various precision expendables they are willing to fund.

Table 1 also sheds some light on the probable future of tube artillery in U.S. ground forces. The Army currently operates two 155-mm howitzers: the self-propelled M109A6 Paladin and the towed M772A2 lightweight howitzer. Excalibur is being developed for both guns. Yet in 2010 the planned buy of Excalibur was reduced from 30,388 to only 7,508 rounds, reportedly due to soaring costs.[65] By comparison, as of March 2012 the planned procurement of the much cheaper XM1156 Precision Guidance Kit (under $3,000) during the first three years of production is 23,000 to 25,000 kits.[66] As for accuracy, over the course of a forty-eight-round test in 2011, PGKs achieved a CEP under thirty meters.[67] In short, these GPS-aided guidance kits seem destined to do for high explosive 155-mm artillery shells what JDAM kits did for general-purpose bombs. As a result of its lower unit cost, PGKs—more than Excalibur rounds—offer the greatest potential for tube artillery to participate fully in the precision-centric operations that the U.S. Army has increasingly embraced over the last decade.

Even for countries as wealthy as the United States and China, the higher unit costs of cruise missiles, such as the Tactical Tomahawk and the Conventional Air Launched Cruise Missile (CALCM) relative to much cheaper "direct attack" munitions, such as the SDB and JDAM, constitute a constraint on procurement quantities and, hence, on the stockpiles of the more expensive PGMs available at the outset of hostilities. One of the Chinese systems that poses the greatest potential threat to U.S. power projection from airbases such as Kadena on Okinawa and Kunsan in South Korea, or from carrier strike groups operating well inside the second island chain, is the DongFeng-21 (CSS-5) medium range ballistic missile. But China has not deployed these missiles in large numbers. The Department of Defense's latest report to the U.S. Congress on China's military programs estimated that only 75 to 100 DF-21s and mobile launchers have been fielded by the Second Artillery Corps.[68] Most likely this small quantity compared to the Second Artillery Corps' estimated 1,000-1,200 DongFeng-15 (CSS-6) and DongFeng-11 (CSS-7) SRBMs and 200-250 CSS-6/CSS-7 launchers reflects operational as well as economic constraints. China's rulers do not need MRBMs to dissuade the Taiwanese from straying toward independence from Beijing; the SRBMs have sufficient range to cover Taiwan. The far smaller deployment of MRBMs, however, may also reflect the greater resource demands of these two-

[65] "Update 1—Unit Cost of Raytheon Artillery Program Soared," *Reuters*, November 15, 2010, available at https://www.fbo.gov/index?s=opportunity&mode=form&tab=core&id=e0cf769f03b55a3b6174d9a2319e3fe9&_cview=0, accessed on February 13, 2013.

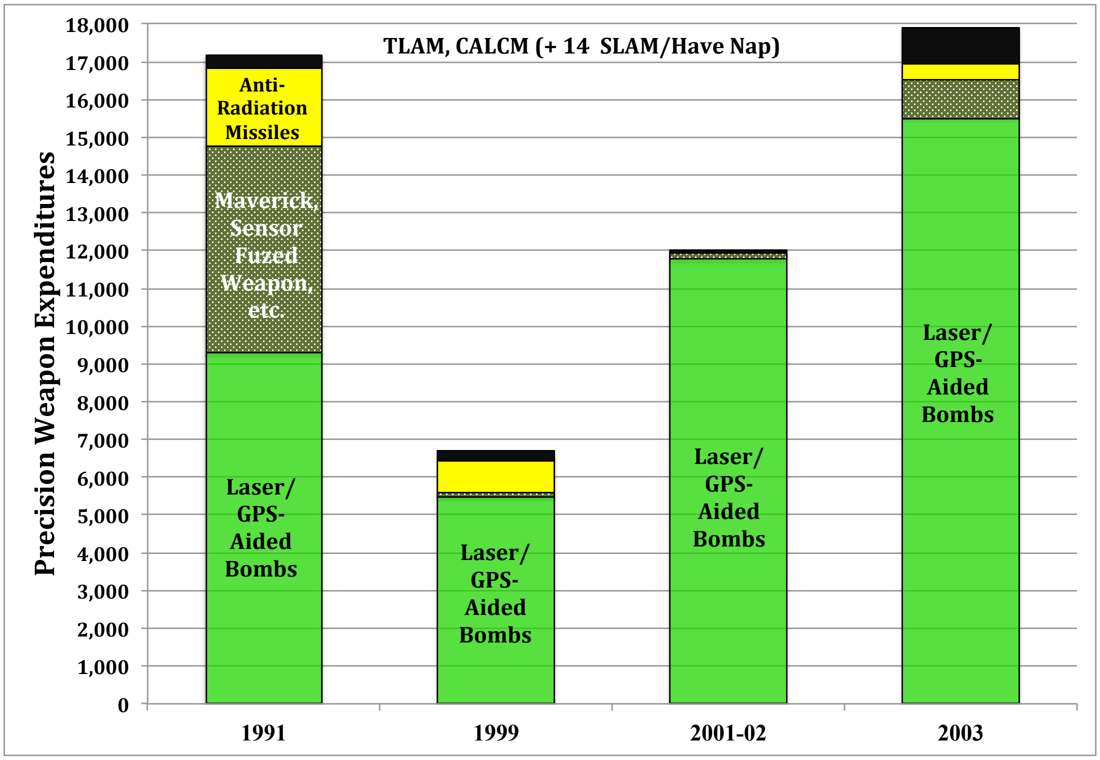
[66] Department of the Army, "Precision Guidance Kit (PGK) Production," Solicitation 12-X-A0009, March 15, 2012, available at https://www.fbo.gov/index?s=opportunity&mode=form&tab=core&id=e0cf769f03b55a3b6174d9a2319e3fe9&_cview=0, accessed on February 13, 2013.

[67] Alliant Techsystems Inc., "ATK Completes Successful Artillery Precision Guidance Kit Testing," October 5, 2011, available at https://www.fbo.gov/index?s=opportunity&mode=form&tab=core&id=e0cf769f03b55a3b6174d9a2319e3fe9&_cview=0, accessed on February 13, 2013.

[68] Department of Defense (DoD), Office of the Secretary of Defense (OSD), "Annual Report to Congress: Military and Security Developments Involving the People's Republic of China," May 2012, p. 29.

stage missiles.[69] As Charles Hitch and Roland McKean observed in 1960, "Resources are always limited in comparison with our wants, always constraining our action. (If they did not, we could do everything, and there would be no problems of choosing preferred courses of action.)."[70]

FIGURE 5: U.S. PGM USAGE IN FOUR AIR CAMPAIGNS



U.S. dependence on relatively inexpensive PGMs during high-intensity combat operations reflects, in turn, longstanding choices in delivery platforms.

Table 1 illustrates the greater resource constraints on the procurement of more expensive PGMs compared to cheaper ones. This constraint is reflected in actual U.S. PGM expenditures during the four air campaigns shown in Figure 5. Ignoring the fourteen relatively short-range cruise missiles expended over the course of these campaigns, the long-range CALCM and TLAM cruise missiles constituted only three percent of the more than 53,700 PGMs expended in 1991, 1999, 2001-2002, and 2003. Unpowered, direct-attack JDAMs and LGBs made up over 78 percent of the total expenditures.

U.S. dependence on relatively inexpensive PGMs during high-intensity combat operations reflects, in turn, longstanding choices in delivery platforms. With the exception of TLAMs (and Tactical Tomahawks), which are fired from submarines or naval surface combatants, all of the other PGMs in Figure 5 were released or fired by manned, air-breathing platforms—fighters and bombers—at relatively short distances from the targets. The United States currently operates about 2,600 fighters and attack aircraft plus some 160 bombers. None of the fighters and attack aircraft have unrefueled

[69] DoD, "Annual Report to Congress: Military and Security Developments Involving the People's Republic of China," May 2012, p. 29. This latest report gives the estimated range of China's SRBMs as less than 1,000 kilometers (540 nautical miles).

[70] Charles J. Hitch and Roland N. McKean, *The Economics of Defense in the Nuclear Age* (Cambridge, MA: Harvard University Press, 1960), p. 23.

combat radii—the distances they can fly out and back without air refueling—over 1,000 nm. In fact, the roughly 1,730 F-16s and F/A-18s are hard pressed to manage a 600 nm unrefueled combat radius with realistic combat loads. While the combat radii of the fighters and attack aircraft can be, and often are, significantly extended with air refueling, only the bombers can exploit air refueling to operate over intercontinental distances. There appears, therefore, to be a correlation between the predominance of fighters and attack aircraft in U.S. power-projection forces and PGM expenditure patterns in major campaigns beginning in 1991.

Even in the case of very inexpensive PGMs, resource constraints and institutional preferences can confront even a major power with the prospect of running out during high-intensity operations. By the ninth week of Operation Enduring Freedom in late 2001, U.S. forces had consumed about half of the roughly 10,000 JDAM kits in the inventory in Afghanistan, and there was a real possibility of running out of JDAMs if the high expenditure rates continued.[71] Since the United States had an open JDAM production line at the time, the Pentagon was able to expand production to cope with the surge in wartime demand. By October 2002 JDAM production had increased from 750 kits a month to 2,000, and in 2003 a second production line was opened to increase total production to 5,000 kits monthly. A nation without an indigenous production capacity for preferred PGMs would be forced to rely on producer countries for resupply in any protracted conflict. Stockpiling might suffice for very short wars, but not for ones as long as the American involvement in Afghanistan has turned out to be. And one suspects that even China might be hard pressed to replace the expenditure of 40 or 50 DF-21s, which could occur in a single day. Thus, both high unit costs and production capacities can constitute constraints on the available inventories of modern guided munitions for high-intensity combat operations.

The American bias toward short-range platforms delivering predominately inexpensive PGMs to project military capability is evident in Figure 5. This bias, however, is neither coincidental nor without justification. The combination of short-range delivery platforms and inexpensive PGMs has given the U.S. military the capacity to maximize the volume of guided weapons that can be delivered per day or per week, thereby covering as many aim points as possible in the shortest possible time. This desideratum emerged from Desert Storm, a campaign in which U.S. forces mounted some 43,000 separate strikes against various targets.[72] Nevertheless, as desirable as the goal of compressing the time needed to cover thousands or tens of thousands of aim points may be, the American emphasis on short-range fighter and attack aircraft delivering relatively cheap guided munitions also presents a vulnerability that the PLA is seeking to exploit through its modernization efforts.

[71] "Joint Direct Attack Munition (JDAM) History," Global Security, available at http://www.globalsecurity.org/military/systems/munitions/jdam-history.htm, accessed on February 16, 2013.

[72] Watts and Keaney, *Effects and Effectiveness*, p. 269. The strike counts, of course, include unguided weapons.

CHINA'S GROWING A2/AD CHALLENGE IN THE WESTERN PACIFIC

A major element of the PLA's modernization efforts over the past two decades has been the development of Anti-Access/Area-Denial (A2/AD) capabilities focused on the western Pacific. These emerging A2/AD capabilities are part of a more comprehensive set of initiatives begun after the 1991 Persian Gulf War to prepare the PLA for "local wars under modern high-tech" (and, since 2002, "informationalized") conditions.[73] These more comprehensive initiatives, in turn, should be understood in the broader context of Chinese civilization, which "tends toward actual empire—and traditionally lacks a meaningful concept of coequal, legitimate sovereignties pursuant to which states may coexist over the long term in nonhierarchical relationship."[74] In other words, the PRC's leaders appear to view their country's rise as China finally regaining her natural role as the Asian hegemon rather than in terms of becoming assimilated into a Westphalian family of coequal states.

By 2001, Chinese military theorists such as Peng Guangqian and Yao Youzhi were arguing that local wars under high-tech, "informationalized" conditions were a "brand new form of war" and that their emergence marked a "new stage in the development of the history of war."[75] Keep in mind, however, that the overarching aim of the PLA's military modernization is to contribute to China's comprehensive national power (综合国力 or zōnghé guólì) rather than to field military capabilities per se.[76] By comprehensive national power (CNP), Chinese writers generally mean the sum total of the powers and influence of a country as measured by its economic power (gross domestic product), knowledge and technological resources, human capital (especially educational levels or its working-age population), natural resources, capital resources (such as domestic and foreign investment), the

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[73] Peng Guangqian and Yao Youzhi, eds., *The Science of Military Strategy* (Beijing: Military Science Publishing House, 2005), p. 17; and David M. Finklestein, "China's National Military Strategy," in Roy Kamphausen and Andrew Scobell, eds., *Right Sizing the People's Liberation Army: Exploring the Contours of China's Military Strategy* (Carlisle, PA: Strategic Studies Institute, September 2007), pp. 94, 104, 118.

[74] Christopher A. Ford, *Mind of Empire: China's History and Modern Foreign Relations* (Lexington, KY: University of Kentucky Press, 2010), p. 273.

[75] Peng Guangqian and Yao Youzhi, eds., *Science of Strategy* (Beijing: Military Science Press, 2001), p. 352. See also Peng and Yao, *The Science of Military Strategy*, p. 394. *Science of Strategy* is an earlier version of Peng and Yao's 2005 volume, *The Science of Military Strategy*.

[76] Larry Wortzel and Dean Cheng, "China's Military Ambitions in Space," The George C. Marshall Institute, November 28, 2006, pp. 6, 10, 24.

government's ability to mobilize resources, military power, and international resources.[77] Generally speaking, Chinese quantitative estimates of CNP show the PRC's CNP growing substantially since 1980, whereas the United States, whose CNP is still larger in absolute terms, shows comparatively little growth.[78] In November 2012, the new general secretary of the Chinese Communist Party, Xi Jinping, introduced the aspiration to realize what he has called the "Chinese dream," including a "strong-army dream." What exactly these aspirational slogans mean is unclear at this early stage. But the trends in CNP, of which Chinese military modernization is a component, certainly do not exclude the possibility of China assuming a more belligerent stance in East Asia.

Since the 1995-1996 crisis that witnessed Chinese missiles twice being fired into the waters surrounding Taiwan, the most conspicuous element of PLA A2/AD capabilities has been the Second Artillery Corps' growing inventory of highly accurate, land-based ballistic missiles.

Since the 1995-1996 crisis that witnessed Chinese missiles twice being fired into the waters surrounding Taiwan, the most conspicuous element of PLA A2/AD capabilities has been the Second Artillery Corps' growing inventory of highly accurate, land-based ballistic missiles. These SRBMs and MRBMs offer the capability to place fixed targets out to distances from China's coastline of at least 2,000 kilometers (roughly 1,080 nm) under threat of accurate ballistic-missile bombardment. Augmented with systems ranging from over-the-horizon (OTH) radars and HQ-9 (HongQi-9) surface-to-air missiles (SAMs) to advanced interceptors, submarines, hit-to-kill anti-satellite weapons, radio-frequency jammers, and ground-based lasers, the broader aim appears to be to deny access to China's littoral waters even to moving targets such as U.S. surface combatants.[79]

Among these various A2/AD systems, the one that is causing the greatest concern to the U.S. Navy is the DF-21D MRBM development, which PLA authorities have advertised as an anti-ship ballistic missile (ASBM) capable of hitting warships such as a U.S. aircraft carrier a couple thousand kilometers out into the western Pacific from China's east coast. Figure 6 is a schematic representation of the PLA's DF-21D ASBM concept. Perhaps the most salient observation regarding this system is that the Chinese have yet to conduct an end-to-end test of it against a moving target at sea. In fact, as recently as July 2011, General Chen Bingde of the PLA's General Staff stated in a *Xinhua News Agency* article that the DF-21D was "still in the research stage" and had not yet achieved operational status.[80] It does not take much imagination or analysis to appreciate why Chen may have offered these caveats: hitting a fast-moving warship over long ranges is much more difficult than hitting a fixed installation.

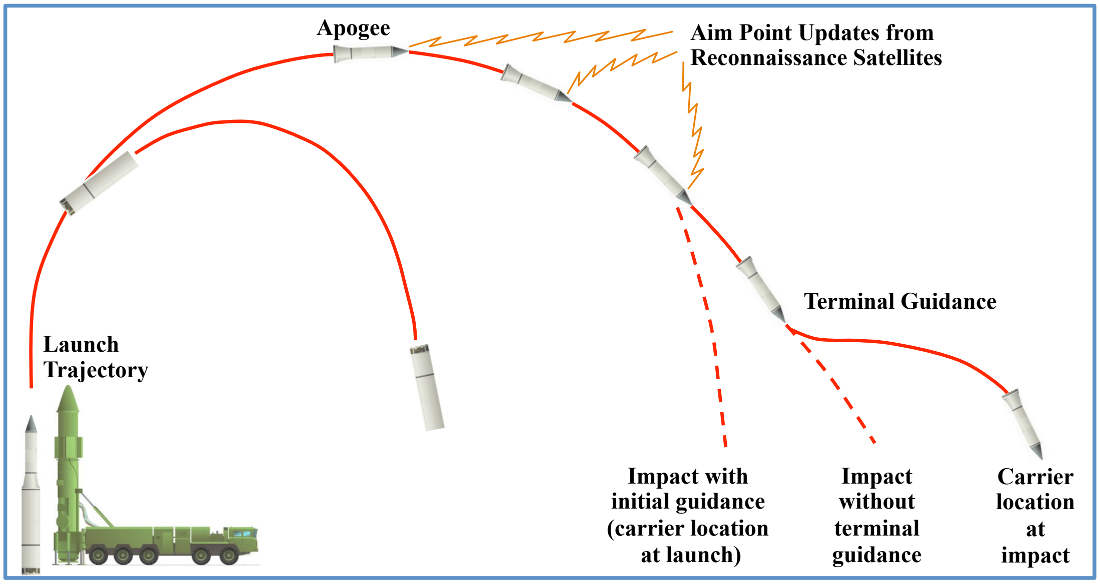
[77] Hu Angang and Men Honghua, "The Rising of Modern China: Comprehensive National Power and Grand Strategy," *Strategy and Management*, No. 3, May 2002, pp. 2, 21.

[78] David M. Lampton, *The Three Faces of Chinese Power: Might, Money, and Minds* (Berkeley, CA: University of California Press, April 2008), p. 23. The CNP table Lampton displays was updated by Professor Hu in 2007.

[79] Wortzel and Cheng, "China's Military Ambitions in Space," p. 17.

[80] Andrew S. Erickson, "General Chen Bingde, PLA Chief of General Staff, Becomes First Chinese Official to Confirm Publicly that '2,700km-Range' DF-21D Anti-Ship Ballistic Missile (ASBM) is in Development; 'Not Operational Yet' by PLA Definition," Blog Posts, July 12, 2011 (subsequently corrected), available at http://www.andrewerickson.com/2011/07/general-chen-bingde-pla-chief-of-general-staff-becomes-first-chinese-official-to-confirm-publicly-that-"2700-km-range"-df-21d-anti-ship-ballistic-missile-asbm-is-in-development/ accessed on March 18, 2013. Erickson is an Associate Professor in the Strategic Research Department at the U.S. Naval War College and a founding member of the department's China Maritime Studies Institute (CMSI) as well as a research associate at Harvard University's John King Fairbank Center for Chinese Studies.

FIGURE 6: PLA ASBM CONCEPT[81]



Against a warship at 1,000 nautical miles, the DF-21D's time of flight would be around 10 minutes. A nuclear aircraft carrier at 30 knots can cover five nautical miles in that time as well as change course. After 10 minutes, therefore, the carrier's position could be anywhere within an area of 79 square nautical miles (or 269 square kilometers) centered on its position at the time the missile is launched. As a result, inflight updates of the warship's position would almost certainly be needed even if the ASBM's maneuverable reentry vehicle had terminal guidance. The PLA's over-the-horizon radars could detect and track a carrier strike group well out in the western Pacific, but the long wavelengths of OTH radars would not provide the accuracy needed for target updates against a fast-moving naval combatant.[82] Chinese military writings indicate that reconnaissance satellites would be needed to complete the strike, or at least to provide aim-point corrections until terminal guidance could take over.[83] Making all this work in real time is, of course, not easy. At present, then, the DF-21D ASBM is at best an emerging component of the PLA's A2/AD strategy, and it seems reasonable to assume that the U.S. Navy is already working on countermeasures to further complicate the already difficult task of hitting a maneuvering warship at sea at long ranges.

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[81] Figure 6 is derived from a graphic used in a 2006 article from the Second Artillery Corps' engineering college. The Chinese diagram is reproduced in DoD, Office of the Secretary of Defense, "Military Power of the People's Republic of China," Annual Report to Congress, 2009, p. 21.

[82] Australia's OTH Jindalee Operational Radar Network operates on wavelengths of 9.99 to 59.96 meters. Airborne fire-control radars use much shorter X-band wavelengths (0.025 to 0.037 meters, which correspond to frequencies of 12 to 8 gigahertz). Patriot's MPQ-53 engagement radar operates at the somewhat lower frequencies of 4 to 6 gigahertz.

[83] Pan Changpeng, Gu Wenji, and Chen Jie, "An Analysis of the Capabilities of Military Satellites to Support an ASBM in Offense and Defense Operations," *Winged Missiles Journal*, 2006, No. 5, p. 12, cited in Ian Easton and Mark A. Stokes, "China's Electronic Intelligence (ELINT) Satellite Developments: Implications for U.S. Air and Naval Operations," Project 2049 Institute, February 23, 2011, pp. 7, 19.

FIGURE 7: SECOND ARTILLERY CORPS' UNDERGROUND TUNNELS[84]

Nevertheless, the unmistakable intent behind China's DF-21D, OTH radars, reconnaissance satellites, and associated battle networks is to force U.S. air and naval forces to operate over distances as far from China's coast as 1,000 to 1,500 nm (1,500 nm being roughly the distance from China's littoral to Guam). At the same time, the PLA's investments in underground facilities for missile, aircraft, and naval forces have made Chinese military bases and naval ports extremely difficult targets even for "near zero miss" precision weapons. In the case of the Second Artillery Corps, starting in March 2008 China's state-run CCTV (China Central Television) network revealed that from 1995 to 2010 the Chinese had added 2,500 kilometers of underground tunnel facilities for their "strategic" missile forces, thereby doubling China's "Great Underground Wall" to some 5,000 kilometers.[85]

These developments promise to complicate traditional U.S. approaches to overseas power projection based predominately on access to relatively secure forward bases, short-range aircraft, and forward deployed naval forces. To the extent that PRC A2/AD capabilities can compel U.S. forces to base and operate initially over distances of 1,000 nm or greater, the tyranny of distance could substantially affect the intensity and volume of precision weapons that could be brought to bear. While air refueling will enable short-range aircraft to strike over distances of 1,000 nm or more, longer mission times inevitably reduce the number of sorties employing inexpensive PGMs that can be mounted per day or week. As for more expensive PGMs such as the Tactical Tomahawk, in a high-intensity conflict with a major power there is a significant risk that the Tactical Tomahawk inventories of Aegis surface combatants and submarines could be quickly exhausted. In the case of the PRC, neutralizing the missiles positioned in China's "Great Underground Wall" would most likely require substantially larger quantities of PGMs than needed to achieve comparable results against the same number of missiles located out in the open or even protected by above-ground shelters. Thus, operating from

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[84] Chinese CCTV images, 2009.

[85] L. C. Russell Hsiao, "China's 'Great Underground Wall' and Nuclear Deterrence," *China Brief*, 9, Issue 25, December 16, 2009, pp. 1-2, available at http://jamestown.org/programs/chinabrief/, accessed on February 17, 2013; James R. Holmes, "China's Great Underground Wall," *The Diplomat*, August 20, 2011, available at http://thediplomat.com/flashpoints-blog/2011/08/20/chinas-underground-great-wall/?print=yes, accessed on February 17, 2013.

bases over 1,000 nm or more away from China's underground facilities could greatly diminish the intensity and effectiveness of U.S. precision-centric strike operations.

A further problem is that PLA military theorists, among others, have concluded that attacking an adversary's battle networks is the most important mission in local wars under high-tech, "informationalized" conditions.[86] While evolving PLA efforts to achieve and maintain overall information dominance are less visible than the development of the DF-21D ASBM or the J-20 prototype stealth fighter, they constitute perhaps the central element of China's evolving A2/AD capabilities. How successful the PLA might be in a future conflict against a major power in degrading or destroying the opponent's intelligence, surveillance, and reconnaissance (ISR) systems and battle networks is difficult to predict. There can be little doubt, however, that PLA military theorists understand how critical ISR, satellite communications, and battle networks are to reconnaissance strike against mobile, moving, emergent, or time-sensitive targets at extended ranges. Indeed, there is good reason to think that Chinese theorists such as Peng and Yao take a more integrated, global approach to the information aspects of future wars under informationalized conditions than do their American counterparts, who tend to put ISR, electronic warfare, space-based communications, PNT, jamming, and cyber into separate, somewhat stove-piped compartments.

[86] "The core of information warfare strategy is to seize and maintain strategic information superiority and battlefield information superiority; and secure the strategic objectives by information control and information attack including soft damage or hard destruction through cyber attacks inflicted upon the infrastructure and the fundamental information resources or battlefield information system which a country's armed forces depend upon. This is a brand-new concept and type of strategy." Peng and Yao, *The Science of Military Strategy*, p. 18. See also Peng and Yao, *Science of Strategy*, pp. 21, 302, 303, 306.

WARGAMING AND EXPLORATORY EXERCISES

Clearly emerging PLA anti-access/area-denial capabilities pose growing challenges to American forces operating in the western Pacific. AirSea Battle aspires to find joint solutions to some of these challenges within the confines of current force structures and whatever additions or changes the Air Force and Navy may be able to fund over the next decade or two. It is not unreasonable, though, to wonder whether, in the end, rather different "combined arms" mixes of weapons, platforms, and operational concepts may ultimately be needed, particularly in response to China's evolving A2/AD capabilities. Available and emerging technologies offer a plethora of alternative paths that the U.S. military could pursue.

Here the problem is choosing one or two of the more promising alternatives. Possibilities include:

- Developing high-energy lasers to alter the cost disadvantage of defending against shorter-range ballistic missiles using hit-to-kill or explosive-warhead interceptors;
- Employing advanced sea mines to divert PLA resources into countermine operations;
- Adopting an alternative satellite architecture to avoid depending so heavily on a small number of large and vulnerable reconnaissance and PNT satellites; or
- Fielding of a new generation of low-yield, highly accurate nuclear warheads that could hold at risk underground and deeply buried facilities.

Absent in-depth wargaming and real-world experimentation such as the U.S. Navy pursued during the interwar years 1918-1941, it is difficult to prioritize these options.[87] Yet in what promises to be an extended period of declining defense budgets, it will likely prove difficult for the Defense Department to pursue these options vigorously and simultaneously. Sadly, even the Naval War College is now

[87] The archives of the Naval War College contain 318 game histories for the years 1919-1941. Michael Vlahos, *The Blue Sword: The Naval War College and the American Mission, 1919-1941* (Newport, RI: Naval War College Press, 1980), p. 133. During this period the U.S. Navy conducted 21 fleet problems, and those during the 1930s involved half or more of the Navy's fleet. Albert A. Nofi, *To Train the Feet for War: The U.S. Navy Fleet Problems, 1923-1940* (Newport, RI: Naval War College Press, 2010), p. 280. Note, however, that while the fleet problems gave naval aviation the practical training and experience that enabled it to "take its place as a central part of the fleet" during World War II, "the main concern of the fleet problems was the battleship and how to employ it." Ibid, pp. 287-288.

reluctant to invest in the persistent wargaming effort needed to inform and guide the setting of priorities.

GLOBAL POWER PROJECTION IN A MATURING PRECISION-STRIKE REGIME

> My impression is that a lot of people sign up to the notion that a military revolution is underway, but very few draw the significant consequences that should flow from that belief.
>
> — Andrew W. Marshall, August 1993[88]

The spread of precision weapons, wide-area ISR, and battle networks raises some long-term challenges for the U.S. military's preferred approaches to overseas power projection. Some nations, of course, will pose tougher challenges than others. At least over the next decade or so, very few countries besides China and Russia are likely to field reconnaissance-strike systems able to attack mobile, moving, emergent, or time-sensitive targets over long distances in near-real time. But many countries will be able to purchase or produce G-RAMM weapons in quantity, and even these systems could make American and allied overseas bases, ports, and troop concentrations far more vulnerable than they have been in the past.

One long-term challenge to U.S. power projection, then, is the prospect that a number of nations will be able to create "no-go" zones into which it would be too difficult and costly for the United States to project military power using today's overseas bases and expeditionary forces. Granted, the costs in blood and treasure that U.S. decision makers might be willing to bear would depend on American stakes in any future conflict with a country that possessed reconnaissance-strike capabilities or even G-RAMM in large quantities. If the stakes for the United States were high enough, American leaders might be willing to accept losses even greater than those experienced in Iraq, Serbia, or Afghanistan since early 1991. Nevertheless, it is possible that the spread of land-based missile forces with precision guidance and G-RAMM will Balkanize the world by creating a number of "no-go" zones, particularly in Asia and the Middle East. Not just China, but lesser powers such as Iran may be able to render power projection into their littoral areas a risky proposition even for the U.S. military.

True, the challenge to global power projection is not exclusively an American problem. Japan—or even Vietnam with U.S. assistance—could also create A2/AD zones into which China's modest power projection forces would not be inclined to venture. Regardless, the Balkanization of the international security environment might well constrain America's foreign policy and military role in the world more than it would nations with fewer global commitments. In such a world, the United States would either have to find alternative ways to project military power into A2/AD areas or else

[88] Marshall, "Some Thoughts on Military Revolutions—Second Version," p. 4.

accede to a diminishing capability to intervene any place around the globe where vital American interests were at risk.

Rethinking power projection in a world Balkanized by the proliferation of G-RAMM and the emergence, in a few cases, of true reconnaissance-strike systems would be no easy matter. Since 1942, the U.S. military has enjoyed an unrivaled capability to fight the nation's wars overseas, either by operating from pre-existing forward bases and ports or by seizing them. Once in theater, U.S. forces have largely depended on short-range systems, high-signature mechanized ground forces, and logistical "iron mountains" to defeat the adversary. But increasing American dependence on information from orbital systems—especially for battle networks and the global communications needed to operate systems like the MQ-1 Predator and MQ-9 Reaper UAVs in the Middle East from Nevada—have created new vulnerabilities in both space and cyberspace. Militaries such as the PLA are fully aware of these vulnerabilities and a central thrust of Chinese thinking about high-tech local wars under informationalized conditions is to develop a variety of ways to exploit these vulnerabilities.[89]

A further complication is that the leaders of several countries—notably Russia, Pakistan, North Korea, and (potentially) Iran—consider nuclear weapons a viable way of compensating for conventional inferiority. For example, current Russian nuclear doctrine maintains: first, that a strategic nuclear arsenal is essential to Moscow's status as a major power; and second, that employing a few relatively clean, lower-yield nuclear weapons with tailored effects would enable Russia to terminate a conventional theater conflict that was going badly before the opponent could seriously undermine Russian sovereignty or territorial integrity.[90] Hence, conventional inferiority has led the Russian Federation to lower the nuclear threshold in future conventional conflicts on the presumption that it could get away with limited nuclear use—especially on Russian territory—to avoid a major conventional defeat. The underlying presumption is that Russia's arsenal of strategic or intercontinental nuclear warheads would deter the opponent from escalating to a major nuclear exchange. Similarly, Pakistan appears to be pursuing a "tactical" nuclear capability to offset India's larger conventional forces.[91] And the Chinese appear to be fully aware of how vulnerable U.S. conventional forces are to nuclear electromagnetic pulse weapons.[92] Thus, a further challenge to the

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[89] Timothy L. Thomas, *The Dragon's Quantum Leap: Transforming from a Mechanized to an Informationalized Force* (Ft. Leavenworth, KS: Foreign Military Studies Office, 2009), pp. 243-244.

[90] Dima Adamsky, "Russian Regional Nuclear Developments," Long Term Strategy Group (LTSG), September 2010, p. 20. To implement their current theater-nuclear doctrine, the Russians have developed a new generation of low-yield nuclear weapons with tailored effects and have been simulating their use in major exercises since 1999. Mark B. Schneider, National Institute for Public Policy, testimony before the Subcommittee on Strategic Forces, House Armed Services Committee, "The Nuclear Forces and Doctrine of the Russian Federation and the People's Republic of China," October 14, 2011, pp. 3-5.

[91] Pakistan is increasing its plutonium production at Khushab in order to "build a new generation of lighter, more powerful . . . warheads small enough to fit on cruise missiles it is currently developing." David Albright and Paul Brannan, "Pakistan Doubling Rate of Marking Nuclear Weapons: Time for Pakistan to Reverse Course," Imagery Brief, Institute for Science and International Security, May 16, 2011, p. 2, available at http://isis-online.org/isis-reports/detail/pakistan-doubling-rate-of-making-nuclear-weapons-time-for-pakistan-to-rever/, accessed on March 9, 2013. Pakistan may also want larger yield (50-100 kiloton) fission weapons that can cause far more damage to Indian cities than its current relatively low-yield weapons. In addition, plutonium-based fission weapons could enable Pakistan to build deliverable thermonuclear weapons. Ibid.

[92] "With the further development of information technology, and its influence on the role of nuclear weapon[s], the discharge of nuclear energy will be controlled by information and be employed to seek information dominance. For instance, the electromagnetic pulse weapon still in [the] laboratory stage is a kind of nuclear

traditional U.S. approach to power projection is that American success in an overseas conflict could, against a country with nuclear weapons, lead to a nuclear response.

Moreover, advances since the Vietnam War in the accuracy of non-nuclear weapons, ISR, and battle networks can also be applied to nuclear weapons. As Keir Lieber and Daryl Press have argued in recent years:

> …the same revolution in accuracy that has transformed conventional warfare has had equally momentous consequences for nuclear weapons and deterrence. Very accurate delivery systems, new reconnaissance technologies, and the downsizing of arsenals from Cold War levels have made both conventional and nuclear counterforce strikes against nuclear arsenals much more feasible than ever before. Perhaps most surprising, pairing highly accurate delivery systems with nuclear weapons permits target strategies that would create virtually no radioactive fallout, hence, vastly reduced fatalities.[93]

They also imply that compared to conventional munitions, even very-low-yield nuclear weapons would have significant advantages in explosive power not just against an opponent's offensive nuclear forces but also against a range of deeply buried or very hard targets. The Air Force's GBU-57 Massive Ordnance Penetrator has an explosive power comparable to only 3 to 5 tons of TNT whereas the lowest yield of the U.S. B-61 "tactical" nuclear bomb is reportedly equivalent to 300 tons of TNT.[94] This suggests that the maturation of reconnaissance-strike capabilities could increasingly blur the "firebreak" between conventional and nuclear warfare, making traditional power projection doubly difficult.

No variant of the JSF offers combat radii great enough to operate from outside the reach of PLA A2/AD systems without air refueling, and neither Predator nor Reaper can survive long within the reach of advanced surface-to-air missile (SAM) systems such as Russia's S-300 and China's HQ-9.

Despite all the growing challenges to longstanding U.S. approaches to overseas power projection posed by a maturing precision-strike regime, the American military has shown little inclination to embrace fundamentally new operational concepts or organizational arrangements to deal with the looming obstacles. Instead, the military services have largely taken evolving American capabilities for reconnaissance strike and layered them onto existing operational concepts and organizations. This general pattern of behavior is especially evident in the priority given to acquisition programs such as the Joint Strike Fighter (JSF) and DoD's guidance to the Air Force to increase the number of Predator/Reaper orbits to sixty-five (with a surge capacity to eighty-five).[95] No variant of the JSF offers combat radii great enough to operate from outside the reach of PLA A2/AD systems without air refueling, and neither Predator nor Reaper can survive long within the reach of advanced surface-to-air missile (SAM) systems such as Russia's S-300 and China's HQ-9.

The premise implied by this general pattern of behavior is that U.S. forces will find ways to continue projecting power overseas from forward bases while relying mainly on short-range systems, non-stealthy UAVs, and brigade-size ground units. At best, China's growing A2/AD capabilities will not succeed in forcing U.S. forces to fight exclusively from long ranges in the western Pacific. Granted, during the opening days of a future conflict involving an opponent with strong reconnaissance-strike capabilities, American forces might have to begin fighting from extended ranges. But enough

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weapon. It is possible for nuclear weapons to move from deterrence into warfighting." Peng and Yao, *The Science of Military Strategy*, p. 404.

[93] Keir A. Lieber and Daryl G. Press, "The New Era of Nuclear Weapons, Deterrence, and Conflict," *Strategic Studies Quarterly*, Spring 2013, p. 3.

[94] Lieber and Press, "The New Era of Nuclear Weapons, Deterrence, and Conflict," p. 9.

[95] Houston R. Cantwell, "The Costs of Remotely Piloted Foreign Policy," *Joint Force Quarterly*, 1st Quarter 2013, p. 71.

adjustments, workarounds, countermeasures, and offsets to American vulnerabilities in basing, forward presence, space, and cyberspace will be found to enable U.S. forces to counter enemy reconnaissance-strike capabilities and quickly begin projecting power from theater bases using forward-deployed forces and short-range platforms. In other words, even by the 2030s, the hope appears to be that the proliferation of short- and long-range precision-strike capabilities will not necessarily demand any fundamental changes in U.S. weaponry, operational concepts, or military organizations.

Perhaps this is the way that a maturing precision-strike regime will unfold. But perhaps not. It is at least equally plausible that fundamental changes in how the U.S. military plans to fight will have to be made in order to cope with a future in which precision strike—nuclear as well as non-nuclear—produces "no-go" areas even more lethal and costly than the machine gun and massed artillery rendered trench warfare during 1914-1918. After all, military art did not stop evolving after World War I. By 1939, the tank, radios, close air support, the flexibility of the *Panzer* division and, most importantly, the concept of deep armored penetrations into the enemy's rear areas restored mobility to the battlefield. The question is whether the U.S. military can find parallel solutions to the challenges of power projection in a mature precision-strike regime being posed by China in the western Pacific and Iran in the Persian Gulf.

A sensible point of departure is to begin developing new operational concepts. In the case of China, AirSea Battle has been proposed. AirSea Battle rests fundamentally on the tighter integration of Air Force and Navy operations in the western Pacific so that each Service can play, in coordination with regional allies, an enabling role for the other in accomplishing critical missions.[96] In Iran's case, the notion of "Outside-In" operations that exploit the U.S. military's ability to fight from extended ranges has been suggested.[97]

Will such concepts generate solutions to the challenge of preserving America's capability to project military power overseas in the face of emerging A2/AD challenges stemming from the spread of precision-strike capabilities? Or will even major powers—including the United States—be left with a difficult choice between either staying out of certain theaters or else going directly to homeland attacks on the adversary's strategic infrastructure, thereby tempting those states with nuclear arsenals to cross an already lowered nuclear threshold? Given the inherent unpredictability of the future, these questions cannot yet be answered. Definitive answers will depend on how the precision-strike regime unfolds in the decades ahead.

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[96] Jan van Tol with Mark Gunzinger, Andrew Kreinevich and Jim Thomas, *AirSea Battle: A Point-of-Departure Operational Concept* (Washington, DC: Center for Strategic and Budgetary Assessments, 2010), p. xiv. In 2010 Air Force Chief of Staff General Norton Schwartz and Navy Chief of Naval Operations Admiral Gary Roughead signed a memorandum of understanding to develop AirSea Battle. Richard Halloran, "AirSea Battle," *Air Force Magazine*, August 2010, p. 47.

[97] Mark Gunzinger with Chris Dougherty, *Outside-In: Operating from Range to Defeat Iran's Anti-Access and Area-Denial Threats* (Washington, DC: Center for Strategic and Budgetary Assessments, 2011), p. xi.

LIST OF ABREVIATIONS

A2/AD	Anti-Access/Area-Denial
APAM	Anti-Personnel, Anti-Material
ASBM	Anti-ship ballistic missile
ATACMS	Army Tactical Missile System
AWOS	Air War over Serbia
BAT	Brilliant Anti-Tank
C2	Command and control
CALCM	Conventional Air Launched Cruise Missile
CCTV	China Central Television
CEP	Circular error probable
CIA	Central Intelligence Agency
CMSI	China Maritime Studies Institute
CNP	Comprehensive national power
CSBA	Center for Strategic and Budgetary Assessments
DARPA	Defense Advanced Research Projects Agency
DF-21	DongFeng-21
DoD	Department of Defense
DPICM	Dual Purpose Improved Conventional Munition
ELINT	Electronic intelligence
EO/IR	Electro-optical/infrared
ER	Extended Range (missile)
FBIS	Foreign Broadcast Information Service
FOFA	Follow-On Forces Attack
G-RAMM	Guided rockets, artillery, mortars, and missiles
GMLRS	Guided Multiple Launch Rocket System
GPS	Global Positioning System
GPS/INS	Global Positioning System/Inertial Navigation System
GWAPS	Gulf War Air Power Survey
HIMARS	High-Mobility Artillery Rocket System
ISR	Intelligence, surveillance, and reconnaissance
JASSM	Joint Air-to-Surface Standoff Missile

JDAM	Joint Direction Attack Munitions
JSF	Joint Strike Fighter
JSTARS	Joint Surveillance Target Attack Radar System
LAM	Loitering Attack Munition
LGB	Laser-guided bomb
LOCAAS	Low Cost Autonomous Attack System
LRRDPP	Long Range Research and Development Planning Program
LTSG	Long Term Strategy Group
MLRS	Multiple Launch Rocket System
MRBM	Medium-range ballistic missile
MTI/SAR	Moving target indicator/synthetic aperture radar
MTR	Military-technical revolution
NATO	North Atlantic Treaty Organization
NLOS-LS	Non Line of Sight-Launch System
ODS	Operation Desert Storm
OIF	Operation Iraqi Freedom
OSD	Office of the Secretary of Defense
OSD/NA	Office of Net Assessment, Office of the Secretary of Defense
OTH	Over-the-horizon
PGK	Precision guidance kit
PGM	Precision guided munitions
PLA	People's Liberation Army
PNT	Positioning, navigation, and timing
PRC	People's Republic of China
QRU	Quick Reaction Unitary
RDT&E	Research, development, testing and evaluation
RMA	Revolution in military affairs
RPV	Remotely piloted vehicle
RUK	Reconnaissance-strike complex (Russian: рекогносцировочно-ударный комплекс)
SAM	Surface-to-air missile
SAR	Synthetic aperture radar
SAR	Selected Acquisition Report
SDB	Small diameter bomb
SRBM	Short-range ballistic missile
TLAM	Tomahawk Land Attack Missile
UAS	Unmanned aviation system
UAV	Unmanned aerial vehicle
USSR	Union of Soviet Socialist Republics

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