



NAVAL POSTGRADUATE SCHOOL

MONTEREY, CALIFORNIA

THESIS

ASSESSING TECHNOLOGY INNOVATION IN THE PLA

by

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March 2015

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REPORT DOCUMENTATION PAGE			Form Approved OMB No. 0704-0188	
Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instruction, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188) Washington DC 20503.				
1. AGENCY USE ONLY (Leave blank)		2. REPORT DATE March 2015		3. REPORT TYPE AND DATES COVERED Master's Thesis
4. TITLE AND SUBTITLE ASSESSING TECHNOLOGY INNOVATION IN THE PLA			5. FUNDING NUMBERS	
6. AUTHOR(S) Gary L. Pembleton				
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Naval Postgraduate School Monterey, CA 93943-5000			8. PERFORMING ORGANIZATION REPORT NUMBER	
9. SPONSORING /MONITORING AGENCY NAME(S) AND ADDRESS(ES) N/A			10. SPONSORING/MONITORING AGENCY REPORT NUMBER	
11. SUPPLEMENTARY NOTES The views expressed in this thesis are those of the author and do not reflect the official policy or position of the Department of Defense or the U.S. Government. IRB Protocol number ____N/A____.				
12a. DISTRIBUTION / AVAILABILITY STATEMENT Approved for public release; distribution is unlimited			12b. DISTRIBUTION CODE A	
13. ABSTRACT (maximum 200 words) In the last 10 years, China's defense capability has increasingly become the focus of military analysts as well as a driving factor in U.S. policy. This thesis asks the question "How much of Chinese military modernization counts as innovation?" In answering this question it defines innovation, creates a standard for identifying innovation, and applies this standard to the PLAN and PLAAF. Historically, technological innovation is either overlooked or ignored by intelligence services and recent developments by China have come as a surprise to many. This thesis identifies a total of 79 instances of innovative technology fielded by the PLAN and the PLAAF since 1970. Many of these innovations, like the DF-21D, PL-12, and recent JY series of radars, comprise weapon systems not yet developed by other nations and thus count as global-level innovations. China is focused on developing innovative technologies to exploit weaknesses inherent in other technologically superior forces such as those fielded by the United States in order to gain an asymmetric advantage in what Chinese strategists label a counter-RMA.				
14. SUBJECT TERMS China, Chinese, innovation, technology, military, modernization, navy, air force, defense, PLA, A2AD, asymmetric, counter-RMA			15. NUMBER OF PAGES 135	
			16. PRICE CODE	
17. SECURITY CLASSIFICATION OF REPORT Unclassified	18. SECURITY CLASSIFICATION OF THIS PAGE Unclassified	19. SECURITY CLASSIFICATION OF ABSTRACT Unclassified	20. LIMITATION OF ABSTRACT UU	

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ASSESSING TECHNOLOGY INNOVATION IN THE PLA

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Submitted in partial fulfillment of the
requirements for the degree of

**MASTER OF ARTS IN SECURITY STUDIES
(FAR EAST, SOUTHEAST ASIA, AND THE PACIFIC)**

from the

**NAVAL POSTGRADUATE SCHOOL
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ABSTRACT

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LIST OF ACRONYMS AND ABBREVIATIONS

A2AD	anti-access area denial
AAA	anti-aircraft artillery
AAM	air-to-air missile
AAV	amphibious fighting vehicle
ABM	anti-ballistic missile defense
AESA	active electronically scanned array
AIP	air independent propulsion
AOR	auxiliary oiler replenishment
AORH	auxiliary oiler replenishment helicopter
APAR	active phased array radar
ASAT	anti-satellite weapon
ASBM	anti-ship ballistic missile
ASCM	anti-ship cruise missile
ASM	anti-ship missile
ASROC	anti-submarine rocket
BMD	ballistic missile defense
CEP	circular error probable
CM	countermeasures
CCM	counter-countermeasures
CIC	combat information center
CIWS	close-in weapon system
CV	aircraft carrier
CVN	nuclear aircraft carrier
DD	destroyer
DDG	guided missile destroyer
ECM	electronic countermeasures
ECCM	electronic counter-countermeasures
ESM	electronic surveillance measures
FF	frigate
FFG	guided missile frigate

FFL	light frigate
GLONASS	global navigation satellite system
GNSS	global navigation satellite system
GPS	global positioning system
HEAT	high-explosive anti-tank
HOTAS	hands-on throttle and stick
HUD	heads up display
ICBM	intercontinental ballistic missile
IOC	initial operating capability
IRBM	intermediate range ballistic missile
INS	inertial navigation system
IR	infrared
LACM	land attack cruise missile
LCAC	landing craft air cushioned
LCM	landing craft medium
LCU	landing craft utility
LHD	landing helicopter dock
LLTV	low light television
LPD	amphibious transport dock
LRF	laser range finder
LSM	landing ship medium
LST	landing ship tank
MANPAD	man-portable air defense missile
MCM	mine countermeasures ship
MMW	millimeter wave radar
MOOTW	military operations other than war
MRBM	medium-range ballistic missile
OPTRONICS	optoelectronics
PLA	People's Liberation Army
PLAAF	People's Liberation Army Air Force
PLAN	People's Liberation Army Navy
PTG	guided missile patrol boat

RAS	replenishment at sea
RMA	revolution in military affairs
SAM	surface-to-air missile
SAR	synthetic aperture radar
SATCOM	satellite communication
SATNAV	satellite navigation
SEAD	suppression of enemy air defenses
SLBM	submarine launched ballistic missile
SLOC	sea lines of communication
SRBM	short-range ballistic missile
SS	attack submarine
SSBN	ballistic missile submarine, nuclear
SSN	attack submarine, nuclear
UAV	unmanned aerial vehicle
UCAV	unmanned combat aerial vehicle
UHF	ultra-high frequency
VHF	very-high frequency

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ACKNOWLEDGMENTS

I would first like to thank my thesis advisors, Wade Huntley and Michael Glosny, for all of their assistance in completing this thesis. Their guidance was instrumental in helping to direct my research and I am greatly appreciative of the time they spent assisting me. I also wish to thank the entire National Security Affairs department; for there is no doubt that the time I spent in class provided great preparation for the writing of this thesis. Most importantly, I would like to express my utmost gratitude and affection to my wonderful wife, Becki, and my children, Arabella and Alex. This thesis would not have been possible without their love and support to motivate me as I spent countless hours buried in research. I certainly could not have done this without them and I am blessed to have such a wonderful family.

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I. INTRODUCTION

A. MAJOR RESEARCH QUESTION AND FINDINGS

Currently, China is in the process of significantly modernizing its military forces. Analysts disagree over whether this modernization will bring China's military capabilities to the level of first-tier nations, and at the center of this debate is China's capacity for innovation.¹ Tai Ming Cheung voices a belief held by many scholars that, "China's present approach appears to be the selective targeting of a few critical areas for accelerated development while the rest of the defense economy pursues a more moderate pace of transformation."²

Despite this focus on China's military modernization, there has not been a significant effort to analyze the innovative military equipment resulting from PLA modernization. The focus on innovative military equipment is where this thesis adds to the current body of work. This thesis defines military equipment as the hardware that comes out of the innovation process; the innovation process itself will be discussed in Chapter II. The primary question this thesis seeks to answer is: "How much of Chinese military modernization counts as innovation?" In order to answer this question, this thesis first adopts the following definition of military innovation: new ways of generating military power, which attempt to increase effectiveness by changing the manner in which a military functions in the field, to enhance a country's ability to fight wars. Second, it focuses on technological developments in military hardware as the basis for analysis. Third, it develops a standard for determining what counts as innovation, and applies that standard to the PLA in order to assess the results of China's military modernization programs. In this way, this thesis seeks to identify technological innovation in each

¹ Tai Ming Cheung, *Forging China's Military Might: A New Framework for Assessing Innovation* (Baltimore, MD: JHU Press, 2014); Klaus Brockhoff and Jiancheng Guan, "Innovation via New Ventures as a Conversion Strategy for the Chinese Defense Industry," *R&D Management* 26, no. 1 (1996): 49–56; Wang Yuan, "Evolution and System Characteristics of China's Science, Technology, and Innovation Policies," *SITC Policy Brief* 2013, no. 2 (2013); Tai Ming Cheung, "The Chinese Defense Economy's Long March from Imitation to Innovation," *The Journal of Strategic Studies* 34, no. 3 (2011): 325–54.

² Tai Ming Cheung, "The J-20 Fighter Aircraft and the State of China's Defense Science, Technology, and Innovation Potential," *Policy Brief* 17 (2011): 4, <http://igcc.ucsd.edu/assets/001/500865.pdf>.

branch of the PLA to determine what percentage of their equipment modernization qualifies as product innovation.

The main findings of this thesis are that China is increasingly focused on fielding world-class technologies. It is now ranked third in terms of total military firepower behind only the United States and Russia.³ It has developed equipment that rivals that of the top militaries and in some cases, such as the DF-21D and YJ-12 exceeds them in performance.⁴ As China continues to innovate in relation to its past capabilities, it is beginning to develop technology that counts as innovation on the global scale: DF-21D, PL-12, JY-26, JY-27A, and JY-50. Despite these advances, this thesis assesses that there are still areas where China has not yet been able to catch up, primarily nuclear submarine quieting, jet engine production, and aircraft carrier technology.

In cases where it has not caught up, China has innovated in areas that provide an asymmetric advantage. Examples of this are the expansive anti-ship missile programs specifically designed to counter U.S. nuclear aircraft carriers (CVN) and stealth-detecting radar designed to defeat U.S. 5th-generation aircraft.⁵ Further, the combination of its technological developments and its security situation both in Asia and with the United States is causing the PLA to undergo a period of doctrinal change. Instead of merely focusing on developing a limited number of highly capable platforms, weapons, and systems, China is following a dual-track of modernization whereby it is developing and fielding these advanced technologies of its own, but is also producing systems that allow its current force structure to be much more capable in a future conflict. This is best seen as a direct counter to the U.S. doctrine of overwhelming force through technological

³ “2014 World Military Powers,” *Global Fire Power*, April 3, 2014, <http://www.globalfirepower.com/countries-listing.asp>.

⁴ Andrew Erickson and Gabe Collins, “China Deploys World’s First Long-Range, Land-Based ‘Carrier Killer’: DF-21D Anti-Ship Ballistic Missile (ASBM) Reaches ‘Initial Operational Capability’ (IOC),” *China SignPost*, no. 14 (December 26, 2010), <http://www.andrewerickson.com/2010/12/china-deploys-world’s-first-long-range-land-based-“carrier-killer”-df-21d-anti-ship-ballistic-missile-asbm-reaches-“initial-operational-capability”-ioc/>; Dennis M. Gormley, Andrew S. Erickson, and Jingdong Yuan, *A Low-Visibility Force Multiplier: Assessing China’s Cruise Missile Ambitions* (Washington, DC: National Defense University, 2014), <http://oai.dtic.mil/oai/oai?verb=getRecord&metadataPrefix=html&identifier=ADA602350>.

⁵ “JY-26 – China’s New Counter Stealth Radar | Defense Update:,” November 11, 2014, http://defense-update.com/20141111_jy-26-chinas-new-counter-stealth-radar.html#.VHYgP4tN3vE.

superiority; China's counter-revolution in military affairs can best be described as numerical superiority combined with advanced technology.⁶

China's strategy, military modernization, and rhetoric all align in what appears to be a deterrent doctrine against any outside intervention in Asia. In terms of numerical strength, the PLAN has already surpassed the U.S. Navy in total number of combatants, and in each ship class with the exception of nuclear submarines and aircraft carriers.⁷ While China is working to close this gap, it is simultaneously fielding equipment designed to neutralize these extremely expensive and vulnerable platforms.⁸ This thesis asserts that China's modernization programs have yielded sufficiently innovative technology that it already possesses the ability to deter armed U.S. intervention in Asia due to the destructive potential it can inflict on U.S. forces.

This thesis identifies a combined total of 79 instances of technological innovation in the PLAN and PLAAF since 1970. Of those 79 instances, half occurred in the last 15 years, while nearly one-fifth (15) took place in the last five years, including all of China's globally significant innovations. Several of the most significant technologies fulfill multiple categories of innovation: nuclear submarine propulsion, AIP, DF-21D, YJ-12, PL-21, JY-50, and KG-300G. Additionally, some innovations only fulfill one or two increase categories but still constitute significant capabilities: multiplex data link, YJ-18, PL-12, JY-26 and JY-27A. The DF-21D, YJ-12, PL-12, JY-26, JY-27A, and JY-50 all constitute global level innovations as they incorporate technological capabilities not seen anywhere else.

Chinese modernization has been based on what it calls counter-RMA. This involves finding efficient methods to take advantage of the technological gap between

⁶ James Mulvenon and David Finkelstein, *China's Revolution in Doctrinal Affairs: Emerging Trends in the Operational Art of the Chinese People's Liberation Army* (Alexandria, VA: The CNA Corporation, 2005), 314–15.

⁷ James R. Holmes, "China's Navy Is Already Challenging the US in Asia," *The Diplomat*, October 16, 2014, <http://thediplomat.com/2014/10/chinas-navy-is-already-challenging-the-us-in-asia/>.

⁸ Bill Gertz, "China Military Buildup Shifts Balance of Power in Asia in Beijing's Favor: Congressional Report Warns the Danger of U.S.-China Conflict Is Rising," *The Washington Free Beacon*, October 13, 2014, <http://freebeacon.com/national-security/china-military-buildup-shifts-balance-of-power-in-asia-in-beijings-favor/>.

China and potential adversaries to turn enemy strengths into weaknesses. This has primarily been accomplished through innovations in both weapons and the systems that support them.⁹ In parallel with its counter-RMA, China is also focused on overall modernization of its forces and does not accept its current technological capabilities as a limiting factor.

B. IMPORTANCE

It is nearly impossible to pick up a newspaper, browse a media outlet, or read a professional journal today without encountering some article on the rise of China and the challenges it brings for the United States and for Asia. Current U.S. military doctrine is based on military strength gained through technological superiority; thus China's capacity for military innovation is a key concern in maintaining this advantage.¹⁰ This doctrine assumes two things: the first is that staying ahead in innovation is essential to maintaining military dominance and second is that other nations will not be able to challenge or counter the U.S. technology advantage. In the words of Dombrowski, "The United States needs to aggressively innovate just to maintain its international position in the face of technological globalization."¹¹ Robert Paarlberg asserts that applied more broadly, military dominance comes from the ability to innovate technology.¹² If China is in fact innovating in its defense modernization, then it can leverage this to challenge U.S. military superiority or counter it through targeted, asymmetric advantages. Chinese military leaders have themselves acknowledged that this is an essential element of PLA strategy.¹³ If this is the case, then the United States must alter its doctrine to prepare for a world in which its technology no longer provides a substantial military advantage.

⁹ Andrew Scobell, David Lai, and Roy Kamphausen, *Chinese Lessons from Other Peoples' Wars* (Carlisle Barracks, PA: Strategic Studies Institute, 2011), 14, <http://www.strategicstudiesinstitute.army.mil/pdffiles/PUB1090.pdf>.

¹⁰ Paul Johnston, "Doctrine Is Not Enough: The Effect of Doctrine on the Behavior of Armies," *Parameters* 30, no. 3 (2000): 33.

¹¹ Peter J. Dombrowski and Eugene Gholz, *Buying Military Transformation: Technological Innovation and the Defense Industry* (New York, NY: Columbia University Press, 2006), 137.

¹² Robert L. Paarlberg, "Knowledge as Power: Science, Military Dominance, and US Security," *International Security* 29, no. 1 (2004): 122.

¹³ Thomas J. Christensen, "Posing Problems without Catching up: China's Rise and Challenges for US Security Policy," *International Security* 25, no. 4 (2001): 9.

For the period beginning after WWII and continuing through today, many analysts use the United States as the standard against which military technology and innovation capability are measured.¹⁴ This association happens primarily for two reasons. First, since WWII, the United States has been the major source of innovation in military affairs with technology such as the atomic bomb, GPS guided munitions, and stealth to name a few. Second, the United States is currently the global hegemon, meaning that it is de facto measure of superior technology, providing the yardstick against which militaries are measured.

Using the United States as the standard for military innovation is flawed for three reasons, however. First, using the United States as the standard sets an unrealistic baseline for innovation, and comparisons against the United States do not account for individual circumstances.¹⁵ At the end of WWII, the United States was arguably the most advanced nation in the world; it possessed a strong economy, vast natural resources, a growing population, and the only industrial base not devastated by the war.¹⁶ It had a significant head start on every other country in this regard. For example, if comparisons to the United States were all that mattered, the launch of China's first successful satellite occurred 12 years too late to be considered groundbreaking. When viewed objectively as the product of a national innovation program, however, the launch of *Dong Fang Hong I* was no less innovative than the launch of *Explorer I*.

Because of this disparity, there is a distinction between what counts as innovation for this thesis and how others consider innovation in a global context; for innovation to be recognized in the global context, it must be compared to all technologies fielded by all countries. For this thesis, analysis will focus on country-level innovation—that is,

¹⁴Bates Gill and Lonnie Henley, *China and the Revolution in Military Affairs*. (Carlisle Barracks, PA: Strategic Studies Institute, May 1996), 4–5, <http://oai.dtic.mil/oai/oai?verb=getRecord&metadataPrefix=html&identifier=ADA311483>. Ibid.; Michael Beckley, “China’s Century? Why America’s Edge Will Endure,” *International Security* 36, no. 3 (2011): 70; Michael C. Horowitz, *The Diffusion of Military Power: Causes and Consequences for International Politics* (Princeton, NJ: Princeton University Press, 2010), 4.

¹⁵ Peter Cowhey, “The Third Wave: Innovation and Strategic Military Capacity in the Future,” *SITC-NWC Policy Briefs* 2013, no. 9 (2013): 1, <http://escholarship.org/uc/item/5s5173w8.pdf>.

¹⁶ Benjamin A. Taylor, “Military Innovation in the Rise and Fall of Great Powers: Lessons for America” (Master’s Thesis, Naval Postgraduate School, 2011), 91–92, <http://hdl.handle.net/10945/5616>.

innovation with a country's past and current capabilities as the important referents. The reasons for this are discussed below.

Country-level innovation proves useful for analysis because historical examples show that a nation may build its innovation potential without breaking out on the global forum, and therefore may be ignored by intelligence analysts. This view is supported by Grissom's research that shows how, in many cases, military intelligence had significant information describing innovations of other countries but discounted it due to views that were constrained by context and cultural bias.¹⁷ Because these analysts only focused on global innovation, they dismissed country-level innovations and the context they provide for innovative capacity, and subsequently refused to believe that certain nations could produce globally significant technological advances. One example of this is the U.S. intelligence service's response to Japan's innovations in aircraft and torpedo technology prior to 1945.¹⁸

Second, just because the United States is currently the leader in innovating technologies, does not mean this will continue to be the case, and there is no guarantee that it will be the nation to develop the next revolutionary technology. Many nations and empires fell from great power status when their rivals successfully innovated.¹⁹ There is already analysis suggesting that the U.S. military is currently suffering from structural problems making it less likely to innovate great military advantages in the future.²⁰ Additionally, some scholars such as Cowen argue that the United States gained its advantage through the mobilization of resources that constituted "low hanging fruit," and that this early advantage has run its course.²¹

¹⁷ Adam Grissom, "The Future of Military Innovation Studies," *The Journal of Strategic Studies* 29, no. 5 (2006): 919.

¹⁸ Thomas G. Mahnken, *Uncovering Ways of War: US Intelligence and Foreign Military Innovation, 1918-1941* (Ithaca, NY: Cornell University Press, 2002), 4.

¹⁹ Taylor, "Military Innovation in the Rise and Fall of Great Powers," ix.

²⁰ Ibid., 108.

²¹ Tyler Cowen, *The Great Stagnation: How America Ate All the Low-Hanging Fruit of Modern History, Got Sick, and Will (eventually) Feel Better*, eSpecial (London: Penguin, 2011).

Third, as Beckley summarizes in his research, military technological superiority alone is not the determining factor in war, nor is numerical superiority; rather the winning nation benefits from a combination of resources, technology, and efficiency.²² In subsequent research, Beckley describes how nations use their resources and efficiency to create the necessary innovation in order to sustain this cycle.²³ China does not necessarily need to invent technology that is superior to that of the United States.²⁴ In fact, part of China's current strategy is to leverage its current equipment in order to take advantage of its technology gap with the United States in what it deems a counter-revolution in military affairs.²⁵ China only has to develop technology advanced enough to leverage its vast resources into an advantage, which China can then use to sustain its own cycle, similar to the methods undertaken by the United States during its rise.²⁶

Answering the question, "How much of China's military modernization counts as innovation?" allows for an objective analysis of China, in order to judge its true capabilities. This will show how effective innovation programs have been within the PLA and project likely trends for the future. Only after we stop making comparisons to the United States and set a standard to determine whether a technology counts as innovation, can further comparisons be drawn between different nations.

The ability for China to innovate, even if only in relation to its past ability, provides indications for innovative capacity and potential for future innovation in the global context. If the global context were all that mattered, then analysis would ignore nations who close the innovation gap with competitors, or which innovate sufficiently to create an asymmetric advantage. Further, if analysis only focuses on innovation on the global scale, then it can miss important indicators of innovation potential until the military balance has already shifted, often with disastrous results. If Chinese innovation is in fact successful as evidenced by the results of PLA modernization efforts, then U.S.

²² Michael Beckley, "Economic Development and Military Effectiveness," *The Journal of Strategic Studies* 33, no. 1 (2010): 44.

²³ Beckley, "China's Century?," 54–56.

²⁴ Christensen, "Posing Problems without Catching up," 7.

²⁵ *Ibid.*, 22, 27.

²⁶ Beckley, "China's Century?," 75.

strategy and doctrine must change if it wishes to successfully respond to a modern China.²⁷

C. LITERATURE REVIEW

China has been the topic of a growing amount of academic literature over the past 20 years both in general, and with more specific focus on the PLA. The study of innovation, and military innovation, goes back even further. The subsets of these categories of literature that are relevant to this thesis are divided into four themes: general business innovation, general military innovation, China's military modernization, and China's military innovation. Each of these groups contains sources that are useful for analyzing and understanding what elements of China's military modernization consist of innovation. The most relevant gap where this thesis can contribute is that current studies of Chinese innovation lack a focused analysis of the technological outputs of China's military modernization programs. In Chapter II, this thesis explores current definitions of innovation to determine which is most fitting for this analysis as well as develops a standard by which innovative military technology can be recognized.

The oldest and broadest set of literature is focused on innovation in industry and business. With the vital importance of the military industrial complex, and dual use of industry, this body of work is essential to understanding innovation. The biggest critique of this literature is that most of it is written by analysts who look at innovation from a U.S. perspective instead of considering the context and culture of each country.²⁸ This means that the general elements must be separated from those influenced by the comparisons to the United States. These authors argue that in order to truly judge innovation potential, an analytic approach needs to be taken to assess the inputs, processes, and resultant outputs that result in new technology.²⁹

²⁷ Christensen, "Posing Problems without Catching up," 7.

²⁸ Cowhey, "The Third Wave," 1.

²⁹ Tai Ming Cheung, Thomas G. Mahnken, and Andrew L. Ross, "Frameworks for Analyzing Chinese Defense and Military Innovation," *SITC* 2011, no. Policy Brief 27 (2011): 77, <http://escholarship.org/uc/item/5cr8j76s.pdf>.

Another shortcoming of this literature for how it applies to China is that it is financially oriented, focusing on how businesses can find customers for innovative products and secure sources of research funding for innovation.³⁰ Neither of these are a major concern in military innovation, especially as it applies to the PLA.

Within this category there are, authors like Yuan who discuss the evolution of China's S&T sector and its relationship with innovation over time.³¹ Yuan determines that China is implementing policies and coordination within its S&T sector, which is resulting in creative solutions, allowing innovation to occur.³² Other authors such as Brockhoff and Davis analyze innovation in the Chinese defense industry from a business standpoint, examining the evolution of drivers of innovation and the benefits of the dual use system.³³ Dombrowski focuses on the relationship in the United States between the defense industry and the military to ultimately identify solutions to the political and financial challenges of innovation.³⁴ All of these sources provide a useful breakdown of the complexities of trying to study innovation. For this thesis, the main usefulness in this body of work is that it includes general frameworks for assessing the products of innovation, as well as explains how and why China is actually promoting a serious focus on innovation. Despite the focus on innovation in business, these concepts and frameworks are applicable to the military sector as well and describe how to identify innovation, which will help in defining a standard for innovation.

Within this literature, Dombrowski's framework claims that innovation consists of three key phases: invention, proposal, and implementation.³⁵ Garstka's framework on innovation can be simplified into the three categories of doctrine, organization, and

³⁰ Dombrowski and Gholz, *Buying Military Transformation*, 20.

³¹ Yuan, "Evolution and System Characteristics of China's Science, Technology, and Innovation Policies," 2.

³² *Ibid.*, 3.

³³ Brockhoff and Guan, "Innovation via New Ventures as a Conversion Strategy for the Chinese Defense Industry," 53.

³⁴ Dombrowski and Gholz, *Buying Military Transformation*, 145.

³⁵ *Ibid.*, 2.

technology.³⁶ He also lays out a simplified spectrum of innovation: incremental, modular, radical, and architectural.³⁷ Garstka's work appears to be the foundation for Cheung's later analysis of military innovation. This thesis accepts Dombrowski's concept of three components and focuses on his implementation phase as the critical identifier of innovation. It then combines this with Garstka and Cheung's framework to narrow down technology as the key element for analysis.

The second category is literature that focuses on general military innovation. The common aim of this work is to determine how the process of innovation in the military occurs. Russell breaks down U.S. operations in recent wars, focusing on the processes involved in doctrinal innovation and notes that new doctrine tends to follow technological innovation.³⁸ He concludes that during combat a lack of doctrine allows true innovation to occur.³⁹ Horowitz offers insight into how innovations diffuse through a globalized society and develops a method of understanding and predicting the incentives that drive nations to respond to military innovation by adopting, copying, or countering new products through their own innovation.⁴⁰

This group also includes studies done on historical instances of military technological innovation. Rosen studies past military innovation successes which he breaks into three categories: peacetime, wartime, and technological.⁴¹ Rosen determines that historically, in the United States, military intelligence only has a very loose connection with technological innovation and has not been very successful at assessing other countries' innovation in a manner that can drive U.S. innovation.⁴² While his main

³⁶ John Garstka, "A Conceptual Framework for Innovation in Capability Development," in *Crosscutting Issues in International Transformation: Interactions and Innovations Among People, Organizations, Processes, and Technology* (Washington, DC: National Defense University, 2009), 39–41, <http://oai.dtic.mil/oai/oai?verb=getRecord&metadataPrefix=html&identifier=ADA512355>.

³⁷ Ibid., 33–34.

³⁸ James Russell, *Innovation, Transformation, and War: Counterinsurgency Operations in Anbar and Ninewa Provinces, Iraq, 2005–2007* (Stanford, CA: Stanford University Press, 2010), 208.

³⁹ Ibid., 220.

⁴⁰ Horowitz, *The Diffusion of Military Power*, ix.

⁴¹ Stephen Peter Rosen, *Winning the next War: Innovation and the Modern Military* (Ithaca, NY: Cornell University Press, 1994), 7.

⁴² Ibid., 253.

conclusions are that national innovation tends to be successful independent of funding and external technological threats, he also provides specific instances where an accurate assessment of enemy innovation allowed for the development of technological counters.⁴³ Rosen's assertion that innovation continues even in austere fiscal environments also proves useful when applied to instances of austere foreign assistance. This is seen as China continues to develop and produce innovative technologies even following the Sino-Soviet split, and again during its post 1989 isolation from the west.

Barry Posen adds to this work by identifying the drivers of military innovation, specifically during peacetime.⁴⁴ Posen also argues that innovation in military doctrine will be a rare occurrence, and that any definition of innovation that requires doctrinal change will likely discount significant advances until they are used in war.⁴⁵ In his work, Mahnken determines that nations have difficulty identifying and assessing new and innovative technology being developed by others.⁴⁶ Millett and Murray provide examples for what constitutes innovation in military technology as well as ways to categorize it.⁴⁷ This categorization will be further explained in Chapter II as the basis for the three increases approach utilized by this thesis. Despite their excellent analysis, neither study actually defines innovation. Collectively this category provides justification for concentrating on technological innovation and the dangers of setting the innovation bar so high that it discounts critical technology indicators and advances.

The third category of literature focuses specifically on Chinese military modernization. Considerable study has been done on this topic, specifically by

⁴³ Rosen, *Winning the next War*, 220, 252.

⁴⁴ Barry Posen, *The Sources of Military Doctrine: France, Britain, and Germany between the World Wars* (Ithaca, NY: Cornell University Press, 1986), 46.

⁴⁵ *Ibid.*, 55.

⁴⁶ Thomas G. Mahnken, *Technology and the American Way of War* (New York, NY: Columbia University Press, 2008), 80–84.

⁴⁷ Williamson R. Murray and Allan R. Millett, *Military Innovation in the Interwar Period* (Cambridge University Press, 1998), 557–645.

organizations such as RAND, the Army's Strategic Studies Institute, and IHS Jane's.⁴⁸ There are also authors like Cole and Cordesman who focus on the products China's modernization.⁴⁹ This group tends to study PLA equipment, doctrine, organization, and training. In the studies on equipment being utilized by the PLA the focus is on capabilities and quantity, rather than innovative qualities.⁵⁰

These authors also examine the reorganization of China's defense industry over time, including the increase in R&D funding from both the government and private sectors within China.⁵¹ The analysts who study China's military modernization tend to fall into two main groups. The first believe that China is rapidly acquiring highly advanced technology and will soon challenge the United States in military capability for example; Cole concludes that China will have a modern, integrated military by 2020.⁵²

The second group consists of authors such as Beckley, Eland, and Shambaugh, who believe that PLA modernization is reliant on foreign assistance and will not prove a challenge to the United States in the near future.⁵³ A common theme for both groups is that China will likely have problems adapting organization and doctrine.⁵⁴ This view,

⁴⁸ Keith Crane et al., *Modernizing China's Military: Opportunities and Constraints* (Santa Monica, CA: RAND Corporation, 2005), <http://www.rand.org/pubs/monographs/MG260-1.html>; Roy Kamphausen, David Lai, and Travis Tanner, *Assessing the People's Liberation Army in the Hu Jintao Era* (Carlisle Barracks, PA: Strategic Studies Institute, 2014), <http://oai.dtic.mil/oai/oai?verb=getRecord&metadataPrefix=html&identifier=ADA599540>; Jane's, *Global Naval Trends and Outlook Report* (IHS Jane's: Defense & Security Intelligence and Analysis, 2014), <http://www.ihs.com/products/janes/defence/download-naval-trends.aspx>.

⁴⁹ Bernard D. Cole, *The Great Wall at Sea: China's Navy in the Twenty-First Century* (Annapolis, MD: Naval Institute Press, 2010), 86; Anthony H. Cordesman and Martin Kleiber, *Chinese Military Modernization: Force Development and Strategic Capabilities*, vol. 23 (Washington, DC: CSIS, 2007), 174.

⁵⁰ Crane et al., *Modernizing China's Military*, 4–5.

⁵¹ Yuan, "Evolution and System Characteristics of China's Science, Technology, and Innovation Policies," 2–3; Tai Ming Cheung, *Fortifying China: The Struggle to Build a Modern Defense Economy* (Ithaca, NY: Cornell University Press, 2009), 21.

⁵² Cole, *The Great Wall at Sea*, 202.

⁵³ Beckley, "China's Century?," 77; Ivan Eland, "Is Chinese Military Modernization a Threat to the United States?," *Policy Analysis*, no. 465 (2003):12–13; David L. Shambaugh, *Modernizing China's military: progress, problems, and prospects* (Berkeley: University of California Press, 2002), 282.

⁵⁴ Gill and Henley, *China and the Revolution in Military Affairs.*, 31–32; Ivan Eland, "Is Chinese Military Modernization a Threat to the United States?," 2012, 6, <http://object.cato.org/publications/policy-analysis/is-chinese-military-modernization-threat-united-states>; Cheung, *Forging China's Military Might*, 39.

however, is a shortcoming in both groups, which is shown through actual developments in the PLA since these works were published. Recent analysis by the DOD notes that PLA doctrine and tactics have evolved and adapted to U.S. capabilities, as well as China's technological modernization.⁵⁵ For this reason, as further laid out in Chapter II, this thesis will focus on the technological aspect of innovation. While this will constitute a lower standard of innovation than other analyses, it more accurately reflects innovation potential for the reasons discussed.

The fourth category of literature examines Chinese military innovation itself, albeit in a broad sense. This group is primarily led by Tai Ming Cheung and has recently made significant efforts to break down and examine China's periods of defense innovation.⁵⁶ In particular Cheung has applied many of the principles from the general innovation literature to assess the inputs and processes of China's defense modernization programs to determine that it is making organizational progress, but not yet reaping the outputs of a truly successful program.⁵⁷

What this body of literature lacks, however, is an analysis on the outputs of these programs. Cheung and Ross both admit that they have not yet applied their framework to China's modernization programs, and when discussing innovation they pick specific examples that they have already deemed as innovative.⁵⁸ Specifically there is a scarcity of studies on the innovative qualities of fielded equipment; this offers an area where this thesis can apply the hallmarks of innovation from Rosen's work to China's modernizing forces. Such a study provides insight into capabilities, measures of success, and future potential.

Cheung and Cordesman have also recently produced in-depth research on the relationships between the Chinese state, the PLA, and the defense industrial sector in order to identify the drivers of modernization through organizations such as SASTIND

⁵⁵ *Annual Report to Congress: Military and Security Developments Involving the People's Republic of China 2014* (Office of the Secretary of Defense, 2014), 12, http://www.defense.gov/pubs/2014_China_Report_FINAL.pdf.

⁵⁶ Cheung, "Chinese Defense Economy's Long March," 326.

⁵⁷ Cheung, *Forging China's Military Might*, 15–18.

⁵⁸ Cheung, Mahnken, and Ross, "Frameworks for Analyzing Chinese Defense."

and COSTIND.⁵⁹ Their consensus is that China is developing technology in specific areas faster than military doctrine can keep up.⁶⁰ As outlined in Chapter II, however, researchers have determined that this is a hallmark typical of innovative countries, and military doctrine adapts based on both the security situation and capabilities provided through technological innovations. Cheung and Cordesman discuss a few successful programs and conclude that China will continue to lag behind in innovation because as Cheung concludes, China is focused on “pockets of excellence in a landscape of technological mediocrity.”⁶¹ After coming to this conclusion, these analysts are now shifting to study the organizational aspects of China’s innovation to determine its future potential; rather than continuing to analyze the innovative products of current modernization efforts.

There is a subset of this literature, which proposes frameworks for analyzing current Chinese military innovation, as well as future innovation potential. Cheung and Ross collaborate to propose the main framework, though they have yet to apply it to China.⁶² This framework is useful for assessing the degree and category of existing innovation, but does not cover how to determine when a technology actually counts as innovation.

Cheung and Ross’s framework breaks innovation into a spectrum containing seven stages, within which to place the components of military innovation.⁶³ This framework is composed of six lenses through which to view the inputs, process, and output of innovation: (1) the components of innovation: technology, doctrine, and organization; (2) the capacity to innovate: that is, innovation potential; (3) the process of innovation: speculation, experimentation, and implementation; (4) the degree of

⁵⁹ Cheung, Mahnken, and Ross, “Frameworks for Analyzing Chinese Defense,” 58–61; Cheung, *Fortifying China*; Cordesman and Kleiber, *Chinese Military Modernization*, 23:178.

⁶⁰ Cheung, Mahnken, and Ross, “Frameworks for Analyzing Chinese Defense,” 39.

⁶¹ Cheung, *Forging China’s Military Might*, 274.

⁶² Cheung, Mahnken, and Ross, “Frameworks for Analyzing Chinese Defense”; Andrew L. Ross, “On Military Innovation: Toward an Analytical Framework,” *SITC* 2010, no. Policy Brief 1 (2010), <http://escholarship.org/uc/item/3d0795p8.pdf>.

⁶³ Cheung, Mahnken, and Ross, “Frameworks for Analyzing Chinese Defense,” 79.

innovation: from duplicative imitation to radical innovation; (5) the scope of innovation; and (6) systems of innovation.⁶⁴

Cheung uses the innovation triad from business literature, which holds that innovation can occur in one of three categories: Technology, Organization, and Doctrine.⁶⁵ His framework also discusses the outputs of innovation as having seven different levels on spectrum: Duplicative Imitation, Creative Imitation, Creative Adaptation, Incremental Innovation, Architectural Innovation, Component or Modular Innovation, and Radical Innovation.⁶⁶ The problem with this scale is that while it proves useful for assessing production capability, not all of the steps on Cheung's scale fit the definition of innovation adopted in this thesis and in other work. Additionally the requirements for some of the levels are vague, blurring the transition from one to the next.

The result is that currently this area of study has some broad analysis spread across processes, inputs, outputs, policy, strategy, and doctrine. With this disparate list of topics, it becomes necessary to break them down and focus on specific ones to gain the best granularity. Even Cheung agrees that a true assessment of innovation “requires the examination of a broad range of tangible and intangible science, technology, and innovation indicators.”⁶⁷

Despite the focus of literature on China's modernization, however, there is little literature that actually assesses the success of Chinese military innovation programs based on their outputs: the actual hardware being produced and utilized. The current studies have not applied an analytic framework to military modernization programs in a way that can provide measures of innovation success by determining what elements actually count as innovation. Is China getting better at modernizing and innovating? What are China's specific successes and failures?

⁶⁴ Cheung, Mahnken, and Ross, “Frameworks for Analyzing Chinese Defense,” 77.

⁶⁵ Ibid., 78.

⁶⁶ Ibid., 79.

⁶⁷ Cheung, “J-20 Fighter Aircraft,” 5.

This thesis applies theories and concepts of the innovation literature to Chinese military modernization. It attempts to fill in the gap left by Cheung and Ross, who have proposed frameworks to assess where on the spectrum innovation lies, but not yet applied these frameworks to the PLA, nor have they determined what the baseline for innovation is. This standard is then applied to China's military modernization programs across PLA forces responsible for power projection. This limits analysis to military forces that are the foundation of China's current A2AD strategy. This thesis examines the outputs of the modernization programs for each relevant service and determines how much of China's military modernization counts as technological innovation, in order to provide a measure of effectiveness. These results provide a list of technologies, which can then be plugged in to the existing frameworks to determine the quality of innovation taking place and whether that quality moves up Cheung and Ross's spectrum over time. Additionally this work can then be combined with other research on the inputs and processes of Chinese military innovation to provide a look at the whole spectrum of the innovation chain in China.

D. POTENTIAL EXPLANATIONS AND RESEARCH DESIGN

To answer to the question of "How much of Chinese military modernization counts as innovation?" this thesis measures what percentage of new equipment in each service is innovative. In order to apply this measure, it has adopted its own standard and criteria for assessment. This helps in assessing how effective China is at innovating as well as determining whether, over time China is getting better at it.

As explained in Chapter II, this thesis establishes the following criteria and standard for innovation. Military innovation provides new ways of generating military power by either significantly increasing effectiveness or changing military function, and it is intended to enhance a country's ability to fight wars. To meet this criterion, a technology must provide an increase in one of three categories: efficiency, capability, or organization.

Instead of defining what constitutes innovation and using that to determine how much innovation is occurring, many analysts typically list one or two programs as

examples of current innovation to base conclusions off of.⁶⁸ This has led Cheung to conclude that China is “making steady progress in building up its innovation capabilities,” although he and many others believe that these are only incremental innovations.⁶⁹ If this view is correct, then China is only able to incrementally improve its technologies and cannot produce global level innovations. Additionally this view dismisses incremental improvements that can cumulatively result in innovation.

An alternative view is that much of China’s military modernization is made up of innovative advances. These advances may not be seen as on par with products developed by the United States, but that does not mean they are not innovative. According to the seminal work of the Chinese military strategist Sun Tzu, “an Army may be likened to water, for just as flowing water avoids strength and strikes weakness.”⁷⁰ It does not make sense that China would base its entire strategy on countering the technological strength of its rivals with similar strengths. Instead, China is focusing on creating strength through technology advances in specific areas where it believes it can exploit American weakness. This is resulting in innovations that are different from what many would commonly accept as global level innovations.

Additionally in chapter six point 19, Sun Tzu claims in that, “knowing the place and the time of the coming battle, we may concentrate from the greatest distances in order to fight.”⁷¹ This is a fitting description of China’s A2AD strategy. It is obvious that any conflict in Asia will occur within what is commonly referred to as the second island chain.⁷² Thus if the U.S. wishes to act militarily on behalf of its Asian allies or against China, it must do so by projecting forces to this area. China however, need only respond with weapons that have the ability to strike targets within this region, and can be launched from within its own territory.

⁶⁸ Cheung, “J-20 Fighter Aircraft,” 2.

⁶⁹ Tai Ming Cheung, *China’s Emergence as a Defense Technological Power* (New York, NY: Routledge, 2013), 1.

⁷⁰ Sun Tzu, *The Art of War*, trans. Lionel Giles (Luzac & Company, 1910), 53.

⁷¹ Ibid., 6–19.

⁷² Ronald O’Rourke, *China Naval Modernization: Implications for U.S. Navy Capabilities—Background and Issues for Congress*, CRS Report for Congress, (December 23, 2014), 4.

While the common belief is that China is only focusing on incremental innovation and is moderately efficient at it, that answer lacks sufficient justification. Any assessment of must be supported by an examination of the products of PLA modernization as this military hardware is likely leading to doctrinal changes within the PLA. This thesis finds that significant innovation programs support China's growing desires for international prestige and widespread modernization.⁷³ Since 1970, the PLAN and PLAAF have fielded 79 innovative technologies, including some that count as innovation on the global scale. Furthermore, these innovations are leading to adaptation in PLA doctrine as it seeks to better use these technologies in support of its military strategy.⁷⁴

E. THESIS ORGANIZATION

This thesis has determined that China's military modernization efforts have resulted in an increasing amount of technological innovations in the PLAN and PLAAF. In the past decade these innovations have resulted in several technologies that count as innovation on the global scale.

This thesis begins with Chapter II describing innovation and the chosen standard for analyzing Chinese military innovation. It sets the groundwork for defining military innovation, as well as establishes which components of innovation it focuses on. It also examines other frameworks that have been proposed for analyzing military innovation. Finally it establishes the chosen framework and justification.

Chapters III and IV are dedicated to analyzing two power projection arms of China's military that are key to A2AD: PLA Naval Forces and PLA Air and Counter-Air Forces. Analyzing each force in its own chapter provides background on that service, including a timeline of equipment modernization that can be used to identify the progression of innovation as well as separate innovation from incremental modernization. It applies the developed standard to these forces in order to determine that since 1970 the PLAN has fielded 41 innovative technologies and the PLAAF has fielded 38.

⁷³ Posen, *The Sources of Military Doctrine*, 46.

⁷⁴ Scobell, Lai, and Kamphausen, *Chinese Lessons from Other Peoples' Wars*; Mulvenon and Finkelstein, *China's Revolution in Doctrinal Affairs: Emerging Trends in the Operational Art of the Chinese People's Liberation Army*.

Finally, Chapter V includes an overall assessment of China's innovation progress and its future potential. It also offers suggestions for the direction of future, complementary research. Finally, it concludes with lessons and recommendations for U.S. policy makers and planners going forward in light of this assessment.

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II. STANDARD OF INNOVATION

The purpose of this chapter is to adopt a definition of innovation in order to create a standard, which can then be used to judge whether equipment fielded as part of the PLA's modernization counts as innovation. There are several views on what defines innovation just as there are different frameworks for assessing it, and multiple areas in which it can occur. This chapter will first adopt a definition of innovation, narrow the focus of research to a specific phase (military technology), rely on past case studies to establish a standard and lay out how innovation will be identified, and finally establish the scope of analysis.

This thesis holds that the concept of innovation as being global is overly narrow and pays insufficient attention to important country-level developments as indicators of global innovation potential. In missing these innovations, it sets the stage for a dangerous security situation in that innovative technologies may not be acknowledged until they are used in war. This concept is best summarized by Mahnken, "it is easy to ignore, overlook, dismiss, or misinterpret evidence of foreign innovation. In particular, preconceptions about the character and conduct of war, ethnocentrism, and incomplete information frequently conspire to prevent observers from understanding new ways of war in peacetime."⁷⁵

A. DEFINING INNOVATION

In order to answer its central question, this thesis takes three steps. The first is establishing a definition for military innovation. The second is developing a measurable standard that is then used to assess whether an aspect of PLA modernization counts as innovation. The third step is applying the definition and standard to equipment fielded by PLA forces that form the foundation of China's military strategy.

This thesis first establishes its own definition innovation and more specifically military innovation, as there are a myriad of definitions proposed by literature on the

⁷⁵ Thomas G. Mahnken, "China's Anti-Access Strategy in Historical and Theoretical Perspective," *Journal of Strategic Studies* 34, no. 3 (June 17, 2011): 308, doi:10.1080/01402390.2011.574971.

subject. A distinction must be made between innovation and invention; this is where elements of business literature and military studies prove helpful. According to Garstka and Cheung, invention is the first occurrence of an idea for a new product whereas innovation is defined as the first attempt to carry it out in practice.⁷⁶ Additionally, business literature in general defines innovation as resulting in new or improved technologies.⁷⁷

A distinction must also be made between innovation and incremental modernization. According to Murray, many modernization efforts consist of a series of incremental improvements, the sum of which can count as innovation, and he refers to this as evolutionary innovation.⁷⁸ Cheung takes this idea and condenses it into a single stage on his innovation spectrum.⁷⁹

Cowhey describes military innovation as “the successful strategic military application of a technology change.”⁸⁰ This leaves the question of how to adequately define change and how to measure success outside of victory in war. Ross’s definition of military innovation is more useful, but broader: “Change in the ways and means employed by militaries to prepare for, fight, and win wars.”⁸¹ This definition brings in the concepts of organization and tactics as well as equipment.

Grissom asserts that, in order to be considered successful, military innovation must do three things: (1) Change the manner in which military formations function in the field, (2) be significant in scope and impact, and (3) be equated with greater military effectiveness.⁸² Grissom’s concept of greater military effectiveness somewhat helps to define Cowhey’s idea of successful, but then introduces another question, how to

⁷⁶ Cheung, *Forging China’s Military Might*, 15.

⁷⁷ Ibid., 16.

⁷⁸ Russell, *Innovation, Transformation, and War*, 29.

⁷⁹ Cheung, Mahnken, and Ross, “Frameworks for Analyzing Chinese Defense.”

⁸⁰ Peter Cowhey, “The Third Wave: Innovation and Strategic Military Capacity in the Future,” *SITC-NWC Policy Briefs* 2013, no. 9 (2013): 1, <http://escholarship.org/uc/item/5s5173w8.pdf>.

⁸¹ Ross, “On Military Innovation,” 187.

⁸² Adam Grissom, “The Future of Military Innovation Studies,” *The Journal of Strategic Studies* 29, no. 5 (2006): 907.

quantify “significant,” while also implying that incremental changes do not constitute innovation. Horowitz agrees with most of Grissom’s elements of innovation, but counters that it is not important whether an innovation actually increases effectiveness and efficiency, it must only be intended to.⁸³ These explanations help narrow down how innovation will affect a military, but often leave issues with interpretation or standards. For example, according to Grissom’s definition, a technology must be used in war before it can be determined to be innovative, hardly an effective method for peacetime planning, especially against a country such as China, which has not fought a war since 1979.⁸⁴

The concern with using the previous definitions lies in limiting the scope to technologies that are truly innovative, while still including non-revolutionary advances and cumulative incremental improvements. Further, the nature of modern war and interwar innovation means that limiting the definition to only include technology or doctrine tested in combat can lead to the same shortcomings exhibited by the U.S. military going in to WWII.⁸⁵ As such, this thesis defines military innovation as new ways of generating military power, which attempt to increase effectiveness or change the manner in which a military functions in the field, to enhance a country’s ability to fight wars.

This definition fits the needs of this thesis in that it acknowledges that the intention of innovation is to increase efficiency or effectiveness. It also does not require that a technology be used in war to count, instead requiring only that it be fielded or implemented by a military. This effectively combines elements common to the previous definitions in order to arrive at one that can be applied during war as well as peacetime, and is not limited to specific categories or roles.

B. PHASES OF INNOVATION

Now that this thesis has established a definition of innovation suitable for answering the question, it narrows the focus of research to a specific phase of innovation.

⁸³ Horowitz, *The Diffusion of Military Power*, 18, 22.

⁸⁴ Scobell, Lai, and Kamphausen, *Chinese Lessons from Other Peoples’ Wars*, 1.

⁸⁵ Mahnken, *Uncovering Ways of War*.

As explained by Dombrowski, innovation consists of three phases: conception (invention), proposal, and implementation.⁸⁶ These elements equate to Cheung's "process of innovation."⁸⁷ The majority of recent analysis on military innovation emphasizes the conception and proposal processes.⁸⁸ This thesis focuses on the implementation phase of innovation, which consists of technologies and hardware produced by the innovation process and subsequently adopted for military use.

Additionally, based on the previous literature reviewed, this thesis presumes that innovation in the implementation phase can be achieved in three possible areas: technology, organization, and doctrine.⁸⁹ Analyzing all three components of innovation is a serious undertaking and beyond the scope of this thesis; as such it focuses only on the technological measure of innovation in PLA modernization.

Focusing solely on technology will inevitably lower the bar for what counts as innovation in relation to other works in this area. The purpose of adopting this approach is not to overinflate China's capabilities or the threat it poses, rather there are three main reasons for why the focus on technology is important. First, many scholars today consider doctrinal innovation the key indicator and are focusing on that aspect of China's modernization; however studies have shown it is technology that actually tends to lead doctrinal innovation.⁹⁰ This thesis' argument that technology leads organizational innovation is based on Russell's conclusion that "military organizations show a propensity to develop complex structures that match the technological complexity of their weapons systems."⁹¹ Russell further argues that the absence of doctrine allows militaries to come up with their own solutions to the environment in which they find themselves.⁹² Chinese military leaders echo this sentiment in PLA education publications by stating

⁸⁶ Dombrowski and Gholz, *Buying Military Transformation*, 2.

⁸⁷ Cheung, Mahnken, and Ross, "Frameworks for Analyzing Chinese Defense," 77.

⁸⁸ Dombrowski and Gholz, *Buying Military Transformation*, 2.

⁸⁹ Cheung, *Forging China's Military Might*, 23.

⁹⁰ Ibid., 23–24, 39.

⁹¹ Russell, *Innovation, Transformation, and War*, 208.

⁹² Ibid., 207.

that the PLA must develop strategies to use the equipment it has already developed to defeat the United States, while still continuing to develop new technologies, rather than merely waiting to develop superior technology.⁹³ With this in mind, an assessment of innovation should begin with a focus on technology, which will then provide indicators for potential military innovation in the other areas.

Second, studies have shown that historically militaries do not actually follow their doctrine when war breaks out; instead they either fall back on their culture or innovate on the battlefield based on their technological capabilities and the threat.⁹⁴ This means any analysis that focuses primarily on doctrinal or organizational innovation is inadequate as a true measure of innovation if it does not first consider technology. This is even more important in the context of Mahnken's work, as he concludes that historically nations tend to either miss or dismiss the technological innovations of their potential adversaries.⁹⁵

Third, technology can still be innovative if it is not employed in new doctrine. Britain and France were the first to develop the tank, yet Germany's doctrine for its use was superior.⁹⁶ This doctrinal difference does not make the initial development the tank any less innovative. In fact if successful doctrine were the criteria for defining a technological innovation, then France's early development of the tank would not be considered innovative at all. Its first doctrinal application was a failure, and Germany merely copied the technology and added its own doctrine.⁹⁷ This distinction is covered by the definition adopted by this thesis, which accepts that the intent of a technology change is what matters.

⁹³ Christensen, "Posing Problems without Catching up," 9.

⁹⁴ Johnston, "Doctrine Is Not Enough," 30.

⁹⁵ Mahnken, *Technology and the American Way of War*, 80–84; Murray and Millett, *Military Innovation in the Interwar Period*, 84.

⁹⁶ Murray and Millett, *Military Innovation in the Interwar Period*, 6.

⁹⁷ Ibid.

C. CREATING A STANDARD

Now that this thesis has accepted a definition of innovation, established which phase it will analyze, and determined an area of focus, the next step is to establish a standard to determine how much of Chinese military modernization actually counts as innovation. There are two primary differences between this thesis and current efforts in this field toward developing frameworks through which to view innovation. The first is that this thesis focuses on the implementation phase of innovation, which is evidenced by military equipment or hardware.

The second difference is that it assesses what products actually count as innovation, whereas other analysts, like Cheung and Ross, are trying to analyze where on a spectrum certain advances fall. Their work does not define innovation and does not provide a standard for determining what counts. They have created frameworks for evaluating where advances and technologies fall without yet determining if and when something crosses the threshold into innovation or whether every advance should be placed within the spectrum and innovation determined later. Additionally they have not yet actually applied their framework.⁹⁸ As explained in Chapter I, Cheung's innovation output spectrum has seven stages: Duplicative Imitation, Creative Imitation, Creative Adaptation, Incremental Innovation, Architectural Innovation, Component or Modular Innovation, and Radical Innovation.⁹⁹

In order to determine if a technology crosses the threshold into innovation it is assessed based on a standard. This thesis holds that for a technology to be considered innovative it must fit into one or more of three primary categories. While a technology is only required to fit one category to count, the nature of innovation means that it is possible for a single technology advance to fulfill multiple categories. The three categories can be thought of as the three increases.

The first category is efficiency increase: An example of this is the development of precision-guided munitions. This capability allowed one ton of PGMs to replace 12–20

⁹⁸ Ross, "On Military Innovation."

⁹⁹ Cheung, Mahnken, and Ross, "Frameworks for Analyzing Chinese Defense," 79.

tons of unguided weapons; a significant increase in efficiency.¹⁰⁰ The second category is capability increase: An example of this is the development of aircraft, which gave armies access to the sky as a dimension of warfare for the purposes of reconnaissance and weapons delivery. The third category is organizational increase, (this can be thought of as changing the way in which units operate): Blue Force Tracker is a great example of this type of innovation. Each commander and soldier now has the ability to track the exact battlefield position of all friendly units in real time, as well as communicate with individual soldiers, providing better coordination and allowing more complex maneuvers.¹⁰¹

D. IDENTIFYING INNOVATION

When applying its standard, this thesis uses specific functions to identify instances of innovation for each increase. Efficiency increases are identified by technological developments that result in significant improvements in areas such as range, speed, and accuracy. Other efficiency increases involve a significant decrease in the number of weapons or platforms necessary to destroy a target. For this research, an improvement of greater than 33% over existing equipment counts as “significant.” Other literature on innovation commonly discusses efficiency and other “significant” improvements without identifying a quantitative measure for what those actually mean. As such this thesis adopts 33%, however when analyzing the PLA, this thesis determined that most advances, which met the 33% threshold would also meet a threshold of 50% improvement.

Organizational increases are identified in that they fundamentally alter the way in which a military interacts with its units and weapons. This is commonly seen with changes in coordination, communication, detection, and targeting capabilities. Specifically these elements see improvements in areas such as range, portability, and cross platform compatibility. While a 20% range increase would not meet the threshold

¹⁰⁰ Mahnken, *Technology and the American Way of War*, 221.

¹⁰¹ Ibid., 222.

for efficiency, it may for example provide an organizational increase by allowing strikes beyond the detection ranges of enemy sensors.

Capability increases are identified in that they provide new avenues for waging war or new methods of employing current platforms that did not exist previously. This is typically seen with the introduction of radical new technologies or the employment of existing technologies in new ways. This requires analyzing both new technologies as well as crossover technologies. An example of this is China's crossover use of ballistic missile technology to target enemy surface ships; the DF-21D was developed from existing medium range ballistic missile (MRBM) designs directly modified to target aircraft carriers, resulting in new weapon, the anti-ship ballistic missile (ASBM). Similarly the CM-400AKG utilized the same core technology, but applied in a different way, which resulted in a scaled down ballistic missile that can be launched from light attack aircraft to target surface ships. Both of these weapons resulted from innovative approaches to anti-surface warfare by using existing technology in new ways.

Further Mahnken, Millett and Murray all identified that innovative technology historically has filled one of several functions, and those functions can be used to help determine innovation. In order to help identify a technology as innovative it can be examined to see if it performs any of the following. (1) Counter critical enemy technology, or eliminate a critical weakness in one's own force by providing a solution that offers either significant advantages or an asymmetric advantage. The development of the aircraft carrier to project power beyond the range of battleship fleets fits this function.¹⁰² (2) Provide a new form or way of war. For example, the development of strategic bombers is heralded by Mahnken as a "truly new approach to war waging."¹⁰³ (3) Create a fundamental, basic change in the context in which war takes place. The radar based British air defense network fundamentally altered how aerial battles were conducted in the Second World War.¹⁰⁴ (4) Provide alternatives to conventional ways of warfare. Fighting in the cyber realm allows an attacker to shut down critical systems or

¹⁰² Murray and Millett, *Military Innovation in the Interwar Period*, 643.

¹⁰³ Ibid., 556.

¹⁰⁴ Ibid., iii.

infrastructure without the need for endangering personnel through bombing.¹⁰⁵ (5) Change the relationship between weapon system and operator. Systems that reduce operator workload and increase effectiveness such as lead computing gun sights on aircraft and automatic detection and tracking modes of modern radar perform this function.¹⁰⁶ (6) Comprise an entirely new technology. This function is typically performed by radical new technologies, historical examples being the development of aircraft and atomic weapons.¹⁰⁷

This thesis adds a seventh function, that of a pure efficiency increase. This concept comes from business literature, which focuses on how important efficiency is within the realm of innovation. This concept carries over to warfare given the nature of human factors in warfare and costs of replacing trained soldiers. This function is sometimes lost in other work, because efficiency often creates such an advantage that it counters critical enemy technology. An example of this is the increase in range of missiles. While a range increase falls under the category of efficiency, it can result in enough of an advantage to provide a first strike capability by allowing weapons to be launched outside of enemy detection or weapons ranges. In this case it is considered to fill the function of countering critical enemy technology, rather than efficiency.

The seven functions are a result of common themes pulled from research by authors such as Mahnken, Garstka, Murray and Millett into the history of military technological advancements and methods for identifying it.¹⁰⁸ Many times innovative technologies are hard to identify. History has shown that many innovative advances are not acknowledged by military intelligence until they are fielded in battle, and in instances where they are recognized; intelligence either ignores or dismisses them. This is where the three increases and seven functions prove useful in identifying innovation.

¹⁰⁵ Murray and Millett, *Military Innovation in the Interwar Period*, 557.

¹⁰⁶ Ibid., 635.

¹⁰⁷ Cowhey, "The Third Wave," 2.

¹⁰⁸ Mahnken, *Uncovering Ways of War*; Garstka, "Conceptual Framework for Innovation"; Murray and Millett, *Military Innovation in the Interwar Period*.

E. SCOPE OF ANALYSIS

In order to assess technological innovation in the PLA, a capability starting point must first be established, and this thesis sets this as the state of the PLA in 1970. This provides an ideal starting point, as prior to 1970, China relied almost exclusively on military equipment procured from other nations.¹⁰⁹ After 1970, China's indigenous development and modernization programs began yielding results.¹¹⁰ In order to augment domestic development, China has taken part in collaborative efforts with other nations as well as continuing to purchase some foreign systems. Most of these instances however, appear specifically designed to temporarily fill a capability gap, and have eventually been followed or replaced with indigenous technology.¹¹¹

Any equipment developed by China, which improves upon existing capabilities can then have the previously developed standard of innovation applied. This thesis requires new equipment be fielded operationally by a military (IOC) in order to be considered. This is opposed to first launch or first successful test, which are actually indications of invention rather than innovation. This matches the criteria previously established by the definition of innovation, in that equipment must actually be fielded by a military in order to be considered military innovation.

There is some difficulty in separating innovation from incremental modernization, without losing the innovation that can often result from the accumulation of incremental modernization. This distinction is captured through the use of a starting point for analysis, which allows for the examination of capability development over time. This thesis tracks innovative changes from one technological advance to the next, as well as innovations that result from cumulative advances. It must be noted that the PLA has experienced both incremental modernization as well as innovation.

An incremental modernization is the development of multiple models within a single platform such as the J-8 series of multi-role fighter aircraft. In total China has

¹⁰⁹ Cheung, *Forging China's Military Might*, 31; Cheung, *Fortifying China*, 24–27.

¹¹⁰ Cheung, *Forging China's Military Might*, 33; Cheung, *Fortifying China*, 33.

¹¹¹ I base this assessment on the modernization timeline I have constructed by analyzing IHS Jane's military industry reports on China as well as PLA military hardware information. <http://janes.ihs.com>.

fielded 18 variants of the J-8 since it achieved IOC in 1980, with some featuring as much as a 70% redesign over previous models. Overall capability increased with each successive model, but that increase did not always count as innovation. For example, the J-8B benefitted from the capabilities of three incremental advances in cockpit design, which when combined resulted in an entirely new relationship between the aircraft and its pilot. Conversely, the J-8G incorporated significant technology improvements over all previous models such that it counts as a single instance of innovation within this incremental development.¹¹²

This thesis breaks military equipment into three categories: (1) Platforms such as ships, vehicles, and aircraft, (2) Weapons such as missiles and torpedoes, and (3) Systems such as data link and radar. This analysis is based on the principle that each platform has its own capabilities, as well as associated systems and weapons, while the systems and weapons themselves can be utilized across many platforms. Each piece of equipment is examined at its IOC and compared against existing PLA capabilities at that time.

F. SOURCES

Data for this thesis is limited to research in unclassified sources. There are obvious shortcomings imposed by limiting data to this medium, mainly that some information on the most recent PLA equipment is not openly available. This is not considered a significant limitation for research, however, as China is trying to sell much of its military equipment to other nations through venues such as international arms exhibitions. While sub-components and specifics of how certain systems work may be concealed, overall capabilities are openly professed, and it is these capabilities that this thesis holds to the innovation standard. Additionally, sources such as IHS Jane's, FAS, and RAND are extremely reliable in the information they provide. The shortcomings of open source information are addressed in Gormley, Erickson, and Yuan's study of China's cruise missile program: "The most authoritative documents tend to cover general

¹¹² Jane's, "China—Air Force," *Jane's Sentinel Security Assessment—China and Northeast Asia*, February 10, 2015, <https://janes.ihs.com/CustomPages/Janes/DisplayPage.aspx?DocType=Reference&ItemId=+++1303145&Pubabbrev=CNA>.

issues only; for specifics, it is often necessary to consult sources whose provenance is less clear.”¹¹³ They then go on to explain that when using unclassified sources such as Jane’s and FAS, the diversity of data points combined with years of experience and accurate reporting have shown reliability.¹¹⁴

¹¹³ Gormley, Erickson, and Yuan, *A Low-Visibility Force Multiplier*, 93.

¹¹⁴ Ibid.

III. INNOVATION IN THE PLAN

A. OVERVIEW

This chapter will discuss innovation in Chinese naval platforms, weapons, and systems. While the PLAN does operate aircraft, they will be covered in Chapter IV as part of air forces. There are a total of 153 PLAN modernizations examined by this thesis. Out of those modernizations this thesis identifies 41 instances of technological innovation in China's naval forces, of which several demonstrate particularly impressive advances and several others pose sharp challenges to U.S. capabilities. Since 1970, 27% of modernization efforts resulted in some form of innovation. The most important technologies identified in this chapter are the YJ-12, DF-21D, air-independent propulsion (AIP), nuclear submarine propulsion, and data link. While some of the more significant innovations meet the criteria for multiple innovation categories, others are significant while only filling one, an example being data link systems, which ties all of the PLAN's modern weapons and platforms together in a way that has resulted in China developing new doctrine for carrying out its anti-access area denial (A2AD) strategy.

For this chapter, unless otherwise cited, information on equipment capabilities and IOC is derived from Jane's Online, and has been corroborated by The Naval Institute, The Federation of American Scientists, and Global Firepower Online. Other sources referenced include SinoDefense.com, IISS, and CRS reports. This chapter first reviews the definition of innovation, provides a brief history of the PLAN, and then discusses instances of innovation broken down by decade starting with 1970.

China has a unique program for naval development in that when implementing new technologies, the PLA will sometimes produce as few as two platforms in a new class before moving on to the next technology change. CRS reports from 2008 and 2014 suggest that this ensures that the PLAN can focus on fielding the most advanced fleet possible, and "a key purpose of at least some of these classes may have been to serve as stepping stones in a plan to modernize the PLA Navy's surface combatant technology

incrementally before committing to larger-scale series production.”¹¹⁵ Cole agrees with this assessment, arguing it “speaks to a willingness to incorporate developments as they emerge.”¹¹⁶

Initially, the focus of modernization was to produce cheap, low visibility weapons such as torpedoes and mines. More recently, this focus has extended to China’s anti-ship missile (ASM) programs. Development has not been limited to these weapons however, as the PLAN has benefitted from innovations in modern platforms, and more importantly a significant output of interconnected systems. Saunders aptly claims that this has resulted in the potential for China’s “system of systems” ability to rival that of the United States’.¹¹⁷

B. INNOVATION

From Chapter II, this thesis defines military innovation as new ways of generating military power, which attempt to increase effectiveness or change the manner in which a military functions in the field, to enhance a country’s ability to fight wars. It is worth stating again that this definition focuses purely on technology innovation, and only in reference to China’s own past capabilities. This standard is lower than what other analysts might use and will likely result in more technologies being considered innovative. As stated in Chapter II, the purpose of adopting this approach is not to inflate China’s accomplishments or the threat it poses, but to establish an indication of the progress that it is making in order to judge future potential.

According to the definition adopted by this thesis, organizational increases fundamentally alter the way in which a military interacts with its own units or the enemy as commonly seen with changes in coordination, communication, detection, and targeting

¹¹⁵ Ronald O’Rourke, *China Naval Modernization: Implications for U.S. Navy Capabilities—Background and Issues for Congress*, CRS Report for Congress, (February 4, 2008), 21; O’Rourke, *China Naval Modernization: Implications for U.S. Navy Capabilities—Background and Issues for Congress*, December 23, 2014, 26.

¹¹⁶ Cole, *The Great Wall at Sea*, 197.

¹¹⁷ Phillip C. Saunders et al., *The Chinese Navy: Expanding Capabilities, Evolving Roles* (Washington, DC: National Defense University, 2011), 258, 275, <http://ndupress.ndu.edu/Portals/68/Documents/Books/chinese-navy.pdf>.

capabilities. Efficiency increases produce at least a 33% improvement in areas such as range, speed, and accuracy, or involve a significant decrease in the number of weapons or platforms that must be employed to destroy a target. Capability increases provide new avenues for waging war or new methods of employing existing technology that did not exist previously, such as typically seen with the introduction of radical new technologies or the employment of existing technologies in new ways.

C. HISTORICAL OVERVIEW OF THE PLAN

The PLAN has undergone several changes since the PRC was established in 1949. At that time China had no navy to speak of; rather, the PLAN inherited a collection of WWII-era patrol craft left by the KMT. Throughout the 1950s, the PLAN gained some Soviet shipbuilding techniques and built up a coastal force consisting primarily of patrol craft and diesel submarines in order to protect the mainland from Taiwanese incursions.¹¹⁸

Following the Sino-Soviet split in 1958, China focused on a continental people's war strategy, which lacked a focus on naval capability and caused the PLAN to fall into disarray. Additionally, The Great Leap Forward and Cultural Revolution promoted anti-intellectualism, which significantly set back all PLA modernization efforts.¹¹⁹ This situation lasted until 1978, when a new Chinese strategy emerged and the PLAN was given the mission of assisting in the process of re-taking Taiwan while preventing American intervention.¹²⁰ This constituted a need for the PLAN to operate in the near seas, its first mission outside of coastal waters.

The role of the PLAN expanded throughout the 1980s, culminating in 1985 when China developed its first island chain strategy. The PLAN's mission became stopping an adversary at a line roughly connecting Okinawa, Taiwan, and the Philippines. China's

¹¹⁸ *The People's Liberation Army Navy: A Modern Navy with Chinese Characteristics* (Suitland, MD: Office of Naval Intelligence, August 2009), 3–4, <http://www.fas.org/irp/agency/oni/pla-navy.pdf>.

¹¹⁹ Jane's, "China–Navy," *Jane's Sentinel Security Assessment–China and Northeast Asia*, February 10, 2015, <https://janes.ihs.com/CustomPages/Janes/DisplayPage.aspx?DocType=Reference&ItemId=+++1303146&Pubabbrev=CNA>.

¹²⁰ *The People's Liberation Army Navy: A Modern Navy with Chinese Characteristics*, 5–6.

strategy at this time was to defend the industrial base, which was built around coastal cities.¹²¹

The 1990s marked a critical turning point for the PLAN. In 1993, China became a net importer of energy, and this resulted in the need to create a true blue water Navy that could secure China's economic interests.¹²² This caused a focus on maritime security and defense of the sea lines of communication (SLOC) through which this energy travels.¹²³ More recently, the role of the PLAN has further expanded to include defense out to the second island chain, anti-piracy operations, and military operations other than war (MOOTW).¹²⁴

This growth has happened primarily for two reasons. First, as China has modernized and grown economically, the PRC desires recognition as a superpower. Chinese leaders consider a strong naval force capable of conducting global operations as a hallmark of this status.¹²⁵ Second, the threats against China have grown and the PRC seeks to prevent U.S. intervention in regional affairs. The capabilities of modern weapons mean that for the PLAN to protect the Chinese mainland, it must defeat its enemy farther out to sea than in the past, which has come to be known as China's A2AD strategy. In 2008, the DOD report to Congress summarized China's A2AD strategy as, "the capacity to hold surface ships at risk through a layered capability reaching out to the 'second island chain' . . . to strike surface ships on the high seas or their onshore support infrastructure."¹²⁶

¹²¹ Paul H.B. Godwin, "From Continent to Periphery: PLA Doctrine, Strategy and Capabilities Towards 2000," *The China Quarterly*, no. 146 (June 1996): 464–65.

¹²² Taylor M. Fravel and Alexander Liebman, "Beyond the Moat: The PLAN's Evolving Interests and Potential Influence," in *The Chinese Navy: Expanding Capabilities, Evolving Roles* (Washington, DC: National Defense University, 2011), 55.

¹²³ Daniel Hartnett and Frederic Velluci, "Toward a Maritime Security Strategy: An Analysis of Chinese Views Since the Early 1990s," in *The Chinese Navy: Expanding Capabilities, Evolving Roles* (Government Printing Office, 2011), 81–82.

¹²⁴ Mahnken, "China's Anti-Access Strategy in Historical and Theoretical Perspective," 317.

¹²⁵ Andrew S. Erickson and Andrew R. Wilson, "China's Aircraft Carrier Dilemma," *Naval War College Review* 59, no. 4 (2006): 3.

¹²⁶ *Annual Report to Congress: Military Power of the People's Republic of China* (Office of the Secretary of Defense, 2008), 23, http://www.defense.gov/pubs/pdfs/China_Military_Power_Report_2008.pdf.

Thus the PLAN is the foundation of China's A2AD strategy. This has seen the PLAN benefit from an increasing budget, greater roles in both military and non-military operations, and the influx and development of a significant amount of equipment, which will be seen in the innovations below.¹²⁷

D. INNOVATION IN NAVAL PLATFORMS

A summary of innovative technologies in PLAN platform modernization, as discussed in this chapter, is shown in Table 1. Despite China's rapid naval modernization, few of the advances have resulted in innovative platform development. Instead, these platforms tend to benefit from the addition of innovative weapons or systems.

Table 1. PLA Naval Innovation: Platforms

Platform	Organizational	Efficiency	Capability
Jin SSBN	X		X
Fuchi AORH	X	X	
Song SS	X		X
Houbei PTG		X	
Type 726 LCAC	X		
Jiangdao FFL		X	X

A summary of innovative technologies in PLAN weapon modernization as discussed in this chapter is shown in Table 2. PLAN weapons have consistently grown more capable, in some cases having no foreign counterparts. Furthermore, many of the more advanced weapons pose credible challenges to current air defense systems. In a 2011 article, Mahnken assessed that, "the most innovative system that China seeks is the ability to attack moving ships at sea far from China's shores."¹²⁸ Since then, China has fielded several weapons which achieve that goal, and a recent analysis argues that China has made significant progress with its anti-ship cruise missiles (ASCM), producing many world-class weapons.¹²⁹ Furthermore, some of these highly advanced ASCMs have no

¹²⁷ Fravel and Liebman, "Beyond the Moat," 75.

¹²⁸ Mahnken, "China's Anti-Access Strategy in Historical and Theoretical Perspective," 314.

¹²⁹ Gormley, Erickson, and Yuan, *A Low-Visibility Force Multiplier*, 15.

comparable Western counterparts and, due to their capabilities, provide a high probability of success against even the most advanced defensive systems.

Table 2. PLA Naval Innovation: Weapons

Weapon	Organizational	Efficiency	Capability
YU-3	X	X	
YU-5	X	X	
YU-6		X	
YU-7		X	X
EM-52	X	X	
Mine Belt	X	X	
ASROC	X	X	
YJ-12	X	X	X
YJ-18		X	X
CM-708UNA	X	X	
C-701		X	
C-801		X	X
DF-21D	X	X	X
JL-1			X
JL-1A		X	
JL-2		X	

A summary of innovative technologies identified in PLAN systems modernization as discussed below is shown in Table 3. Initial PLAN systems innovation focused on creating a modern warship with integrated combat information center. Since 2000, however, this has shifted to an increasingly advanced collection of interconnected systems, which greatly increases PLAN capabilities while countering specific enemy strengths.

Table 3. PLA Naval Innovation: Systems

System	Organizational	Efficiency	Capability
Nuclear Submarine Propulsion	X	X	X
CIC		X	
SATCOM	X		
SATNAV	X		
Data Link	X		X
Towed Array Sonar	X		
ECM			X
ESM			X
OPTRONICS		X	
Missile Data Link	X	X	
APAR		X	X
Stealth			X
Multiplex Data Link	X	X	
AESA		X	
Automated Maintenance Reporting		X	
AIP	X	X	X
Submarine Quieting	X		X
IADS	X	X	
Double Pressure Hull		X	

1. Innovation from 1970–1980

The only innovation identified during this period is the YU-3 torpedo. The YU-3 had a maximum range of 13km, which provided 40% increase over previous torpedoes as well as incorporated acoustic homing.¹³⁰ This fundamentally alters the tactics for conducting submarine attacks, as well as provides a change in the relationship between the weapon and operator, as it incorporated stand-alone guidance. This reduced the complexity of obtaining a firing solution and subsequently operator workload expanding the weapon engagement envelope. The YU-3 counts as an efficiency increase due to its increased range, but also constitutes an organizational increase due to the way acoustic homing technology changed how submarines conduct attacks.

¹³⁰ Jane's, "Jane's Naval Weapons," accessed November 20, 2014, <https://janes.ihs.com/Default.aspx?Category=JNW>.

2. Innovation from 1980–1990

During this period, PLAN modernization benefitted from the increased importance of the PLAN's role China's Taiwan strategy. The 10 innovative technologies fielded by the PLAN during this period show a focus on low visibility, easily fielded methods of deterring U.S. intervention. These technologies show the PLAN's first efforts to integrate sensors and weapons into a single combat system.

a. Weapons

The YU-5 torpedo incorporated a new type of propulsion system that doubled its range over previous PLAN designs, as well as utilized wire guidance for targeting updates, and a new proximity warhead increasing effectiveness.¹³¹ This further changed the relationship between weapon and operator over the YU-3. Now PLAN torpedoes could receive targeting updates after launch. This improves weapon accuracy and reduces the effectiveness of counter-measures constituting an efficiency increase. The increased range provided a larger engagement envelope, which increases lethality of the weapon, as well as increases survivability of the launching platform. Additionally, this places it outside the engagement range of most enemy weapons, which changes how submarines conduct attacks by giving them a first strike ability safely outside the range at which ships could launch a counter-attack.

Mines such as the EM-52 provide stealthy, cost-effective platform designed to neutralize both CVNs and SSNs.¹³² This advance covers two areas: first, it counters a critical enemy technology, the CVN and its defensive formations. Second, it changes the relationship between weapon and operator. By allowing remote operation and long operational life it provides a low-cost, easily implemented and controlled method for denying enemy ships and submarines, access to China's critical SLOCs.¹³³ Because they

¹³¹ Jane's, "Jane's Naval Weapons."

¹³² Jane's, "Chinese Sea Mines," *Jane's Weapons: Naval*, May 19, 2014, <https://janes.ihs.com/CustomPages/Janes/DisplayPage.aspx?DocType=Reference&ItemId=+++1499677&Pubabbrev=JNW>.

¹³³ Eric Wertheim, *The Naval Institute Guide to Combat Fleets of the World*, 15th ed. (Annapolis, MD: Naval Institute Press, 2007), 109.

can be remotely operated, this is accomplished without the traditional limitation of completely closing off mined areas to a nation's own forces. It allows friendly and neutral ships to safely transit mined waters without the use of safe lanes, which can be plotted by enemy surveillance. This greatly changes how fleets operate to defend SLOCs.

The development of the Mine Belt allows submarines to retain a full wartime complement of torpedoes and missiles, while still being able to conduct anti-access mining operations with as many as 50 mines per submarine.¹³⁴ This solves the limitation that mines impose in that they normally must take the place of other weapons in submarine launch tubes. Mine belts allow submarines to continue their normal operations in addition to conducting mine-warfare, without having to return to port in order to refit. This changes the relationship between the weapon and operator, as well as changing the context in which anti-surface warfare takes place. Prior to this innovation, intelligence analysts could determine a submarine's mission and capability based on its weapons load at the docks additionally, intelligence analysts could predict areas that had been mined based on when submarines returned to port in order to load torpedoes following mining operations. Mine belts count as an organizational increase by allowing submarines to mine SLOCs, while still maintaining normal anti-ship attack capabilities.

In addition to being significantly smaller than previous Chinese ASMs, the C-801 incorporated folding wing technology, which means that twice as many missiles could be carried in the same space.¹³⁵ This smaller size also allows the C-801 to be launched from a variety of aircraft in addition to surface vessels. Finally, the C-801 introduced the first instance of sea skimming capability in Chinese ASMs, which counters enemy radar and air defense technologies. This improved utilization of space counts as an efficiency increase, and the application of cruise missiles to light aircraft constitutes a capability increase.

¹³⁴ Scott C. Truver, "Taking Mines Seriously," *Naval War College Review* 65, no. 2 (2012), <http://www.usnwc.edu/getattachment/19669a3b-6795-406c-8924-106d7a5adb93/Taking-Mines-Seriously-Mine-Warfare-in-China-s-Ne>.

¹³⁵ Norman Friedman, *The Naval Institute Guide to World Naval Weapon Systems*, 5th ed. (Annapolis, MD: Naval Institute Press, 2006), 516.

The JL-1 constituted China's first submarine launched ballistic missile (SLBM) capability. This changed the context of China's nuclear deterrence forces, as submarines are not easily tracked and much more difficult to neutralize than land-based sites. This contributed to the first credible instance of a survivable second-strike capability.¹³⁶ While the missile itself reached IOC in 1987, it was only reliably deployed from test and evaluation submarines until the introduction of the Jin in 2007. The adaptation of inter-continental ballistic missile (ICBM) technology to submarines counts as a capability innovation.

b. Systems

The application of nuclear propulsion to submarines was first seen in the Han class and provided a nearly unlimited increase in submerged range, which fundamentally alters the way in which the PLAN can employ submarines. This innovation provides a solution to the critical weakness of conventional submarines (the requirement to periodically snorkel). These increases were achieved through the use of civilian nuclear power technology modified to work in a submarine, which also counts as a capability innovation. This provided the Han with a maximum speed of 25 knots, a 92% speed increase over previous PLAN submarines.¹³⁷ While this does fulfill an efficiency increase, the improvement is significant enough that it also changed the way submarines are employed. Instead of being forced to lie in wait at a chokepoint to execute frontal attacks, the Han's speed allows it to catch up to transiting ships and attack from all aspects. Furthermore, it has the capability to outrun most surface combatants, providing the ability to successfully escape following detection, increasing survivability. Nuclear submarine propulsion fulfills all three innovation categories. The drastic increase in speed fundamentally changed how submarines conduct attacks while also filling the criteria for efficiency increase. Finally, the application of nuclear reactors to a submarine counts as a capability innovation.

¹³⁶ Michael P. Pillsbury, *An Assessment of China's Anti-Satellite and Space Warfare Programs, Policies and Doctrines* (Washington, DC: U.S. China Economic Security Review Commission, 2008), 12, handle.dtic.mil/100.2/ADA476735.

¹³⁷ Jane's, "Jane's Fighting Ships," accessed November 20, 2014, https://janes.ihs.com/Default.aspx?Category=JFS_.

The use of satellites for navigation (SATNAV) and communication (SATCOM) was first demonstrated on the Ming SS, allowing more precise coordination, control, and secure communications while underway. In addition, this replaced the previous low frequency radio communications, which were easily intercepted and susceptible to exploitation by direction finding.¹³⁸ The use of satellite technology in this manner counts as an organization innovation because it fundamentally changes how fleet commanders interact with these platforms.

The development of the Type 88C data link allows ships to communicate with shore based radar sites, improving sensor coverage, allowing better coordination and reduced reaction times to threats. This resulted in a change in the context in which war takes place. This allows for much more complex maneuvers, as well as increased sensor coverage and cooperation among units.¹³⁹ Data link counts as an organizational innovation by giving fleets the ability to integrate a much greater amount of information on friendly and enemy movements.

The combat information center (CIC) links all of the ships sensors and weapons into a single control scheme providing a unified, integrated source of information as well as seamless handoff between weapons systems through each range of engagement, increasing effectiveness and reducing operator workload. CIC was first introduced as an incremental upgrade to the Luhui in the 1980s; however, the first ship built with a dedicated CIC was the Luhai in the late 1990s. It is considered the hallmark of modern warships, due to the manner in which it changes the relationship between weapon and operator.¹⁴⁰ CIC counts as efficiency innovation because it improves coordination and response time within individual platforms.

¹³⁸ Jane's, "Jane's Fighting Ships."

¹³⁹ Myron Hura et al., "Tactical Data Links," in *Interoperability: A Continuing Challenge in Coalition Air Operations* (RAND Corporation, 2000), http://www.rand.org/pubs/monograph_reports/MR1235.html.

¹⁴⁰ Jane's, "Chinese Command and Weapon Control Systems," *C4ISR & Mission Systems: Maritime*, September 3, 2014, janes.ihs.com/CustomPages/Janes/DisplayPage.aspx?DocType=News&ItemId=+++1498400&Pubabbrev=JC4IM.

Optoelectronics (OPTRONIC) such as the OFC-3 integrate several sensors such as electro-optics (EO), infra-red (IR), and low light (LL) into a self-contained system capable of being operated by a single person or as part of a larger integrated air defense system (IADS) to increase capability and weapons accuracy while decreasing reaction time and reducing operator workload. This counts as an efficiency innovation because it changes the relationship between weapon and operator to increase the combat effectiveness of a ship.

3. Innovation from 1990–2000

The 12 innovations fielded by the PLAN during this period are the result of the PLAN's expanding role to provide maritime security for its SLOCs. These capabilities allow the PLAN to reach farther through new technology in submarine, torpedo, and especially cruise missiles. This period saw the IOC of the YJ-12, one of the most capable anti-ship weapons currently in existence.

a. Platforms

When the Song SS reached IOC in 1999, it was China's first indigenous submarine capable of launching ASCMs while still submerged, allowing it to engage targets at much longer ranges and without exposing itself via surfacing. The C-801's attack range of 80km resulted in a 60% increase over torpedoes, and more recent ASCMs such as the CM-708UNA's 128km range provide a further improvement of 60%.¹⁴¹ This provided a counter to defensive fleet formations, specifically those based around an aircraft carrier. Additionally, this adds the capabilities of an entirely new class of weapons to submarines, which also provides for new targeting methods and integration with other fleet assets. When combined with over the horizon targeting, this allows the Song to remain undetected when carrying out an attack. The Song counts as both organizational and capability increases because it provided increased offensive range as

¹⁴¹ Wendell Minnick, "China Shows Off New Sub-Launched Missile at Zhuhai," *Defense News*, November 11, 2014, <http://www.defensenews.com/article/20141111/DEFREG03/311110028/China-Shows-Off-New-Sub-Launched-Missile-Zhuhai>.

well as incorporated new methods for conducting coordinated attacks through the application of ASCM technology to submarines.

b. Weapons

Anti-submarine rockets (ASROC) add between 3,000–5,000m to the maximum range of torpedoes.¹⁴² This serves to counter enemy submarine technology by allowing surface ships to engage submarines outside the range at which submarines can launch a counter attack. The Type 81 ASROC provided a 100% increase in effective torpedo range over its predecessor, the Soviet RBU-1200. The Type 87 ASROC further improved this by an additional 56%.¹⁴³ This is an organizational increase because it gives PLAN surface ships a credible counter to enemy submarine first strike capability.

The YU-6 incorporated wake homing capability that vastly improves effectiveness and decreases operator workload.¹⁴⁴ Wake homing changes the relationship between the weapon and operator by eliminating the need to acquire a targeting solution before firing the weapon. The YU-6 only has to be fired in the direction of a ship's wake, and the torpedo itself will determine target location and course on its own. The YU-6 counts as an efficiency innovation because it removes the requirement to calculate a firing solution, greatly simplifying the job of the operator.

The YU-7 torpedo has an operating depth of 400m, providing a 33% increase over previous PLAN torpedoes, allowing it to engage nuclear submarines down to the limit of their operating depth.¹⁴⁵ This counters a critical capability of nuclear submarines, which prior to the introduction of the YU-7 could dive deeper than PLAN torpedoes. The YU-7 is also the only lightweight torpedo in the PLAN inventory capable of being launched from surface ships as well as aircraft.¹⁴⁶ This extended ASW attack capability to aircraft, which vastly increases attack range over surface vessels. The YU-7 counts as efficiency

¹⁴² Wertheim, *The Naval Institute Guide to Combat Fleets of the World*, 109.

¹⁴³ Ibid.

¹⁴⁴ Jane's, "Jane's Naval Weapons."

¹⁴⁵ Patrick Tyler, *Running Critical: The Silent War, Rickover, and General Dynamics* (New York, NY: Harper & Row New York, 1986), 365.

¹⁴⁶ Jane's, "Jane's Naval Weapons."

innovation by significantly increasing operating depth to counter nuclear submarines; it also counts as a capability increase by providing anti-submarine attack technology to aircraft.

The C-701 introduced TV guidance and millimeter wave radar (MMW) targeting capability to ASMs. This changes how the weapon tracks targets, which greatly reduces the circular error probable (CEP) down to 5–10 meters and makes the job of the operator much easier by incorporating a fire and forget mode.¹⁴⁷ Both technologies also reduce susceptibility to countermeasures and jamming. The C-701 counts as an efficiency innovation because of its improved accuracy and counter-countermeasures ability.

c. Systems

Variable depth, towed array sonar technology first employed on the Luhuhu allows for the passive detection of submarines, which changes the way in which PLAN units operate at sea and defend against underwater threats. These systems include variable depth capability and provide the most effective method of detecting enemy submarines.¹⁴⁸ This counts as an organizational innovation because it fundamentally changes how surface ships can detect and track submarines by countering submarine technology that relies on acoustic stealth, provides early detection against torpedo launch with more precision, and unlike active sonar, does not alert a submarine to the fact that it has been detected.¹⁴⁹

Missile data link allows for weapons to be launched over the horizon, outside of detection range and have targeting information provided/updated mid-course, decreasing the chances of interception, as well as improving accuracy and lethality. This fundamentally changes the relationship between the weapon and operator, allowing one platform to launch the weapon from a safe location and the weapon can be updated either

¹⁴⁷ Jane's, "C-701 (YJ-7, Kosar)," *Jane's Air-Launched Weapons*, September 29, 2014, <https://janes.ihs.com/CustomPages/Janes/DisplayPage.aspx?DocType=Reference&ItemId=+++1307746&Pubabbrev=JALW>.

¹⁴⁸ Cole, *The Great Wall at Sea*, 194.

¹⁴⁹ David Fisher, "Images Show JF-17 Flying with CM-400AKG Hypersonic ASM," *IHS Jane's Defence Weekly*, October 22, 2014, <http://www.janes.com/article/44897/images-show-jf-17-flying-with-cm-400akg-hypersonic-asm>.

by expendable platforms, or stealthy ones.¹⁵⁰ Allowing units that are stealthy, expendable, or more survivable than the weapon launch platform to provide targeting data to weapons launched from more vulnerable platforms greatly changes fleet organization and operation. This application of data link counts as an organizational innovation because it protects the most vulnerable platforms, while simultaneously improving weapon accuracy.

The Type 821 electronic surveillance measures (ESM) provide the capability to passively detect an enemy in a new sensor spectrum. This changes the context in which war takes place as it allows a ship to detect enemy combatants and weapons without having to give up its own location. ESM counts as capability innovation because it provides access to a new spectrum of information for offensive and defensive operations.

The Type 928 electronic counter measures (ECM) provide non-consumable countermeasures against enemy weapon systems. This counters enemy weapon targeting technology without having to rely on expending a limited number of countermeasures or weapons trying to destroy it. ECM counts as capability innovation because it provides a new method for defeating enemy weapons.

Active phased array radar (APAR) automates anti-air detection, tracking, and target discrimination as well as increasing detection range.¹⁵¹ APAR counts as an efficiency innovation because it changes the relationship between weapon and operator, as well as changing the context in which war takes place, by allowing ships to detect and discriminate a broader array of targets at much longer ranges than previous designs.

Acoustic quieting technologies change the context of submarine operations in a manner similar to stealth technology. This category consists of several complementary technologies: anechoic tiles, shock absorbing engine mounts, and seven bladed propeller designs such as those first fielded on the Song vastly improve submarine quieting and propulsion efficiency. This capability was further expanded by on the Yuan SS with the

¹⁵⁰ Gormley, Erickson, and Yuan, *A Low-Visibility Force Multiplier*, 59.

¹⁵¹ Jane's, "Type 346 ('Dragon Eye')," *C4ISR & Mission Systems: Maritime*, January 16, 2015, <https://janes.ihs.com/CustomPages/Janes/DisplayPage.aspx?DocType=Reference&ItemId=+++1511843&Pubabbrev=JC4IM>.

addition of a rubberized sonar absorbent hull coating. These features count as capability innovations because they provide passive counters to enemy sonar technology.

The YJ-12 is arguably one of the most dangerous weapons fielded by the PLAN, or any military; it has a 500km range, ramjet engine, electronic countermeasures (ECM), electronic counter-counter measures (ECCM), data link, sea skimming, utilizes a multiple stage warhead, travels at Mach 4+, and can be carried by nearly any ship or aircraft operated by the PLA.¹⁵² A Naval War College study argues that the YJ-12 counters every air defense system currently fielded, including the U.S. Aegis radar and SM-2/3 system.¹⁵³ Additionally, it outranges competing ASMs like the Harpoon by a factor of 3.25.¹⁵⁴ This results in a weapon that can attack both land and sea targets at hypersonic speeds with a 5m CEP, and currently has no credible counters. The only comparable weapon currently fielded is the Russian KH-31, which has a lower speed, shorter range, and utilizes a less capable seeker. The YJ-12 achieves innovation in all three increase categories due to its significant range and speed, ability to defeat enemy IADS, and utilization of new propulsion technology.

¹⁵² Robert Haddick, "China's Most Dangerous Missile (So Far)," *War on the Rocks*, July 2, 2014, <http://warontherocks.com/2014/07/chinas-most-dangerous-missile-so-far/>.

¹⁵³ Vitaliy O. Pradun, "From Bottle Rockets to Lightning Bolts: China's Missile Revolution and PLA Strategy Against US Military Intervention," *Naval War College Review* 64, no. 2 (2011): 7–38.

¹⁵⁴ *Ibid.*, 13.



Figure 1. Anonymous Photo of YJ-12 ASCM¹⁵⁵

4. Innovation from 2000–2010

The 13 innovations fielded by the PLAN during this time are the result of the further expansion of Chinese strategy out to the second island chain. These technologies provide the ability for the PLAN to operate for extended periods of time at sea and further improves the automation and integration of weapons and systems.

a. *Platforms*

The Jin SSBN provided the PLAN's first operational submarine capable of reliably launching SLBMs, ensuring a survivable nuclear deterrent and vastly increasing striking range. This capability also allows the Jin to employ other weapons based on ICBM technology, like the DF-21D anti-ship ballistic missile (ASBM) and anti-satellite weapons (ASAT) such as the SC-19 and DN-2.¹⁵⁶ This comprises a new way of waging war, but also creates a fundamental change in the context of war by merging the survivability and stealth of submarines with the capabilities of nuclear weapons. This provides China a true credible first strike option, as well as a survivable second-strike

¹⁵⁵ Jane's, "YJ-12," *Jane's Air-Launched Weapons*, January 28, 2014, <https://janes.ihs.com/CustomPages/Janes/DisplayPage.aspx?DocType=Reference&ItemId=+++1307793&Pubabbrev=JALW>.

¹⁵⁶ O'Rourke, *China Naval Modernization: Implications for U.S. Navy Capabilities—Background and Issues for Congress*, February 4, 2008, 21.

capability.¹⁵⁷ The Jin counts as a capability increase because it was the first instance of SLBM technology fielded in a combat deployable Chinese submarine.

The Type 726 landing craft air cushioned (LCAC) introduced the capacity to conduct amphibious landings much quicker, and over longer distances than in the past, increasing the size of equipment and amount of forces that can be landed in a given amount of time.¹⁵⁸ This changes the conduct of amphibious assaults by allowing the vulnerable LPD size ships to remain farther away from shore defenses. For example, the use of LCACs would allow an amphibious assault launched from the Chinese mainland to reach Taiwan in just over an hour, which would allow an initial assault to be conducted without the use of larger ships at all. These advantages result in less stress and fatigue imparted to troops being transported, allowing them to maintain readiness during the transit.¹⁵⁹ This platform counts as organizational innovation because it changes the relationship between the craft and the operator in that it allows much smoother and shorter transits, bypasses traditional obstacles, and expands potential landing sites greatly changing the conduct of amphibious operations.¹⁶⁰

The Houbei class missile boat provides several innovations for guided missile patrol craft (PTG), including increased speed and stability in heavy seas, as well as stealth. While the top speed of the Houbei is not significantly greater than its predecessors, it can maintain this speed in much heavier seas, while still being stable enough to accurately launch weapons.¹⁶¹ Additionally, the Houbei can carry eight YJ-83 ASCMs, a 33% increase over the larger Houjian and a 100% increase over the Houxin

¹⁵⁷ Pillsbury, *An Assessment of China's Anti-Satellite and Space Warfare Programs, Policies and Doctrines*, 5.

¹⁵⁸ "Landing Craft, Air Cushion," *Global Security*, July 7, 2011, <http://www.globalsecurity.org/military/systems/ship/lcac.htm>.

¹⁵⁹ Samson C. Stevens and Michael G. Parsons, "Effects of Motion at Sea on Crew Performance: A Survey," *Marine Technology* 39, no. 1 (January 2002): 29–47.

¹⁶⁰ Pewter J. Thede, Richard C. Staats, and William S. Crowder, *Assessment of the Heavy Lift Landing Craft, Air Cushioned*. (McLean, VA: Logistics Management Institute, 1995), <http://oai.dtic.mil/oai/oai?verb=getRecord&metadataPrefix=html&identifier=ADA313340>.

¹⁶¹ "Houbei Class (Type 022) Fast Attack Craft, Missile," *Global Security*, May 5, 2013, <http://www.globalsecurity.org/military/world/china/houbei.htm>.

and Houdong.¹⁶² When combined, these capabilities increase survivability and lethality, while reducing operator workload and fatigue.¹⁶³ The increased stability of the Houbei changes the relationship between the weapon system and the operator. Stealth changes the context of war as covered in the systems section. These improvements constitute both efficiency and organizational increases. The Houbei counts as an efficiency innovation because it significantly increases weapons payload and effectiveness.

b. Weapons

Both upgrades to China's SLBMs have innovative characteristics. The JL-1A improved upon the JL-1 by increasing maximum range by 66% and improving accuracy through the addition of satellite and radar guidance to reduce its CEP from 700m to 50m.¹⁶⁴ The JL-2 increases range an additional 220% over the JL-1A. There is some doubt that the JL-2 is operational, but is included here due to China's claims that it has reached IOC following successful tests.¹⁶⁵ Additionally, 2014 CRS reports indicate that the JL-2 began operational deployment onboard a Jin SSBN.¹⁶⁶ Improvements to the JL series of SLBMs count as efficiency innovations because they significantly increase the range and improve the accuracy of China's SLBM arsenal.

c. Systems

The development of the HN-900 and Joint Service Integrated Data Link System (JSIDLS) multiplex data systems provide two-way information sharing across multiple platforms, allowing fleets to coordinate and share sensor data along with shore-based installations and all their associated weapons systems. This merges all sensors and targeting information for combatants, as well as integrates with ASM data links. These

¹⁶² Gormley, Erickson, and Yuan, *A Low-Visibility Force Multiplier*.

¹⁶³ Stevens and Parsons, "Effects of Motion at Sea on Crew Performance: A Survey."

¹⁶⁴ Jane's, "Jane's Strategic Weapon Systems," accessed November 20, 2014, <https://janes.ihs.com/Default.aspx?Category=JSWS>.

¹⁶⁵ Ibid.

¹⁶⁶ O'Rourke, *China Naval Modernization: Implications for U.S. Navy Capabilities—Background and Issues for Congress*, December 23, 2014; *Annual Report to Congress: Military and Security Developments Involving the People's Republic of China 2014*.

upgraded data link systems count as organizational innovations because all units in the fleet gain access to the same information, providing a complete threat picture, and allowing faster responses to orders, while the increased weapon accuracy and reduced reaction time constitutes an efficiency innovation.

AIP first fielded on the Yuan class submarine provides a non-nuclear means of power generation that does not require oxygen to operate while submerged. This solves the vulnerability imposed by conventional submarine propulsion (the requirement to routinely snorkel), but without the added expense and complexity imposed by nuclear propulsion. AIP improves the submerged speed, range, and stealth of non-nuclear submarines by reducing or even eliminating the need to continually re-surface in order to charge batteries. AIP counts as capability innovation because it uses an entirely new technology to provide nuclear endurance, with the stealth of electric propulsion.¹⁶⁷

The Type 730 close-in weapon system (CIWS) increased anti-air capability and vastly reduced operator workload and crew requirements by automating air defense. Additionally, since it is a closed loop system, it has a faster reaction time than the Soviet AK-630 it replaced, and provides independent operation in the event other defensive systems become damaged.¹⁶⁸ The pairing of radar, optics, and computer direction with a high rate of fire weapon provides a counter to enemy aircraft and anti-surface missiles. This capability is further expanded with the PLAN's first true IADS, introduced on the Luyang II, which is capable of intercepting cruise missiles with CIWS as well as the HHQ-10/FL-3000N missile system in tube launchers.¹⁶⁹ These systems can operate in isolation, but can also work as part of the integrated sensor suite in modern ships. Combined with the multiplex data systems, IADS now share targeting information across the fleet, providing the PLAN's first "area-defense" anti-air (AAW) system.¹⁷⁰ IADS

¹⁶⁷ O'Rourke, *China Naval Modernization: Implications for U.S. Navy Capabilities—Background and Issues for Congress*, December 23, 2014, 91.

¹⁶⁸ Jane's, "Jane's Naval Weapons."

¹⁶⁹ Pradun, "From Bottle Rockets to Lightning Bolts," 19.

¹⁷⁰ Cole, *The Great Wall at Sea*, 193.

counts as efficiency and organizational increases because it fundamentally changes the way in which PLAN fleets conduct self defense.

The automated maintenance reporting system first introduced on the Jiangkai II improves maintenance efficiency by making yard turnaround times shorter, increasing readiness and unit availability. This results in increased system efficiency and warship lethality, allowing fleets to spend more time at sea.¹⁷¹ This counts as an efficiency innovation because it changes the relationship between fleet planners, the operator, and the ship itself.

Double pressure hulled submarine design such as that seen on the Shang increases survivability significantly. This counters enemy torpedo technology by requiring the employment of at least twice as many weapons to achieve the same amount of damage.¹⁷²

Stealth features have been incorporated in all PLAN surface combatants introduced since 2004. This makes surface ships harder to detect and in many cases almost impossible to distinguish from smaller merchant traffic, denying enemy ships the advantage offered by long-range search radar. This decreases susceptibility to enemy sensors as well as decreases the range at which enemy weapons can be employed. Stealth counts as a capability innovation because it provides a capability increase by changing the context in which surface fleets fight.

PLAN advanced radar designs minimize operator workload as well as include stealth detection features. This is seen in the Dragon Eye APAR on the Luyang II and III. These detection systems negate the advantages of stealth, which changes the context in which war takes place.¹⁷³ This is further improved in China's active electronically scanned array (AESA) radars that further increase detection range and tracking against small air targets, such as cruise missiles. Because this is incorporated in the automatic

¹⁷¹ Cole, *The Great Wall at Sea*, 196.

¹⁷² Gerhardt Thamm, "Unravelling a Cold War Mystery," *Center for the Study of Intelligence* 52, no. 3 (September 16, 2008), <https://www.cia.gov/library/center-for-the-study-of-intelligence/csi-publications/csi-studies/studies/vol52no3/unravelling-a-cold-war-mystery.html>.

¹⁷³ Dave Majumdar, "Chinese and Russian Radars On Track To See Through U.S. Stealth," *USNI News*, July 30, 2014, <http://news.usni.org/2014/07/29/chinese-russian-radars-track-see-u-s-stealth..>

functions of the radar, it further improves the operator weapon relationship over APAR, as well as counters enemy weapon technology.

5. Innovation from 2010–2015

The six innovations fielded by the PLAN during this time are evidence of China's two goals of achieving recognition on the global scale as a superpower, and desire to deter U.S. intervention in a regional conflict. These technologies include China's first true global-level innovations, such as the DF-21D, which comprises a capability not yet fielded by any nation.

a. Platforms

The development of the Fuchi class of auxiliary ships changed fleet organization by incorporating the ability to replenish dry stores (food and ammunition) in addition to wet stores (fuel, oil, etc.) from the same platform while underway.¹⁷⁴ This provided PLAN fleets their first ability to operate globally, while halving the number of resupply ships needed.¹⁷⁵ This platform counts as efficiency innovation because it vastly increases the time conventional ships can spend on deployment, changing how fleets are organized and employed by providing full replenishment capability for blue water operations.

The Jiangdao FFL was the first instance of a modular ship design fielded by the PLAN, and provides a single platform capable of fulfilling the roles of several different ship classes.¹⁷⁶ It can be outfitted to conduct coastal patrol, AAW, anti-submarine (ASW), anti-surface (ASuW), and command and control roles.¹⁷⁷ This results in a change to the relationship between the platform and the operator as it provides a single ship class that can be mass-produced and configured to fill all fleet roles. This advance is designed

¹⁷⁴ Ridzwan Rahmat, "China Launches Fifth Fuchi Class Vessel," *IHS Jane's 360*, June 8, 2014, <http://www.janes.com/article/38887/china-launches-fifth-fuchi-class-vessel>.

¹⁷⁵ "AOR-X Future Integrated Replenishment Ship," *Global Security*, September 28, 2013, <http://www.globalsecurity.org/military/world/china/aor-x.htm>.

¹⁷⁶ "Type 056 Jiangdao Class Corvette," *Navy Recognition*, March 18, 2013, www.navyrecognition.com/index.php?option=com_content&task=view&id=941; "Jiangdao 056," accessed December 2, 2014, <http://www.mdc.idv.tw/mdc/navy/china/056.htm>.

¹⁷⁷ Jane's, "Jane's Fighting Ships."

to make training and maintenance more efficient, while increasing fleet size through standardized production without giving up capability. The Jiangdao counts as organizational as well as efficiency innovation because it allows a single platform to fill multiple fleet roles, giving fleet commanders greater flexibility.

b. Weapons

The recently released CM-708UNA incorporates many of the features of the YJ-12, but in a weapon that is submarine launched. It is hypersonic, sea skimming, and has a range of 128km, a combination of capabilities that counters multiple enemy defensive technologies and vastly increases the offensive range of submarines.¹⁷⁸ The CM-708UNA counts as an efficiency increase because it brings advanced cruise missile features to submarines, allowing them to strike with increased lethality.

The YJ-18 is the newest development in Chinese ASCM technology. It improves on some features of the YJ-12, while incorporating new ones. It is a dual-speed missile, starting off with a subsonic flight profile, and then accelerating to Mach 3+ when within 46km of the target. This is counter to traditional ASCMs, which either maintain speed, or slow down due to fuel exhaustion in the terminal phase. Additionally, video from Chinese media claims to show the missile performing evasive S-turns prior to impact in order to defeat current air defense systems that are programmed to counter constant bearing, linear missile trajectories.¹⁷⁹ One variant of the YJ-18 also features an electromagnetic pulse (EMP) warhead, which China claims can destroy 60% of any electronics within 50m.¹⁸⁰ The YJ-18 counts as an efficiency innovation because it increases lethality by defeating current air defense systems. The use of a new warhead type allows it to achieve a mission kill even if it does not hit the target.

¹⁷⁸ Minnick, "China Shows Off New Sub-Launched Missile at Zhuhai."

¹⁷⁹ Tony Capaccio, "Navy Lacks Plan to Defend Against 'Sizzler' Missile," *Bloomberg*, March 23, 2007, <http://www.bloomberg.com/apps/news?pid=newsarchive&sid=a5LkaU0wj714&refer=home>.

¹⁸⁰ Guang-Wen Chen, "简氏称中国鹰击-18反舰导弹可‘空中急拐弯’(图) (Jane's Said the Chinese YJ-18 Anti-Ship Missiles Can 'Air Sharp Turn')," *Sina Military News*, September 12, 2013, <http://mil.news.sina.com.cn/2013-09-12/1004740170.html>.

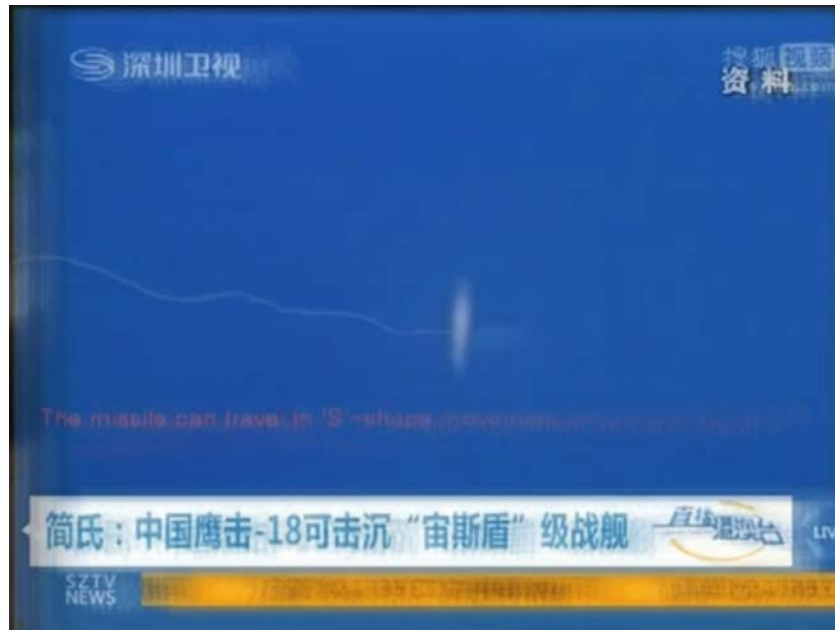


Figure 2. YJ-18 Terminal Guidance Composite Image¹⁸¹

The DF-21D is the anti-ship version of the DF-21 medium range ballistic missile (MRBM) designed to sink an aircraft carrier. According to an Office of Naval Intelligence assessment, it is fitted with a maneuverable reentry warhead, advanced IR and radar seekers, has an accuracy of five meters, and a range of 2000km; this combination of features makes it almost impossible to defeat with any defensive system.¹⁸² This provides an asymmetric counter to CVNs and the air defense networks designed to protect them.¹⁸³ In 2010, Admiral Willard, the U.S. Pacific Commander, admitted in an interview that, with the DF-21D, “Beijing has successfully developed, tested, and deployed the world’s first weapons system capable of targeting a moving carrier strike group (CSG) from long-range, land-based mobile launchers.”¹⁸⁴ The DF-21D meets the criteria for all three innovation categories because it provides a credible, land based, long range anti-ship defense, it significantly improves lethality by defeating

¹⁸¹ SZTV News obtained from <http://tv.sohu.com>

¹⁸² Mahnken, “China’s Anti-Access Strategy in Historical and Theoretical Perspective,” 315.

¹⁸³ Pradun, “From Bottle Rockets to Lightning Bolts,” 28.

¹⁸⁴ Erickson and Collins, “China Deploys World’s First Long-Range, Land-Based ‘Carrier Killer’: DF-21D Anti-Ship Ballistic Missile (ASBM) Reaches ‘Initial Operational Capability’ (IOC),” 2.

enemy IADS technology, and it does all of this by incorporating new guidance to ICBM technology resulting in an entirely new weapon type not fielded by any other nation.

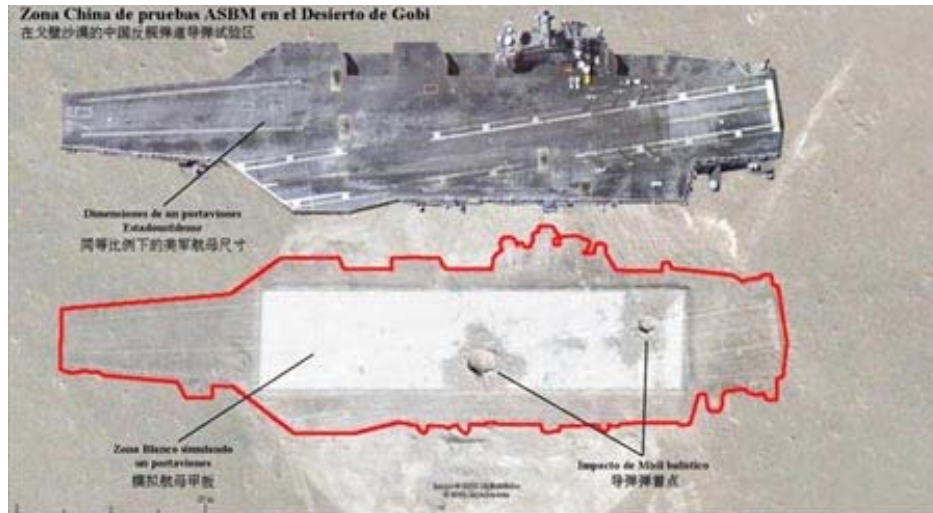


Figure 3. Chinese News Release Showing Two Large Craters on a 200-Meter-Long Platform in the Gobi Desert Simulating the Flight Deck of an Aircraft Carrier¹⁸⁵

E. SUMMARY

In summary, innovations are occurring across all areas of platforms, weapons, and systems in the PLAN. Many of the advances are in areas that provide an asymmetric advantage to counter what China considers the strengths of its potential adversaries. The modernization of the PLAN supports its role in China's A2AD strategy and has resulted in significant advances and innovations, particularly in the range and lethality of weapons as well as systems integration and enemy detection capability. The 41 innovations identified here are likely more numerous than other analysts would accept due to the overly narrow focus of their methods. When tracked by category and over time, however, these innovations provide indicators for future innovation potential. As the number of country-level innovations increases, so does the significance of these innovations, ultimately leading to what would be considered global-level innovations.

¹⁸⁵ Bob Simpson, "The End of Domain Centered Theories of Warfare — On Theory," *Medium*, December 18, 2014, <https://medium.com/on-theory/the-end-of-domain-centered-theories-of-warfare-d3ec7347bf28>.

Given that there are 41 instances of innovation, a useful comparison is how many technologies have been developed that were not innovative. This can be hard to quantify in that systems, by their nature, are typically either a part of a specific platform or weapon at its introduction; as such, it can be difficult to identify whether they are innovative. There are a total of 153 PLAN modernizations examined by this thesis. Since 1970, 27% of modernization efforts resulted in some form of innovation.

PLAN modernization is increasingly resulting in innovative technology. The only innovative technology fielded in the 1970s was the YU-3. In the 1980s, the PLAN fielded 10 innovative technologies and in the 1990s this was increased to 12. From 2000 to 2010, the PLAN fielded 13 innovations and, since 2010, this has stayed steady with six additional innovations. Furthermore, the increase in innovative advances over time has culminated in China fielding technology, such as the YJ-12 and DF-21D, that meets all three innovation categories while also counting as innovation on the global level. This is not to discount technology that only meets the criteria for innovation in one or two categories, as systems like data link create integration across the platforms and weapons of the PLAN, providing significant improvement to fleet capabilities. Furthermore, while the YJ-18 only counts as an efficiency increase, it is of a significant magnitude that it poses a direct challenge to the IADS capabilities of all naval fleets.

As the role of the PLAN has evolved, its modernization efforts have produced innovations to match. During the first few decades examined, a significant lag is seen between strategy and equivalent capability. Innovation trends over the last two decades, however, show that the timeline of technology development in the PLAN is drastically decreasing. This has resulted in a highly modern fleet that integrates the various capabilities of its platforms and weapons into a highly effective system of systems. Major innovations have occurred in categories that support China's counter-revolution strategy. This has resulted in technologies that are cheap to produce and operate, such as mines, non-nuclear submarines, ASBMs, ASCMs, and stealth defeating radar, but that challenge the most expensive capabilities of other nations.

There are still areas where China is either not innovating or is unable to innovate. The first is nuclear submarine quieting; while China has made significant progress with

the Shang, it is still far behind the levels obtained by modern U.S. and Russian submarines.¹⁸⁶ This is likely because conventional submarines are inherently quieter, cheaper to produce and operate, and with the addition of AIP have sufficient range to support the PLAN's role in China's A2AD strategy. Second, China has yet to produce an indigenous CV class platform. While China is currently building several large hulled vessels, it is not yet clear whether these will all be future Type-081 amphibious assault ships or whether China is producing an indigenous aircraft carrier hull.¹⁸⁷ Third, and perhaps most surprising, despite achieving innovations in complex propulsion such as AIP and ramjets, China's ships still utilize traditional marine engines purchased from abroad. One example is the Yuan class submarine, which incorporates indigenous AIP, but German-built diesel engines.¹⁸⁸ Similarly, China had previously claimed that indigenous engines powered the Liaoning CV, but it was recently revealed that these were actually provided by Ukraine.¹⁸⁹

¹⁸⁶ Jane's, "China–Navy."

¹⁸⁷ Agence France-Presse, "Reports That China Is Building Second Aircraft Carrier Deleted from Websites," *The Guardian*, February 2, 2015, <http://www.theguardian.com/world/2015/feb/02/reports-that-china-is-building-second-aircraft-carrier-deleted-from-websites>.

¹⁸⁸ Chan Kai Yee, "China to Build 15 More Yuan-Class Submarines with German Engines," *China Daily Mail*, April 11, 2013, <http://chinadailymail.com/2013/04/11/china-to-build-15-more-yuan-class-submarines-with-german-engines/>.

¹⁸⁹ Minnie Chan, "Mission Impossible: How One Man Bought China Its First Aircraft Carrier," *South China Morning Post*, January 19, 2015, <http://www.scmp.com/news/china/article/1681710/sea-trials-how-one-man-bought-china-its-aircraft-carrier?page=all>.

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IV. INNOVATION IN PLA AIR FORCES

A. OVERVIEW

This chapter discusses innovation in PLA air and counter-air platforms, weapons, and systems. This includes aircraft operated by the PLAAF, the PLAN, and some equipment operated by the PLA ground forces. This chapter has identified 38 instances of technological innovation across all PLA air forces from 1970–2015, of which several demonstrate particularly impressive advances and several others pose sharp challenges to U.S. capabilities. The most significant technologies identified in this chapter are the PL-12, JY-26, JY-27A, and JY-50.

For this chapter, unless otherwise cited, information on equipment capabilities and IOC is derived from Jane's Online, and has been corroborated with The Federation of American Scientists, and Global Firepower Online. Other sources referenced include SinoDefense.com, IISS, and CRS reports. This chapter first reviews the definition of innovation, provides a brief history of the PLAAF, and then discusses instances of innovation by decade beginning in 1970.

The most significant finding is that China is designing its advanced weapons and systems to be utilized across nearly all fielded platforms. Unlike the modernization process undertaken by the PLAN, the PLAAF has not focused on the limited production of increasingly complex and expensive platforms. Rather modernization has been based mainly on applying indigenous upgrades and innovations to existing airframe designs. Only in the last decade has this included simultaneously working to develop 5th generation aircraft capabilities.

The PLAAF's approach to modernization has resulted in a handful of basic airframes being improved through the development of numerous variants as incremental advances take place. The likely reason for this is the historic problem experienced by all militaries: it is more expensive and more risky to try developing new aircraft than it is to

upgrade existing ones.¹⁹⁰ A Naval War College study explains that it can be more beneficial and efficient to focus on integrating improved components into existing airframes because it fosters “the accumulation of improvements over short time periods.”¹⁹¹

The strategy behind PLAAF modernization efforts also mirrors that of the PLAN in the concept of counter-RMA. The PLA claims to have developed and fielded ground-based radar systems that can detect stealth aircraft with enough accuracy for weapons targeting.¹⁹² This negates the benefits of key technologies in U.S. aircraft such as the B-2, F-22, and F-35. These aircraft are extremely expensive to produce and operate, and include design trade-offs that decrease traditional survivability features in favor of stealth.¹⁹³ If the PLAAF does possess its claimed anti-stealth capability, then it can counter the primary benefits of these advanced platforms to create a critical, asymmetric advantage.

Recently, China produced its first indigenous aircraft designs, beginning with the J-10 and an export-only fighter, the JF-17. The use of a dual modernization track is seen through the continued production of existing aircraft designs enhanced with highly sophisticated weapons, while simultaneously working to produce fifth-generation aircraft such as the J-20 and J-31. This runs counter to the strategy of the United States, which is increasingly focused on fielding a limited number of top line aircraft and systems. While the J-20 and J-31 have yet to reach IOC, they are already being publicly demonstrated and marketed for foreign sale. In her study of global fighter development, Marcum finds that China has advanced to the point where its timeline for fielding fifth-generation fighters now matches that of the United States.¹⁹⁴ She further asserts, “most aviation

¹⁹⁰ Thomas C. Hone, Norman Friedman, and Mark D. Mandeles, *Innovation in Carrier Aviation*, Newport Papers (Newport, RI: Naval War College, 2011), 23–24, <https://www.usnwc.edu/getattachment/313c5780-cfa3-4ed4-8716-5543d78e8d31/37.pdf>.

¹⁹¹ *Ibid.*, 23.

¹⁹² “JY-26 – China’s New Counter Stealth Radar | Defense Update.”

¹⁹³ John Stillion and Scott Perdue, “Air Combat Past, Present and Future,” *RAND Project Air Force*, August, 2008, 77–80.

¹⁹⁴ Maggie Marcum, “A Comparative Study of Global Fighter Development Timelines,” in *Getting to Innovation: Assessing China’s Defense Research, Development, and Acquisition System* (SITC, 2014), 38.

experts agree that the [J-20] program has progressed at an accelerated pace, suggesting a higher degree of competency in the design and development stages.”¹⁹⁵

B. INNOVATION

Chapter II of this thesis defines military innovation as new ways of generating military power, which attempt to increase effectiveness or change the manner in which a military functions in the field, to enhance a country’s ability to fight wars. Again, it must be emphasized that this definition focuses purely on technology innovation, and only in reference to China’s own past capabilities. This standard is lower than what other analysts might use and will likely result in more technologies being considered innovative. As stated in Chapter II, the purpose of adopting this approach is not to inflate China’s accomplishments or the threat it poses, but to establish an indication of the progress that China is making in order to judge its future potential.

According to the definition adopted by this thesis, organizational increases fundamentally alter the way in which a military interacts with its own units or the enemy, as commonly seen with changes in coordination, communication, detection, and targeting capabilities. Efficiency increases produce at least a 33% improvement in areas such as range, speed, and accuracy, or involve a significant decrease in the number of weapons or platforms that must be employed to destroy a target. Capability increases provide new avenues for waging war or new methods of employing existing technology that did not exist previously, such as typically seen with the introduction of radical new technologies or the employment of existing technologies in new ways.

C. HISTORICAL OVERVIEW OF THE PLAAF

Similar to the PLAN, the PLAAF has undergone several phases of modernization since its inception. The first phase began in 1949 when the PLAAF was founded with the limited mission of defending Beijing and Shanghai from a Taiwan-based attack.¹⁹⁶ In the

¹⁹⁵ Marcum, “A Comparative Study of Global Fighter Development Timelines,” 37.

¹⁹⁶ Kenneth W. Allen, Glenn Krumei, and Jonathan D. Pollack, *China’s Air Force Enters the 21st Century*. (Santa Monica, CA: RAND Corporation, 1995), 100, http://www.rand.org/pubs/monograph_reports/MR580.html.

1950s, China's participation in the Korean War demonstrated the importance of airpower in support of ground forces. This resulted in the PLAAF experiencing a brief period of modernization and expansion when it benefitted from the ability to procure short-range fighters and bombers from the Soviet Union.¹⁹⁷

Following the Sino-Soviet split in 1958, the PLAAF lost its ability to procure foreign technology. Furthermore, the continental people's war strategy adopted by China during this time de-emphasized the use of air power, which caused a shifting of resources away from the PLAAF, causing it to fall into disarray. Additionally, the highly technical nature of aircraft production means that it suffered disproportionately in relation to the other services under The Great Leap Forward and Cultural Revolution.¹⁹⁸

In the late 1970s, the changing strategic environment both within and surrounding China caused the PRC leadership to once again stress the importance of air power in China's military strategy. The PLAAF worked to develop high-tech aircraft and well-trained pilots, but ultimately produced little in the way of tangible results. Instead, the modernization of the PLAAF (as well as the PLAN) was subjugated to that of ground forces as PRC leadership placed a greater emphasis on the role played by those services in the defense of China's borders.¹⁹⁹

In 1985, the role of the PLAAF again changed with China's strategy of limited local war. This caused a focus on creating a credible defense along China's periphery, which was to be accomplished mainly through the development of air superiority platforms. Throughout this time, however, PLAAF modernization still remained a lower priority than the PLA ground and naval forces, as Chinese industry lacked the ability to develop suitable aircraft.²⁰⁰

Following the demonstration of U.S. air power in the 1991 Iraq War, the role of the PLAAF became more important in Chinese strategy. During this time, the PLAAF

¹⁹⁷ John Wilson Lewis and Xue Litai, "China's Search for a Modern Air Force," *International Security* 24, no. 1 (1999): 65–66.

¹⁹⁸ Allen, Krumel, and Pollack, *China's Air Force Enters the 21st Century.*, 72–73.

¹⁹⁹ Lewis and Litai, "China's Search for a Modern Air Force," 72.

²⁰⁰ Allen, Krumel, and Pollack, *China's Air Force Enters the 21st Century.*, 109.

finally developed its first true strategy for fighting an air war.²⁰¹ This period saw the development of more advanced fighters and attack aircraft, which possessed the ability to project force out to the first island chain in support of regional defense.²⁰² This concept of active defense constituted the PLAAF's first true offensive role. This further expanded in 2004 when the PLAAF began to discuss operations in the space realm, culminating in the 2007 strategic discussion of the Integrated Air and Space Realm and use of offensive strikes as a deterrent.²⁰³ Recent efforts have focused on fostering "integrated cooperation" among all branches of the PLA in support of China's A2AD strategy.²⁰⁴

D. INNOVATION IN AIR FORCES

A summary of innovative technologies in PLA Air platform modernization as discussed in this chapter is shown in Table 4. It must be noted that most of the basic airframes listed here originally began as foreign designs, but Chinese modifications constitute significant improvements such that they count as innovation.

Table 4. PLA Air Innovation: Platforms

Platform	Organizational	Efficiency	Capability
Q-5		X	
Z-8	X		X
H-6E-U		X	X
JH-7			X
J-11			X
J-8G	X		X
J-15	X		
UCAVs		X	X

A summary of innovative technologies in PLA air weapon modernization as discussed below is shown in Table 5. In a manner similar to PLAN weapons, PLAAF

²⁰¹ Lewis and Litai, "China's Search for a Modern Air Force," 78.

²⁰² Ibid., 79.

²⁰³ Murray Scot Tanner, "The Missions of the People's Liberation Army Air Force," in *Chinese Air Force: Evolving Concepts, Roles, and Capabilities* (National Defense University, 2012), 133.

²⁰⁴ Lewis and Litai, "China's Search for a Modern Air Force," 82.

weapons have consistently grown more capable through increased range and lethality. The PL-21, and TB-1 have few known counterparts, while the PL-12, and TY-90, incorporate capabilities that are not currently seen in weapons fielded by other nations.

Table 5. PLA Air Innovation: Weapons

Weapon	Organizational	Efficiency	Capability
PL-5	X	X	
TY-90		X	X
HJ-8B			X
YJ-91		X	X
PL-9		X	
PL-12	X	X	
AKD-10		X	
TB-1	X	X	
CM-400AKG		X	X
PL-21	X	X	X
HQ-9			X
HQ-10		X	
TL-1			X

A summary of innovative technologies identified in PLA air systems modernization as discussed below is shown in Table 6. Many of the systems innovations are designed to modernize existing aircraft by providing advanced capabilities without requiring modernization of the entire airframe. This is accomplished through the use of specialized pods and other bolt-on systems, which are much cheaper and easier to manufacture than entirely new aircraft. This allows China's substantial fleet of older generation aircraft to continue to provide a credible threat, in addition to the threat posed by its more modern equipment. This serves the additional purpose of maintaining a fleet of aircraft that are not dependent on high-tech systems, which can be disabled or exploited. As further discussed in Chapter V, China has developed the ability to counter, exploit, and defeat modern systems of systems such as GPS, satellite communications, data-link, and radar. China's innovation in systems allows it to operate craft suited for operations in degraded environments, but still capable of operating in their own networked system of systems.

Table 6. PLA Air Innovation: Systems

System	Organizational	Efficiency	Capability
Fly-by-Wire		X	X
TY-3		X	
KZ-800	X		X
HOTAS		X	
Helmet Targeting		X	
JL-10A		X	
Blue Sky			X
KG-300G	X	X	X
No 613 FLIR			X
In Flight Refueling	X		
GJV289A	X	X	
KJ-8602 / MAWS		X	X
AESA		X	
JY-26	X		X
JY-27A	X		X
Strap-On Guidance		X	X
JY-50	X	X	X

1. Innovation from 1970–1980

This thesis has not identified any instances of innovation between 1970 and 1980. The lack of innovation during this time period is likely a direct result of the emphasis on low-tech land war tactics that came out of the Cultural Revolution and Great Leap Forward.

2. Innovation from 1980–1990

The six innovations identified during this period are the result of China's first real efforts to build indigenous aircraft and weapons. The PLAAF's role in China's periphery defense strategy necessitated the development of short-range weapons and the associated aircraft systems needed to employ them.

a. Platforms

The Q-5 was China's first indigenously produced aircraft dedicated to the attack role. Its 2000kg weapons payload provided a 300% increase over previous platforms, and

its ability to carry individual bombs up to 500kg, which were twice the size carried by previous aircraft.²⁰⁵ This constitutes an efficiency increase by providing much greater destructive capability for the same number of aircraft, as well as allows the PLA-AF to strike reinforced targets by employing 500kg bombs with greater penetration characteristics than previous 250kg models.²⁰⁶

b. Weapons

The PL-5 was the first indigenous missile that incorporated all-aspect IR homing capability. This allows aircraft to engage targets from any direction, making the pilot's job much easier by removing the previous limitations imposed by rear-aspect engagements and simplifying the targeting solution. The PL-5 also increased range of IR missiles by 500%, as well as incorporated a proximity fuse, and increased missile maneuverability to 40g, providing the ability to effectively outmaneuver evasive aircraft.²⁰⁷ This expanded the beyond visual range (BVR) attack envelope to include IR weapons. The PL-5 counts as an organizational increase because it fundamentally changed how aerial combat is conducted and how aircraft are employed in the air-to-air role, but also counts as an efficiency innovation due to the increased range, maneuverability, and lethality it provided.

The HJ-8B anti-tank missile was the first Chinese anti-tank weapon designed for aircraft use. It incorporates a high explosive anti-tank (HEAT) warhead that defeats explosive reactive tank armor, incorporates both optical tracking and wire guidance, with a single hit kill probability of 90%.²⁰⁸ The HJ-8B counts as a capability innovation because it constituted the first true anti-tank capability for PLAAF aircraft.

²⁰⁵ Jane's, "China-Air Force."

²⁰⁶ Friedman, *The Naval Institute Guide to World Naval Weapon Systems*.

²⁰⁷ Jane's, "China-Air-Launched Weapons," *Jane's Air-Launched Weapons*, September 29, 2014, <https://janes.ihs.com/Default.aspx?Category=JALW>.

²⁰⁸ Christopher Chant, *A Compendium of Armaments and Military Hardware* (New York, NY: Routledge & Kegan Paul, 1987), 544.

c. Systems

The TY-3 0/0 ejection seat first introduced on the J-8 significantly increases pilot survivability. While not a direct increase in combat efficiency, the improved survivability in both combat and non-combat scenarios prevents the loss of trained and qualified aircrew. This helps to solve the historical problem wherein trained aircrew, once lost, prove much more costly and difficult to replace than aircraft.²⁰⁹ The TY-3 counts as an efficiency innovation because of how significantly it increases pilot survivability.

Hands on throttle-and-stick (HOTAS) cockpit design features were first incorporated on the J-8B, and later adapted to helicopter design on the Z-10. This combination of features greatly reduces pilot workload by allowing for normal aircraft operation with the pilot's attention primarily focused outside the cockpit. According to aircraft systems designers, this provides the advantage of allowing "more immediate and effective operation during the most critical phases in the mission."²¹⁰ This improves a pilot's situational awareness and war fighting ability, especially when combined with a heads-up display (HUD). The addition of the No. 613 helmet mounted sighting and weapons targeting system first introduced on JH-7 and later adapted for rotary wing use on the Z-10 further improves targeting accuracy and reduces pilot workload beyond that of just a HUD. When combined, these systems count as efficiency innovations because they allow a pilot to focus on employing weapons without having to take his eyes off the target during an attack.

Fly-By-Wire was first introduced on J-8, improved with triple redundancy on J-8B, and incorporated into helicopter design with the Z-10. This allows for more precise aircraft control while reducing pilot workload. Additionally, the integration of computers allows the aircraft to be flown to the edge of its performance ability without the risk of exceeding limitations. Finally, the use of small, redundant, digital components increases

²⁰⁹ Williamson Murray and Allan Reed Millett, *A War to Be Won: Fighting the Second World War* (Cambridge, MA: Harvard University Press, 2009), 328–329.

²¹⁰ Ian Moir and Allan Seabridge, *Design and Development of Aircraft Systems*, vol. 68 (West Sussex: John Wiley & Sons, 2012), 113–115.

survivability in the event of damage.²¹¹ Fly-by-Wire counts as an efficiency innovation by reducing pilot workload while simultaneously improving aircraft performance; however, it also is a capability innovation because this was accomplished through the application of computer technology to aircraft control.

3. Innovation from 1990–2000

The 13 innovations identified during this time period show the results of the first modernization efforts that truly focused on the PLAAF. China produced several indigenous aircraft and helicopter designs. The PLAAF's role in China's expanding regional focus fostered the development of innovative weapons and systems designed to enhance the capabilities of older airframes that could fill the capability gap while new airframes were still being developed.

a. Platforms

The Z-8 airframe is based on the SA 321 Super Frelon; however, it includes several Chinese modifications that add innovative capabilities. The most important of which is the ability to carry the YU-7 torpedo and C-802K ASCM.²¹² This provides alternatives to the ship-based employment of these weapon systems, extending the range and organization of PLA ASW and ASuW capability, and provides greater flexibility in fleet organization and defense. Aircraft are harder to detect and track than surface ships, and provide a cheap, expendable platform over the significantly more expensive ships that they operate from. When used as an ASCM launch platform for its parent ship, the Z-8 extends the offensive reach of surface fleets by over 500%. In many cases, this gives the PLA a first strike advantage, allowing attack beyond the range at which other navies are even capable of responding. This combination of new weapons capability and change in the conduct of fleet warfare make the Z-8 both a capability and an organizational innovation.

²¹¹ "Rarely Does a Single Aircraft Change Our Daily Lives as Much as NASA 802 Has," *Airsoc.com*, December 16, 2014, <http://airsoc.com/articles/view/id/549123873139447c1b8b4570/rarely-does-a-single-aircraft-change-our-daily-lives-as>.

²¹² Jane's, "China–Air Force."

The H-6E-U variants are the PLA-AF's indigenous modifications to the Soviet TU-16-based H-6 strategic bomber. Chinese modifications include the incorporation of an automatic fire control that linked attack radar to an automated navigation system, as well as a terrain-following radar to allow precision bombing.²¹³ This incremental series of modernizations applied to an existing airframe resulted in a combination of automations and linked systems that change the relationship between the weapon and operator by significantly reducing operator workload while increasing targeting accuracy and aircraft survivability, which counts as both a capability and an efficiency increase.

The JH-7 was China's first light attack aircraft developed with the capability of launching cruise missiles. This vastly increases the range, lethality, and survivability of PLA anti-ship capabilities by providing the advantage of longer range over any possible threats. This pairing changes the relationship between operator and weapon by providing a delivery platform that can be more cheaply produced than larger aircraft and ships, as well as being more survivable. This effectively adds the 1800km combat range of the JH-7 to the attack range of ASCMs, resulting in up to a 1400% increase in range over conventional surface launchers.²¹⁴ The JH-7 counts as a capability increase due to its ability to utilize ASCMs, extending the PLA's sphere of influence beyond the reach of traditional land- and ship-launched weapons.

While the central design of the J-11 is a copy of the Russian SU-27, it incorporates several technology advances indigenous to China. These include the incorporation of new electronics and radar into the J-11B to make it a multi-role aircraft. Additional upgrades include the SF-18 radar absorbent material and paint, as well as redesigned engine intakes, which combine to reduce its radar signature. This makes the J-11B much harder to detect via radar, equating to a near-stealth generation 4+ or 4.5 design that does not suffer from the limitations imposed by developing a purely stealth aircraft like the U.S. F-35.²¹⁵ This counters enemy radar technologies as well as changes the context in which war takes place, by reducing or negating advantages provided by

²¹³ Jane's, "China-Air Force."

²¹⁴ Gormley, Erickson, and Yuan, *A Low-Visibility Force Multiplier*, 57.

²¹⁵ Stillion and Perdue, "Air Combat Past, Present and Future."

enemy radar systems. The J-11 constituted an efficiency increase because of the improvements it provides in the radar realm.

b. Weapons

The PL-9 IR missile increases lethality through the incorporation of a multiple element seeker allowing for better target discrimination and counter-measures rejection. The PL-9 also incorporates infrared counter-countermeasures (IRCCM) that use digital signal processing within the missile itself to increase effectiveness.²¹⁶ This greatly increases lethality by countering the critical enemy countermeasures of IR suppression and flares. The PL-9 counts as an efficiency increase because of the increased lethality and effectiveness it offers over previous weapons.

The YJ-91 incorporates several features seen on the YJ-12 such as sea skimming, ramjet propulsion, and hypersonic capability. The YJ-91 adds the ability to swap warheads in the field, as opposed to the factory. Additionally, later models incorporate a single, advanced warhead that provides multiple selectable modes, providing both anti-radiation and anti-ship capability, entirely eliminating the need to swap warheads.²¹⁷ This changes the relationship between weapon and operator, specifically maintenance personnel. The increase in speed and lethality count as an efficiency increase, and the use of the anti-radiation seeker to target enemy IADS constitutes a capability innovation for aircraft.

The TY-90 is the first air-to-air missile (AAM) specifically designed for helicopters. It has an 80% single-shot kill probability against helicopters.²¹⁸ Due to the innovative design, it is smaller and weighs less than traditional AAMs. This changes how attack helicopters are employed, by allowing them to effectively self-escort without the need for dedicated fighter protection against air threats as well as ground threats. The TY-90 counts as an efficiency innovation due to the significant reduction in size that it

²¹⁶ Jane's, "China–Air-Launched Weapons."

²¹⁷ Gormley, Erickson, and Yuan, *A Low-Visibility Force Multiplier*, 22; Jane's, "China–Air-Launched Weapons."

²¹⁸ Jane's, "China–Air-Launched Weapons."

provides over previous AAMs. Additionally, the TY-90 counts as a capability innovation because it provided a true air defense weapon to Chinese helicopters.

The HQ-9/FT-2000 air defense weapon incorporates AESA capability to provide ICBM defense.²¹⁹ This counters the enemy ICBM weapons technology, and helps provide China a credible second-strike ability by assuring the survivability of some of its own nuclear forces in the event of a strike. The HQ-9 counts as a capability innovation because it provided the PLA its first indigenous ballistic missile defense.

The HQ-10 missile used in the FL-3000 air defense system was based on the Russian TOR SAM. It incorporates Chinese improvements such as dual mode radar and imaging IR seeker, making it a fire-and-forget system capable of defeating saturation attacks even against supersonic targets.²²⁰ The 18-cell version of the launcher also incorporates automatic reloading. The HQ-10 counts as an efficiency innovation because it is capable of protecting against significantly more simultaneous threats than previous systems, as well as automating the missile reloading process, decreasing operator requirements.

c. Systems

In-flight refueling capability first introduced on the J-8D vastly extends the range of combat aircraft, which also increases effective weapon range.²²¹ This changes the context of war and fleet operations by allowing fighters and bombers to operate and strike from much farther than their standard operational ranges, allowing naval fleets to remain safely out of enemy weapons range while conducting reconnaissance and attacks. Furthermore, it sets the stage for China's first truly indigenous CV battle group by changing organizational aspects of how aircraft operate far from land-based facilities.

²¹⁹ Jane's, "Multilayered Chinese Integrated Air Defence System (IADS)," *Jane's Strategic Weapon Systems*, July 24, 2014, <https://jan.es.ihs.com/CustomPages/Janes/DisplayPage.aspx?DocType=Reference&ItemId=+++1705286&Pubabbrev=JSWS>.

²²⁰ Jane's, "FL-3000N (HQ-10)," *Jane's Weapons: Naval*, July 29, 2014, <https://jan.es.ihs.com/CustomPages/Janes/DisplayPage.aspx?DocType=Reference&ItemId=+++1499590&Pubabbrev=JNW>.

²²¹ Jane's, "China-Air Force."

In-flight refueling also constitutes an efficiency innovation because it reduces the fuel fighters are required to carry, thus reducing weight and improving aircraft performance.

When utilized together, the KJ-8602 radar warning receiver (RWR) and missile approach warning systems (MAWS) provide alerts to flight crews of enemy weapons launch based on EO, IR, and radar emissions while also incorporating automatic counter-measures dispensing, which increases aircraft survivability.²²² This decreases reaction time by eliminating the need for a pilot to notice an incoming weapon, determine what type of countermeasure would be best, and then dispense the appropriate one. Automation of the process allows a much faster reaction than the equivalent actions could be performed by a pilot. This combination of self-defense systems counts as an efficiency innovation by increasing survivability through the incorporation of counter-measures.

The Blue Sky low-altitude navigation pod combines terrain following radar, synthetic aperture radar, and forward looking infrared (FLIR), to allow traditionally non-attack aircraft to perform attack roles, especially when paired with multi-role, all-platform weapons such as the TB-1.²²³ It also adds all-weather terrain following and night attack ability to all platforms. This technology provides a capability increase because it allows older aircraft to utilize modern weapons, without requiring a refit of the entire aircraft.

4. Innovation from 2000–2010

The ten innovative technologies identified during this period provide further capability increases to older airframes in order to make them competitive with the fourth- and fifth-generation designs of other militaries. This includes capabilities such as jamming, advanced radar, and precision guided weapons.

²²² “Infrared Countermeasures Systems,” *Global Security*, July 7, 2011, <http://www.globalsecurity.org/military/systems/aircraft/systems/ircm.htm>.

²²³ Jane’s, “China Considers Plans to Extend Fighter-Bomber’s Capabilities,” *Jane’s International Defense Review*, January 1, 1999, <https://janes.ihs.com/CustomPages/Janes/DisplayPage.aspx?DocType=News&ItemId=+++1618831&Pubabrev=IDR>.

a. Platforms

The J-8G was the first indigenously designed aircraft dedicated to suppression of enemy air defenses (SEAD). It includes a dedicated fire control system for anti-radiation operations, as well as incorporates ESM, and can carry the anti-radiation variant of the YJ-91.²²⁴ This capability allows the PLA to penetrate and disable enemy air defenses prior to conducting dedicated strikes. This changes the organization and utilization of other platforms and weapons by allowing SEAD aircraft to weaken or neutralize enemy air defenses before conducting weapon strikes, greatly increasing offensive capability and reducing the number of weapons required to overcome enemy air defenses, in addition to increasing the survivability of aircraft delivering these weapons. This counters the critical technology of enemy air defense networks, by specifically targeting the systems that are designed to destroy incoming weapons such as the SM-2 and SM-3. The J-8G constitutes an organizational innovation because it provides a single aircraft to defeat enemy air defenses and allows the rest of the aircraft to attack more efficiently. It also counts as a capability increase because of the ability to specifically target and neutralize enemy defensive systems.

b. Weapons

The AKD-10 is a derivative of the HJ-10 air to surface missile that utilizes a combined EO, IR, and MMW radar seeker to achieve 3m CEP and an 80% single-hit kill probability.²²⁵ This provides greater versatility and accuracy when engaging targets. The multiple seeker modes can defeat traditional counter-measure systems, which traditionally only protect against a single or dual threat. The AKD-10 counts as an efficiency innovation because the utilization of a multi-spectrum seeker greatly improves weapon accuracy.

The TL series of missiles are compact weapons designed for use by both helicopters and drones. This series of missiles includes multi-nationality GPS guidance,

²²⁴ Gormley, Erickson, and Yuan, *A Low-Visibility Force Multiplier*, 57.

²²⁵ "Blue Arrow 7 Air-to-Surface Missile China," *Air Force World*, accessed December 21, 2014, <http://www.airforceworld.com/pla/english/blue-arrow-7-air-to-surface-missile.html>.

INS, and optical target recognition. The TL-2 incorporates utilizes Laser, IR, and MMW guidance to achieve a CEP of 2m.²²⁶ The TL missiles count as a capability innovation because they provide precision guidance weapon capability to drones.

c. Systems

The KZ-800 is an electronic intelligence (ELINT) radar first fielded on the Y-8JB. This provides the benefits of a ground radar site, but with much longer ranges, more versatility and in a survivable platform. This counts as an organizational increase because it changes the context of air warfare, as well as the relationship between weapon and operator by incorporating ground based radar technology to aircraft.

GJV289A is the designation for Chinese aircraft data bus system. It provides the ability to utilize indigenous Chinese weapons, as well as Western weapons based on the U.S. MIL-STD-1553B standard.²²⁷ In addition, it allows GPS-capable Chinese aircraft and weapons to utilize three different GPS constellations: U.S. GPS, Chinese Beidou, and Russian GLONASS. This provides PLA forces the ability to utilize a multitude of weapons, expanding supply options. In addition, the ability to switch between GPS networks provides redundancy for both navigation and precision weapons guidance during a combat scenario in which either Chinese or U.S. systems are compromised. This provides an organizational innovation because it allows PLA aircraft to utilize indigenous GPS guidance, or foreign GPS guidance if Chinese networks become compromised.

AESA air radar introduced on J-10 allows for radar use while remaining stealthy, is resistant to jamming, and provides redundancy and greater targeting accuracy. This changes context in which war takes place by reducing jamming effectiveness and maintaining stealth capabilities.²²⁸

Strap-on precision guidance kits allow traditional, unguided weapons to have precision strike ability through the addition of inertial, laser, satellite, or imaging

²²⁶ Jane's, "China–Air-Launched Weapons."

²²⁷ Jane's, "Jane's All the World's Aircraft," January 7, 2015, <https://janes.ihs.com/Default.aspx?Category=JAWA>.

²²⁸ Richard G. Wiley, "The Future of EW and Modern Radar Signals," *Research Associates of Syracuse Inc.*, 2004, 13, <http://ieeetmc.net/r5/dallas/aes/IEEE-AESS-Nov04-Wiley.pdf>.

guidance. These kits combined with the No. 613 FLIR/Laser pod provide a low-cost imaging and attack capability to all PLA aircraft. This counts as a capability increase because it adds precision targeting to aircraft not traditionally able to perform such roles, and does so more economically than modernizing all of China's older aircraft.²²⁹ Additionally, the FT-3, FT-4, and FT-6 kits add glide ability, which lowers pilot workload while increasing weapon effectiveness and accuracy. It also adds glide ability, which increases range and standoff.²³⁰

The JL-10A pulse Doppler radar provided greater targeting precision with a lower power requirement than previous designs. This makes it harder to detect by ESM systems, while also providing greater capability through the ability to track targets low to the ground.²³¹ Previous radars were unable to detect targets significantly below the altitude of the radar itself due to interference with ground returns. The JL-10A counts as an efficiency innovation because it increased detection capability while reducing susceptibility to ESM.

The KG-300G jamming pod provides digital radio frequency memory (DRFM) jamming to all aircraft including helicopters, a drastic capability increase. This type of ECM jams enemy targeting radar, as well as missiles.²³² The KH-300G counts as an efficiency increase because it increases survivability by countering enemy sensor and weapon technology. Additionally, it provides a capability increase by providing modular SEAD ability to non-SEAD and older aircraft not equipped with ECM. Finally, this serves as an organizational innovation because it adds SEAD capability to existing strike aircraft, which improves strike package organization and capability without requiring a change of composition.

²²⁹ Carlo Kopp and Martin Andrew, *PLA Guided Bombs* (Air Power Australia, August 8, 2009), <http://www.ausairpower.net/APA-PLA-GBU.html>.

²³⁰ Ibid.

²³¹ Jane's, "JL-10A Airborne Interceptor Radar," *C4ISR & Mission Systems: Air*, December 20, 2007, <https://janes.ihs.com/CustomPages/Janes/DisplayPage.aspx?DocType=Reference&ItemId=+++1553564&Pubabbrev=JC4IA>.

²³² Ibid.

5. Innovation from 2010–2015

The nine innovations identified during this time show rapid progress in developing advanced capabilities to rival other nations. These include highly capable drones and multi-role, multi-platform missiles like the TB-1. Additionally, missiles such as the PL-12 and CM-400AKG count as innovative technology on the global scale.

a. *Platforms*

The J-15 is China's first indigenously produced aircraft designed to operate from an aircraft carrier. Like other platforms, its basic airframe is based on the Russian SU-30, but has been extensively modified by China to accommodate CV operations.²³³ This capability greatly changes fleet organization and composition. Combined with the Liaoning CV, it gives China a mobile platform allowing for aircraft operations away from China's shores and increases the offensive range of surface fleets.

Drones are an area of the PLAAF where specific information is scarce. Based on arms show demonstrations, enough is known to make some general determinations about capabilities. China is producing a wide array of drones for various roles from ISR, to land attack, and even anti-air defense. A notable example is the Dark Sword UCAV, which was unveiled at the 2006 Zhuhai airshow, was first operated in 2008, and is claimed to be the world's first supersonic drone. Additionally, it incorporates stealth, and is designed for anti-air missions.²³⁴ Overarching trends in drone design include the incorporation of stealth features, high-altitude capability, internal weapon bays, and an array of precision-guided as well as glide bombs. These weapons boast a CEP of 3m, which is a significant upgrade from the 15m CEP typical bombs launched from aircraft.²³⁵ This provides an efficiency increase by improving weapon accuracy without the need to risk pilots in combat.

²³³ Jane's, "Jane's All the World's Aircraft."

²³⁴ Jane's, "China—Unmanned Aerial Vehicles," *Jane's Unmanned Aerial Vehicles and Targets*, November 7, 2014, <https://janes.ihs.com/Default.aspx?Category=JUAV>.

²³⁵ Ibid.



Figure 4. Dark Sword AAW UCAV²³⁶

b. Weapons

According to Jane's, the TB-1 is one of the few dual-role weapons of its kind fielded anywhere.²³⁷ Based on proven MANPAD designs, it is effective against both ground and air targets, as well as being able to be employed by both aircraft and ground forces via handheld launcher. This changes the way in which forces are equipped and trained by providing commonality for supplying parts and training. Additionally, the TB-1 allows units to attack a wider variety of targets with the same weapon, expanding capability in a truly multi-role manner and simplifying aircraft load selection. This is further improved with its multi-mode warhead, which incorporates an advanced shaped-charge armor penetrating, blast-fragmentation warhead. This makes the TB-1 effective against armored, unarmored, and aerial targets. These capabilities allow the TB-1 to effectively fill the role of four different weapon types: AAM, AGM, SAM, and SSM, changing the relationship between weapon and operator. While the TB-1 incorporates features that provide an organizational increase, it also includes an efficiency increase as it allows for a single weapon that can engage a wider variety of targets.

²³⁶ Jane's, "Unmanned Dragons: China's UAV Aims and Achievements," *Jane's International Defence Review*, January 23, 2012, <https://janes.ihs.com/CustomPages/Janes/DisplayPage.aspx?DocType=News&ItemId=+++1108569&Pubabrev=IDR>.

²³⁷ Jane's, "China-Air-Launched Weapons."

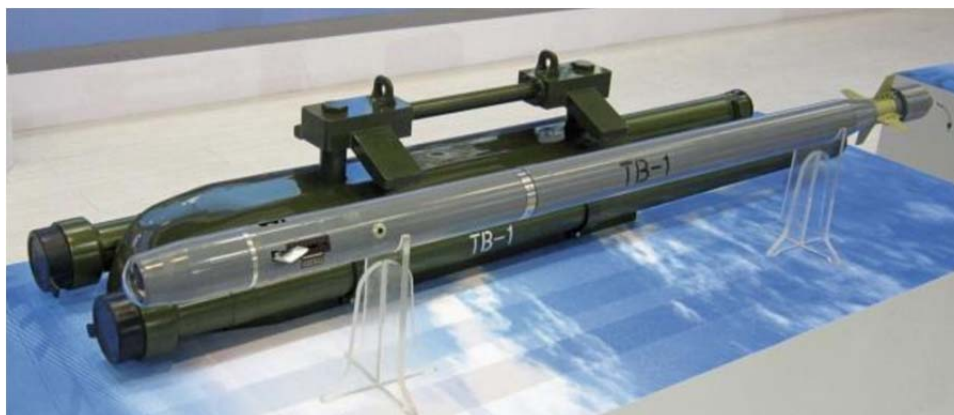


Figure 5. TB-1 Dual-Role Missile²³⁸

The PL-12 provides a 300% range increase over the PL-11 and was the first Chinese BVR, fire-and-forget radar guided missile. It is also the first operational instance of a active/passive dual radar missile fielded by any military; it includes data-link, and can track four targets simultaneously. The active/passive dual radar seeker allows for the weapon to be launched without being detected by enemy ESM and ECM systems, which drastically decreases the time a target aircraft has to react. This changes the context of aerial warfare by countering enemy defensive technology. The fire and forget functionality reduces pilot workload and increases lethality by making the weapon self-seeking, allowing the pilot to focus on other tasks following launch.²³⁹

The PL-21 combines ramjet and solid rocket motor propulsion to vastly increase its range and speed over previous AAMs. This allows the PL-21 to catch targets that can outrun traditional rocket-powered missiles. Additionally, the range of the PL-21 gives PLAAN aircraft a first shot advantage over Western counterparts and could potentially allow Chinese aircraft to attack and retreat before an opponent could ever launch a counter attack. The PL-21 counts as an efficiency innovation by changing the relationship between weapon and pilot by allowing rear-aspect shots even against high-speed fleeing targets at long ranges, as well as providing a first-shot capability in combat.²⁴⁰ This also

²³⁸ Jane's, "China—Air-Launched Weapons."

²³⁹ Richard DeMeis, "Fire-and-Forget Tactical Missiles," *Aerospace America*, 1984.

²⁴⁰ "PL-21," *Global Security*, November 7, 2011, <http://www.globalsecurity.org/military/world/china/pl-21.htm>.

counts as an organizational innovation by changing the conduct of air warfare through the PL-21's ability to catch long-range targets. Finally, the accomplishment of this through the introduction of ramjet propulsion counts as a capability innovation.

The CM-400AKG incorporates ballistic missile technology applied to aircraft-launched weapons. This results in a weapon that can attack both land and sea targets at hypersonic speeds. It is highly accurate, with a 5m CEP out to a range of 250km.²⁴¹ It can be used by the JH-7A, the J-11, and the JF-17. This counts as a capability increase because it is ballistic missile technology applied to an aircraft-fired weapon. Additionally, the increase in range and use of an evasive flight profile to defeat IADS constitutes an efficiency innovation.

c. Systems

The JY-26 and JY-27A AESA radars add both anti-stealth and anti-ICBM capability to Chinese IADS.²⁴² These radars include manned and automatic modes, modular design, and high levels of integration with fire control radars and weapon systems, as well as electronic ECCM.²⁴³ The JY-27A utilizes VHF in a new way to counter-stealth, while the JY-26 radar does the same, using UHF, in a road mobile system.²⁴⁴ Further, no Western equivalents exist for these two systems. These systems count as a capability increase because they constitute the first radars capable to detecting and tracking stealth aircraft.

The JY-50 constitutes a new technology for detecting aircraft, including those utilizing stealth. It is a completely passive system, using emissions from RF signals from everyday objects, including civilian mobile phone, radio, and television broadcasts, to identify targets. This passive ability makes the JY-50 highly survivable against counter-

²⁴¹ Fisher, "Images Show JF-17 Flying with CM-400AKG Hypersonic ASM."

²⁴² Wendell Minnick, "China's Anti-Stealth Radar Comes to Fruition," *Defense News*, November 22, 2014, <http://archive.defensenews.com/article/20141122/DEFREG03/311220016/China-s-Anti-Stealth-Radar-Comes-Fruition>.

²⁴³ Bill Sweetman, "How China Will Track—and Kill—America's Newest Stealth Jets," *The Daily Beast*, December 2, 2014, <http://www.thedailybeast.com/articles/2014/12/02/how-china-will-track-and-kill-america-s-newest-stealth-jets.html>.

²⁴⁴ "JY-26 – China's New Counter Stealth Radar | Defense Update."

detection and attack, defeating enemy ESM, SEAD, and stealth technology. This changes the organization of air defense by providing an IADS system that facilitates the launch of AAMs in a way that cannot be detected by enemy aircraft. The JY-50 counts as a capability innovation because it utilizes an entire spectrum of information in a new manner.²⁴⁵

E. SUMMARY

The 38 innovations identified here are more numerous than what other analysts would assess given their overly narrow scope of analysis. However, when tracked by category and over time, this approach shows how innovation in the PLAAF is increasing over time in accordance with the expansion of the PLAAF's role in Chinese military strategy. The PLAAF fielded no innovative technology in the 1970s. From 1980–1990, the PLAAF fielded six technological innovations, and from 1990–2000 an additional 13 innovative technologies reached IOC. From 2000–2010 it fielded 10, and between 2010–2015 it has already fielded nine, of which four can be considered global-level innovations: the Dark Sword UCAV, PL-12, JY-26/27A, and JY-50.

The most significant innovations consist of multiple increases, such as the KG-300G, JY-50, and PL-21; however, as with the PLAN, technology that does not meet all increase categories can still count as innovation on the global scale. The use of AAW UCAVs presents a unique capability for China. Currently, no other military is fielding unmanned craft that are supersonic or used to perform air defense. This would allow China to extend its defensive range farther from its home shores in a wartime scenario without placing its manned aircraft at risk.

China is still in the process of developing its own fifth-generation fighters to rival those fielded by the United States; however, the United States is still the only nation fielding such aircraft. At the same time, however, China is not relying on the development of this technology. Instead, the PLAAF is very focused on developing systems that enhance the capabilities of its existing aircraft. Of the systems and weapons

²⁴⁵ Jane's, "Russia's Mistrals on Course," *Jane's Navy International*, October 23, 2013, <https://janes.ihs.com/CustomPages/Janes/DisplayPage.aspx?DocType=News&ItemId=+++1590351&PubAbbr=JNI>.

examined for this chapter, many are designed to be employed by the early- as well as late-generation aircraft and helicopters fielded by the PLA. This provides a dual-track to modernization whereby China benefits from modern technological capabilities, without having to replace its current inventory of aircraft.

China's counter-RMA strategy can also be seen in systems modernization, many of which are specifically designed to counter foreign technologies, as evidenced by the development of ground-based stealth-detecting radar. Furthermore, the use of older aircraft designs coupled with modern anti-air and anti-ship weapons exploits the limitations of modern fleet defense, which have difficulty in dealing with large numbers of simultaneous threats. Additionally, when completed, the PLAAF's own stealth aircraft under development will take advantage of the lack of stealth detection fielded by other nations. Within the role of A2AD, this combination of cheap platforms with highly capable detection systems and weapons greatly enhances combat effectiveness and in turn deterrence.

Finally, several of China's weapon systems incorporate design features that are innovative on the global scale. One notable example of this is the TB-1, which serves as an AAM, AGM, SAM and SSM, all in a single weapon. Additionally, the PL-12 and PL-21 incorporate features that make them extremely capable, and hard to counter. If China's claims are true, then the JY-26, JY-27A, and JY-50 all change the context in which future wars will take place. The United States has invested significantly in stealth technology by intentionally setting the F-35 program up to have a monopoly over the future of U.S. air power.²⁴⁶ Due to the complexity and expense involved in the J-35, it has sacrificed traditional performance to meet this need. If China's newest radars can detect and target stealth aircraft, then these expensive platforms no longer provide any advantage over older, inexpensive aircraft that can be mass-produced.²⁴⁷ Additionally, in order to help fund the F-35 program, the United States has convinced its allies, including Japan and

²⁴⁶ Stillion and Perdue, "Air Combat Past, Present and Future."

²⁴⁷ Andrew Metrick, "A Cold War Legacy: The Decline of Stealth," *War on the Rocks*, January 20, 2015, <http://warontherocks.com/2015/01/a-cold-war-legacy-the-decline-of-stealth/>.

South Korea, to purchase it as well.²⁴⁸ This gives China a significant advantage over potential regional rivals, further strengthening its A2AD capability.

Weapons modernization has seen a steady increase of performance with advanced weapons replacing aging ones. In some cases, these weapons comprise entirely new types not fielded by other militaries, while others were developed through significant improvements applied to collaborative designs. These modernizations show an increasing ability reach farther with more lethality, increasing PLA capabilities beyond that of potential adversaries.²⁴⁹

Most of the innovations are occurring in the category of weapons, but also are seen increasingly in systems. Again, the influence of counter-RMA is prominent. The most significant systems ensure air superiority within the second island chain as required by China's A2AD strategy. The PL-12 and PL-21 target weaknesses in fighter design, while the KG-300G ECM pod and JY series of radars enhance the self-defense capability of China's own platforms. These systems are much cheaper to produce and operate than the equipment they are designed to counter, in addition to having much shorter development timelines.²⁵⁰

Given that there are 38 instances of innovation, a useful comparison is the number of technologies developed that were not innovative. This can be hard to quantify in that systems, by their nature, are typically either a part of a specific platform or weapon at its introduction. There are a total of 213 PLAAF modernization technologies examined by this thesis. Based on those technologies, since 1970, 18% of modernization efforts resulted in some form of innovative technology.

There are still areas where China is not innovating, or may be unable to innovate. The first of these is jet aircraft engines. China has finally begun serial production of its WS-10 engine, but output is still low and there are reports of tolerance problems on

²⁴⁸ Kate Brannen, "The Pentagon's \$399 Billion Plane to Nowhere," *Foreign Policy*, July 8, 2014, <http://foreignpolicy.com/2014/07/08/the-pentagons-399-billion-plane-to-nowhere/>.

²⁴⁹ Robert Haddick, "The Real U.S.-China War Asia Should Worry About: The 'Range War,'" *The National Interest*, July 25, 2014, <http://nationalinterest.org/feature/the-real-us-china-war-asia-should-worry-about-the-range-war-10952>.

²⁵⁰ Metrick, "A Cold War Legacy: The Decline of Stealth."

precision manufacturing equipment. Additionally, the engines must be serviced much more often than Western counterparts. This has resulted in the continued use of Russian engines in most PLAAF aircraft. There is also some question as to whether China is able to truly produce fifth-generation stealth aircraft. What production has occurred is often credited to espionage rather than indigenous development. Currently, China has only produced two indigenous airframes, both of which qualify as fourth-generation, multirole fighters. All others it operates are still based on foreign platforms, although they are so highly modified at this point that they bear little resemblance to their original designs. Also, all of China's helicopter airframes are based on foreign designs with indigenous modifications.

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V. CONCLUSIONS

A. ASSESSMENT OF INNOVATION IN CHINESE MILITARY MODERNIZATION

This thesis examined an array of literature to develop a definition for innovation that suits the purpose of identifying military innovation. It then narrowed the scope of analysis to focus specifically on technology innovation and created a standard in order to determine which technological advances actually count as innovation. Finally, it applied this standard to the modernization of PLA naval and air forces since 1970 in order to identify specific instances of technological innovation. This thesis has found that, as the roles of the PLAN and PLAAF have become more important to Chinese military strategy, their resulting modernization has resulted in an increasing number of innovative technologies and that the accumulation of country-level innovation within China has resulted in several global innovations.

What this thesis has found is that China is increasingly focused on fielding world-class technologies. It has developed equipment that rivals that of the top militaries, and in some cases, exceeds them in capability. As China continues to innovate in relation to its past capabilities, it is beginning to develop technology that counts as innovation on the global scale. Despite these advances, there are still areas where China has not yet been able to catch up, primarily nuclear submarine quieting, jet engine production, and aircraft carrier design. Recent news reports indicate that China has recently begun construction on its first indigenous carrier, however.²⁵¹

In cases where it has not caught up, China has innovated in areas that provide an asymmetric advantage. Examples of this are seen in its expansive anti-ship missile programs specifically designed to counter U.S. CVNs and stealth-detecting radar designed to defeat U.S. fifth-generation aircraft. Furthermore, the combination of its technological developments and its security situation both in Asia and with the United States is causing the PLA to undergo a period of doctrinal change. Instead of merely

²⁵¹ France-Presse, “Reports That China Is Building Second Aircraft Carrier Deleted from Websites.”

focusing on developing a limited number of highly capable platforms, weapons, and systems, China is following a dual-track of modernization whereby it is innovating advanced systems of its own, but is also developing systems that enable its current force structure to be much more capable in a future conflict. This is best seen as a counter to the U.S. doctrine of overwhelming force through technological superiority. China's self-described counter-revolution in military affairs can best be characterized as numerical superiority combined with current technology to exploit the capability gap to turn an enemy's strength into weakness.

1. Technological Innovation

The approach taken by this thesis, which focuses on country-level technology innovation, sets a lower standard than what many other analysts accept. This is not designed to overstate the threat that China poses, but rather to assess how modernization has progressed within China up to this point. This method shows that innovation within China has increased to match the needs of the PLA's expanding role in Chinese strategy. This increasing number of innovations has resulted in several breakout technologies that count as innovation on the global scale. Based on the trends identified here, China will likely continue to innovate both in relation to its past capabilities, as well as on the global scale.

Determining the actual percentage of military modernizations that count as innovation is difficult, since not all modernization consists of new programs. This thesis identified a combined total of 79 instances of technological innovation in the PLAN and PLAAF since 1970. Of those 79 instances, half have occurred in the last 15 years, while nearly one-fifth (15) took place in the last five years, including all of China's global-level innovations. Several of the most significant technologies (nuclear submarine propulsion, AIP, DF-21D, YJ-12, PL-21, JY-50, and KG-300G) fulfill all three increase categories. Additionally, some innovations only fulfill one or two increase categories but still constitute significant capabilities: multiplex data link, YJ-18, PL-12, JY-26 and JY-27A. The DF-21D, YJ-12, PL-12, JY-26, JY-27A, and JY-50 all constitute global-level innovations as they incorporate technological capabilities not seen anywhere else.

Chinese modernization has been based on what it calls counter-RMA. This involves finding efficient methods to take advantage of the technological gap between China and potential adversaries to turn enemy strengths into weaknesses. This has primarily been accomplished through innovations in both weapons and the systems that support them.²⁵² In parallel with its counter-RMA, China is also focused on overall modernization of its forces and does not accept its current technological capabilities as a limiting factor. China sees itself as a great power, and is working to develop what it considers great power technologies such as aircraft carriers, and fifth-generation aircraft. China is capitalizing on what capabilities it does have, while still striving to develop technology that is equivalent or superior to that fielded by the top militaries of the world.

Not all of China's technological modernization counts as innovation and there certainly are still gaps. A RAND study from 2005 noted that, at the time, China was making significant progress in its modernization, but was still procuring a significant amount of specialized, high-tech military equipment from abroad, specifically jet engines, electronics, and weapons control systems.²⁵³ Recent developments in the Chinese military industry show how far China has come in the 10 years since RAND made its assessment.

In the time since the RAND report was compiled, China has effectively caught up, and is now producing indigenous equipment in most of these categories. For example, China has begun serial production of its first modern jet engine, the WS-10. China has also cancelled several arms deals with Russia because it claims that Russian electronics technology no longer meets the PLA's needs. Specifically, China replaced its SU-27 fighter contract with the multi-role J-11, its own version of the airframe utilizing indigenous electronics, radar, and cockpit systems. Additionally, China cancelled further purchases of the Soviet Kh-31P missile system and instead developed the YJ-91, incorporating a Chinese multi-function warhead and multi-mode seeker to provide improved performance.

²⁵² Scobell, Lai, and Kamphausen, *Chinese Lessons from Other Peoples' Wars*, 14.

²⁵³ Crane et al., *Modernizing China's Military*, 144.

China has also demonstrated the ability in some cases to produce more advanced capability than the United States and Russia.²⁵⁴ PLAN and PLAAF modernization programs have resulted in an increasing number of innovative technologies being fielded, including ones that count as innovation on the global scale. China's new series of JY anti-air radar systems are the first of their kind, and the DF-21D is the first instance of an ASBM fielded by any military. In 2005, China was not considered capable of such innovations, but today it possesses not only the ability to produce these increasingly advanced components but is innovating capabilities in these areas beyond what other nations have produced. Furthermore, China claims to have made advances towards producing other technologies that no other nation has yet fielded, such as hypersonic weapons, railguns, and super cavitating submarines.²⁵⁵

There are, however, areas this thesis has identified where China has not innovated. These areas include marine diesel and turbine propulsion systems, nuclear submarine quieting, high-performance jet engines, and aircraft carrier design. Although based on the way current innovations meet the needs of China's overall strategy, it is possible that these are areas where China does not feel it needs to innovate in order to achieve its goal of deterrence.

2. Doctrinal Adaptation

As discussed in Chapter II, many analysts claim that China's modernizations do not constitute innovation because its technological advances are not accompanied by doctrinal changes. Contrary to that view, however, research shows that the PLA has been adapting its doctrine to better utilize innovative technologies in support of its A2AD strategy. As discussed in Chapter II, doctrinal change is actually very rare, and tends to occur mainly in combat as opposed to peacetime. While China has not been involved in

²⁵⁴ Crane et al., *Modernizing China's Military*, 189–190.

²⁵⁵ Robert Farley, "A Mach 5 Arms Race? Welcome to Hypersonic Weapons 101," Text, *The National Interest*, (December 31, 2014), <http://nationalinterest.org/feature/mach-5-arms-race-welcome-hypersonic-weapons-101-11935>; "China Has Brought Supersonic Submarines close to Reality, Claims to Have Solved Critical Challenges," *International Defence, Security & Technology*, September 4, 2014, <http://myidst.com/index.php/en/military/sea/item/59-china-has-brought-supersonic-submarines-close-to-reality-claims-to-have-solved-critical-challenges>.

any recent conflicts through which to test and develop its doctrine, it does study other nations' wars in order to develop its own modern doctrine before conflict occurs.²⁵⁶

Russell and Dombrowski both argue that rather than new doctrines leading to new technology, doctrinal change occurs from a combination of technological capability and the strategic environment. This thesis has found that the PLA conforms to this view as evidenced by several factors. The first is that PLA military academies currently focus on teaching counter-RMA, a concept based on addressing China's security situation in light of the capability gap between itself and other nations.²⁵⁷ Second, research finds that traditional methods used to identify innovative doctrine in the PLA fail to yield significant results because they are based on the prevalence of U.S. terms appearing in PLA literature, and in reality China's unique approach to the use of ballistic missiles is just one example of its doctrinal innovation.²⁵⁸ Recent studies note that the PLA has integrated Joint Operations, information sharing, and complex maneuvering to classroom training as well as in the field.²⁵⁹ Additionally, the DOD has documented changes in current PLA military operations including exercises, participation in international task forces, and CV operations demonstrating advanced capabilities.²⁶⁰

An analysis conducted by the U.S. Naval War College determined that the PLA is changing the way it recruits, trains, and educates its personnel to better make use of increasingly sophisticated technology.²⁶¹ In his study of China's A2AD strategy, Christopher Yung assesses, "the People's Liberation Army (PLA) will continue participating in exercises that stress combined arms ground-sea-air operations; amphibious operations; coordination among surface combatants, air forces, and sub-

²⁵⁶ Scobell, Lai, and Kamphausen, *Chinese Lessons from Other Peoples' Wars*, 1, 9; Daniel Alderman and Joe Narus, *Other People's Wars: PLA Lessons from Foreign Conflicts* (Strategic Studies Institute, 2011), <http://www.strategicstudiesinstitute.army.mil/pdffiles/PUB1062.pdf>.

²⁵⁷ Mulvenon and Finkelstein, *China's Revolution in Doctrinal Affairs: Emerging Trends in the Operational Art of the Chinese People's Liberation Army*, 314–15.

²⁵⁸ Scobell, Lai, and Kamphausen, *Chinese Lessons from Other Peoples' Wars*, 115.

²⁵⁹ Cordesman and Kleiber, *Chinese Military Modernization*, 23:175–76.

²⁶⁰ Scobell, Lai, and Kamphausen, *Chinese Lessons from Other Peoples' Wars*, 12.

²⁶¹ Kenneth Allen and Morgan Clemens, *The Recruitment, Education, and Training of PLA Navy Personnel*, August 2014, 4, <https://www.usnwc.edu/Research---Gaming/China-Maritime-Studies-Institute.aspx>.

surface forces; command and control of forces afloat, in the air, and ashore; and a combination of general purpose forces with ballistic missiles and other Second Artillery forces.”²⁶² Even the DOD’s 2014 report to Congress highlighted China’s focus on utilizing new technologies, such as information warfare, to gain an asymmetric advantage in its A2AD strategy.²⁶³ These analyses do not show a PLA that is confined to a static and unchanging doctrine. Rather, they show that China is adapting its doctrine to match development of innovative technology in order to respond to its strategic environment.

3. Joint Ventures and Espionage

Some analysts assert that many of China’s development programs originated from joint ventures with other countries, and thus are not truly indigenous. This view fails to acknowledge that many modernization programs undertaken by nations are composed of joint efforts, especially recent work on fourth- and fifth-generation fighters.²⁶⁴ This includes the Russian-Indian PAK-FA and multinational F-35. Even Russia, one of the few nations capable of building indigenous ships of all classes, outsourced construction of its newest LHD to France.²⁶⁵ Also, while modern carrier aviation is most often associated with the United States, all the hallmark innovations of modern aircraft carriers (the angled deck, optical lens landing system, and steam catapult) were developed by England.²⁶⁶ Even the U.S. spaceflight and ICBM programs arguably would not have been possible without the knowledge acquired through the influx of German scientists captured after the second world war.²⁶⁷ Furthermore, the father of China’s space and missile industry, Qian Xuesen, was a founding member of the U.S. Jet Propulsion Lab before being deported to China and founding China’s own aerospace research and development organization.²⁶⁸

²⁶² Scobell, Lai, and Kamphausen, *Chinese Lessons from Other Peoples’ Wars*, 76.

²⁶³ *Annual Report to Congress: Military and Security Developments Involving the People’s Republic of China 2014*, 30.

²⁶⁴ Marcum, “A Comparative Study of Global Fighter Development Timelines,” 36.

²⁶⁵ Jane’s, “Russia’s Mistral on Course.”

²⁶⁶ Hone, Friedman, and Mandeles, *Innovation in Carrier Aviation*.

²⁶⁷ Cheung, *Forging China’s Military Might*, 251.

²⁶⁸ *Ibid.*, 251–52.

China's use of espionage combined with its technological advances has provided it a unique opportunity to study U.S. military equipment in order to identify capabilities and weaknesses prior to combat. Numerous reports have highlighted China's use of espionage to gain knowledge of key foreign military systems such as the F-22 and F-35.²⁶⁹ A GAO report also found that a significant amount of counterfeit components have appeared in supply chains for a variety of U.S. military equipment.²⁷⁰ The use of espionage to identify or create critical weaknesses in otherwise superior technology is further evidence of the counter-RMA element of China's A2AD strategy.

B. IMPLICATIONS FOR UNITED STATES POLICY

As explained in Chapter I, U.S. military strategy and doctrine is based on the concept of overwhelming force gained through technological superiority. This thesis assesses that China has developed its own viable strategy based around leveraging asymmetric advantages.²⁷¹ The PLA has innovated weapons with the advantage of longer range, flight profiles, and ECM all specifically developed to target weaknesses in critical enemy systems. Common arguments point to the superior number of U.S. aircraft carriers and ballistic missile submarines as evidence that it can defeat China. This, however, fails to take into account the vulnerability and cost associated with such platforms, especially given the range advantage possessed by PLA anti-surface weaponry.

China has built a layered redundancy such that it possesses the capability to match or even defeat the U.S. technological advantage through both physical and cyber efforts.

²⁶⁹ Jeff Sistrunk, "DOJ Investigates Honeywell Over F-35 Parts Made In China—Law360," *LAW 360*, January 13, 2014, <http://www.law360.com/articles/500803/doj-investigates-honeywell-over-f-35-parts-made-in-china>; "Chinese Fake Parts 'Used in US Military Equipment,'" *BBC News*, May 21, 2012, <http://www.bbc.co.uk/news/world-us-canada-18155293>; *Operation SMN: Axiom Threat Actor Group Report* (Novetta, November 2014), https://www.novetta.com/wp-content/uploads/2014/11/Executive_Summary-Final_1.pdf; Mark A. Stokes and LC Russell Hsiao, *Countering Chinese Cyber Operations: Opportunities and Challenges for U.S. Interests* (Project 2049 Institute, 2012), <http://www.cyberconflict.org/repository/china-and-north-korea/Project%202049%20-%20Countering%20Chinese%20Cyber%20Ops.pdf>.

²⁷⁰ *DOD Supply China: Suspect Counterfeit Electronic Parts Can Be Found on Internet Purchasing Platforms* (GAO, February 2012), <http://www.gao.gov/assets/590/588736.pdf>.

²⁷¹ Mulvenon and Finkelstein, *China's Revolution in Doctrinal Affairs: Emerging Trends in the Operational Art of the Chinese People's Liberation Army*, 314; Christopher J. McCarthy, "Anti-Access/Area Denial: The Evolution of Modern Warfare," *Journal of Security Studies*, 2010, 8.

Additionally, the PLA possesses the ability to continue to operate in technologically degraded environments by using its older platforms to deliver self-guiding weapons such as anti-radiation missiles, wake-homing torpedoes, and programmable mines to attack U.S. ships. The United States has all but abandoned its ability to operate in such an environment in pursuit of creating the most technologically superior force possible. It has not planned or trained for operations in a degraded environment where it loses the information advantage.²⁷² Thus if the U.S. military wishes to prepare for a potential conflict in Asia, it must adapt its doctrine and training to this new strategic environment and the challenges it brings.²⁷³

In 2011, VADM Dorsett, the U.S. Navy's senior intelligence officer, stated that the "Defense Department 'certainly would not have expected [the Chinese] to be as far along as they are today' in technology and has argued that the Pentagon needs to refine its intelligence on military matters in China."²⁷⁴ That this development was unexpected is direct testament to the usefulness of this thesis' the method of analysis. Since 1970, the PLA has fielded an increasing amount of country-level innovations. As the rate of development of these innovations has increased over time, so have their capabilities. This has culminated in several global-level innovations that have come as a surprise to most analysts.²⁷⁵

1. Chinese Deterrence

Sun Tzu taught that, "knowing the place and the time of the coming battle, we may concentrate from the greatest distances in order to fight."²⁷⁶ These lessons provide fitting descriptions of China's A2AD strategy. It is obvious that any conflict in Asia will occur within either the first or second island chains. Thus if the U.S. wishes to act in

²⁷² *Capstone Concept for Joint Operations: Joint Force 2020* (Washington, DC: Joint Chiefs of Staff, September 10, 2012), 9, http://www.dtic.mil/doctrine/concepts/ccjo_jointforce2020.pdf.

²⁷³ McCarthy, "Anti-Access/Area Denial," 9.

²⁷⁴ Mahnken, "China's Anti-Access Strategy in Historical and Theoretical Perspective," 300.

²⁷⁵ Mahnken, "China's Anti-Access Strategy in Historical and Theoretical Perspective"; Erickson and Collins, "China Deploys World's First Long-Range, Land-Based 'Carrier Killer': DF-21D Anti-Ship Ballistic Missile (ASBM) Reaches 'Initial Operational Capability' (IOC)."

²⁷⁶ Tzu, *Sun Tzu on the Art of War*, 48.

Asia, it must do so by projecting its forces across the Pacific Ocean. As seen in Figure 6, China has built a layered defense with the ability to strike targets anywhere in this region with weapons that can be safely launched from its homeland.

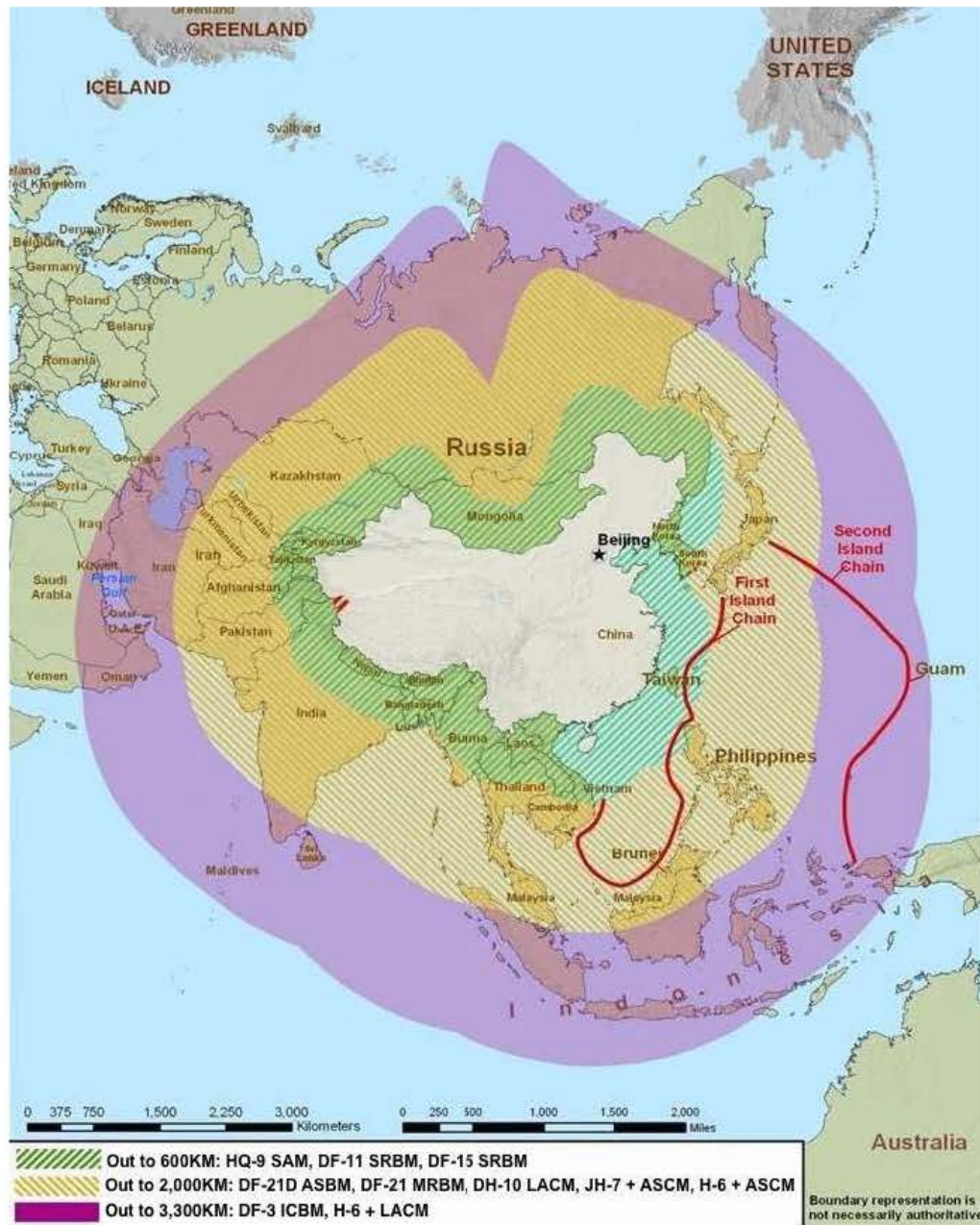


Figure 6. China's Conventional A2AD Capabilities²⁷⁷

²⁷⁷ Gormley, Erickson, and Yuan, *A Low-Visibility Force Multiplier*, 31.

Based on Thomas Schelling's analysis of the relation between military technology and deterrence, it is clear that China falls directly under his ideal type for a deterrent force.²⁷⁸ That is, China has developed equipment, which deters an attack on itself, yet does not itself require an offensive strategy. Chinese strategy documents reveal that China's A2AD strategy is based around raising the cost of power projection and intervention in Asia by raising the threshold of destruction, loss, and pain that China can inflict on another nation in order to contain intervention.²⁷⁹ China has embraced a defense that makes the cost of initiating an attack on China extremely costly to any aggressor.²⁸⁰

China has identified critical vulnerabilities in U.S. capabilities and has innovated technologies to exploit them. The most obvious areas are in anti-surface capacity. The PLA currently fields weapons that can attack or neutralize U.S. aircraft carriers at ranges far beyond the range at which the CVN's own weapons and aircraft can reach. Additionally, even with the integrated air defense network of U.S. fleets, there is a limited capacity for these networks to defend against the vast number and complexity of weapons that China can bring to bear. Furthermore, even U.S. military leaders admit the limits of stealth technology in relation to China's ability to detect and target these aircraft.²⁸¹

This means that the U.S. Pacific pivot is unlikely to deter China's increasingly antagonistic actions in Asia. In addition to the PLA's anti-ship capabilities, China possesses the ability to disable or degrade other critical U.S. technologies such as data-link, GPS, satellite communications, and radar; while simultaneously providing redundancy and alternatives for these capabilities within its own forces. For example, Chinese precision-guided munitions can utilize any of the three currently operational

²⁷⁸ Thomas C. Schelling, *Arms and Influence* (London: Yale University press, 1966), 224.

²⁷⁹ Mahnken, "China's Anti-Access Strategy in Historical and Theoretical Perspective," 301; Christensen, "Posing Problems without Catching up," 19–20.

²⁸⁰ Schelling, *Arms and Influence*, 79.

²⁸¹ Jeremy Bender, "A Top US Navy Top Officer Thinks That One of the F-35's Most Hyped Capabilities Is 'Overrated,'" *Business Insider*, February 10, 2015, <http://www.businessinsider.com/naval-head-stealth-may-be-overrated-2015-2>.

GNSS constellations, whereas U.S. forces can only utilize their own indigenous GPS. This is encompassed in comments by U.S. Secretary of Defense Gates in a 2010 speech, “We simply cannot afford to perpetuate a status quo that heaps more and more expensive technologies onto fewer and fewer platforms—thereby risking a situation where some of our greatest capital expenditures go toward weapons and ships that could potentially become wasting assets.”²⁸²

C. RECOMMENDATIONS FOR THE UNITED STATES

Unless the United States is willing to abandon its presence in the Atlantic and shift almost all of its assets to the Pacific, any rebalancing of forces will prove insufficient to gain numerical superiority over the PLA in the Pacific.²⁸³ The United States has strong ties to its allies Japan and South Korea, which include the basing of U.S. service members and military equipment in those countries as well as cooperative security agreements. While China has made no indication that it wishes to replace the United States as a global hegemon, it has explicitly proclaimed the desire to exert more influence in Asia to become the dominant force in the region.²⁸⁴

Additionally, as discussed in Chapter II, there are numerous historical instances of intelligence services failing to identify innovative technology fielded by other nations. Intelligence services can use the approach followed by this thesis in order to track increases in country-level innovation over time. The changes in country-level innovation can then be used to provide indicators for current and future global innovation potential. These indicators provide the context that is lacking in other methods that fail to identify the first globally innovative technologies produced by rising powers.

D. AVENUES FOR FUTURE RESEARCH

This thesis focused on innovation in the PLAN and PLAAF, as they are critical to China’s A2AD strategy. Additionally, modernization timelines for both services can be

²⁸² Hone, Friedman, and Mandeles, *Innovation in Carrier Aviation*, xiii.

²⁸³ Holmes, “China’s Navy Is Already Challenging the US in Asia.”

²⁸⁴ “The Diversified Employment of China’s Armed Forces,” *Information Office of the State Council*, April 2013, http://news.xinhuanet.com/english/china/2013-04/16/c_132312681.htm.

tracked and compared to the emphasis each service received as part of China's evolving strategy.

There are several areas where future research could build upon this thesis. The first is expanding to conduct an assessment of other branches of China's military such as PLA ground and non-conventional forces. An assessment of other PLA forces would fill out the picture of the entirety of Chinese military modernization and allow for assessments to determine if innovations are affected by the larger strategy.

There would likely be a significant amount of innovation in non-conventional forces, specifically ones that provide an ideal low cost for the ability to counter advanced technology, such as cyber and other weapons designed to counter electronic systems. China's strategy and desire for global prominence should be driving innovation in those services as well, especially as they support A2AD. This is especially true with regard to cyber, as it provides a relatively cheap yet highly effective method for exploiting the technological advantage of an adversary.²⁸⁵ In China's 2013 Defense White Papers, the PRC claims that cyber space is a vital aspect of its A2AD strategy.²⁸⁶ Recent news reports also indicate that China has already used this ability to compromise at least two-dozen of the U.S. military's programs including the F-35.²⁸⁷ China has also demonstrated the ability to disable GPS and data link networks as part of its "electronic dominance" strategy.²⁸⁸

²⁸⁵ Joseph S. Nye, *Cyber Power* (Cambridge, MA: Belfer Center for Science and International Affairs, Harvard Kennedy School, May 2010), <http://oai.dtic.mil/oai/oai?verb=getRecord&metadataPrefix=html&identifier=ADA522626>.

²⁸⁶ "The Diversified Employment of China's Armed Forces."

²⁸⁷ Franz-Stefan Gady, "New Snowden Documents Reveal Chinese Behind F-35 Hack," *The Diplomat*, January 27, 2015, <http://thediplomat.com/2015/01/new-snowden-documents-reveal-chinese-behind-f-35-hack/>; Ellen Nakashima, "Confidential Report Lists U.S. Weapons System Designs Compromised by Chinese Cyberspies," *The Washington Post*, May 27, 2013, http://www.washingtonpost.com/world/national-security/confidential-report-lists-us-weapons-system-designs-compromised-by-chinese-cyberspies/2013/05/27/a42c3e1c-c2dd-11e2-8c3b-0b5e9247e8ca_story.html.

²⁸⁸ Jane's, "Strategic Weapon Systems," *Jane's Sentinel Security Assessment—China and Northeast Asia*, November 30, 2014, <https://janes.ihs.com/CustomPages/Janes/DisplayPage.aspx?DocType=Reference&ItemId=+++1303170&Pubabbrev=CNA>.

Another avenue for future work would be to apply the innovations posited by this thesis to the frameworks of Cheung and Ross. More specifically, the individual innovations could be assessed to see where they fall along the spectrum of innovation. This would provide more granularity on whether China's innovation capability is improving and whether these instances show a progression along Cheung's spectrum of: Duplicative Imitation, Creative Imitation, Creative Adaptation, Incremental Innovation, Architectural Innovation, Component or Modular Innovation, and Radical Innovation.²⁸⁹ Using these frameworks may provide a clearer progression from adaptation to revolutionary innovation.

An additional avenue of future research would be to take the principles of innovation presented by this thesis and apply them to other nations, one example being the United States prior to the 1991 Gulf War, or following WWII when its security strategy drastically changed in light of the communist threat. This would provide comparisons for how country-level innovation relates to global innovation, especially in light of expanding military strategy. This concept could be taken further by examining other nations in a similar manner during their rise to global innovation (e.g., Japan pre-WWII or the Soviet Union during the space race).

E. SUMMARY

U.S. Congressional studies on national defense issues consistently discuss the fundamental changes imposed by modern technology. They stress that the real concern is the potential of systems of systems, instead of directly focusing on individual weapons.²⁹⁰ Chapter III on innovation in the PLAN and Chapter IV on innovation in the PLAAF showed that, until the 1990s, China put most of its effort into developing new platforms and weapons. From 2000–2015, however, the PLA has increasingly produced more advanced systems, including ones that are interconnected with an increasing array of platforms, weapons, and other systems. This shows that contrary to common analysis, China is focused on and capable of developing equipment to fight or deter a modern war.

²⁸⁹ Cheung, Mahnken, and Ross, "Frameworks for Analyzing Chinese Defense," 79.

²⁹⁰ Saunders et al., *The Chinese Navy*, 275.

While China has not yet innovated the next great RMA in the eyes of the United States or the world, it has succeeded in innovating according to its own counter-RMA. Even a third-generation aircraft such as the JH-7 poses a credible threat when equipped with fourth- and fifth-generation weapons and systems. This use of innovative technology to modernize existing platforms provides an abundance of capable assets. This is counter to the U.S. strategy of highly capable, expensive and non-expendable equipment that relies on a superior technological advantage to survive.

As the role of the PLAN and PLAAF has expanded and become central to China's overall strategy, their modernization efforts have increasingly resulted in innovative technologies. As evidenced by the DF-21D, YJ-12, PL-12, JY-26, JY-27A, and JY-50 China is capable of producing global level innovations.

In order to deal with a modern China, U.S. strategy must shift to account for these facts. Planners cannot assume that the U.S. will have the technological and electronic advantage in a conflict. China has already demonstrated the ability to neutralize, exploit, or destroy key systems such as satellites, GPS, datalink, and radar. At the same time, the U.S. has demonstrated that it is increasingly reliant on these advanced technologies to operate.

As Russell's research predicts, the PLA has been incorporating and developing doctrine to match its technological advances. In the words of the DOD's 2014 Annual Report to Congress on the PLA, "Almost all of the PLA's 2013 exercises focused on operating in 'informationized' conditions by emphasizing system-of-systems operations, a concept that can be viewed as the Chinese corollary to U.S. network-centric warfare. This concept requires enhancing systems and weapons with information capabilities and linking geographically dispersed forces and capabilities into an integrated system capable of unified action."²⁹¹ Additionally, the PLA has practiced the use of these new forces to counter major threats; for example, in constructing F-117, F-22, F-35, and B-2 mock-ups

²⁹¹ *Annual Report to Congress: Military and Security Developments Involving the People's Republic of China 2014*, 12.

to test its anti-stealth technology.²⁹² Further evidence suggests that successful ASBM tests have been carried out in the Gobi desert that simulate attacks against a U.S. CVN.²⁹³ The 2014 IISS analysis of China military states, “Over the past 15 years, PLA units have undergone major structural changes and received significant amounts of new equipment. A new doctrine has also been introduced, emphasizing joint operations using all units, with both old and new equipment, and integrating new capabilities from all services.”²⁹⁴

This thesis has found that China is increasingly focused on fielding world-class technologies. It has developed equipment that rivals that of the top militaries, and in some cases, exceeds them in performance. As China continues to innovate in relation to its past capabilities, it is beginning to develop technology that counts as innovation on the global scale. Despite these advances, there are still areas where China has not yet been able to catch up, primarily in nuclear submarine quieting, jet engine production, and aircraft carrier technology.

In cases where it has not caught up, China has innovated in areas that provide an asymmetric advantage. Examples of this are the expansive anti-ship missile programs specifically designed to counter U.S. CVNs and stealth-detecting radar designed to defeat U.S. fifth-generation aircraft. Furthermore, the combination of its technological developments and its security situation both in Asia and with the United States is causing the PLA to undergo a period of doctrinal change. Instead of merely focusing on developing a limited number of highly capable platforms, weapons, and systems, China is following a dual-track of modernization whereby it is developing and fielding advanced systems of its own, but is also developing systems that allow its current force structure to be much more capable in a future conflict. This is best seen as a direct counter to the U.S. doctrine of overwhelming force through technological superiority.

²⁹² “China Touts Anti-Stealth Radar,” *Defense News*, October 4, 2014, <http://archive.defensenews.com/article/20141004/DEFREG03/310040023/China-Touts-Anti-stealth-Radar>.

²⁹³ Simpson, “The End of Domain Centered Theories of Warfare — On Theory.”

²⁹⁴ “The Military Balance: Asia,” *The Military Balance* 114, no. 1 (February 5, 2014): 208, doi:10.1080/04597222.2014.871879.

China's strategy, military modernization, and rhetoric all align in what appears to be a deterrent doctrine against the United States. In terms of numerical strength, the PLAN has already surpassed the U.S. Navy in total number of combatants, and in each ship class with the exception of nuclear submarines and aircraft carriers.²⁹⁵ While China is working to close this gap, it is simultaneously fielding equipment designed to neutralize these extremely expensive and vulnerable platforms.²⁹⁶ China's modernization programs have yielded sufficiently innovative technology that it already possesses the ability to deter armed U.S. intervention in Asia due to the destructive potential it can inflict on U.S. forces.

²⁹⁵ Holmes, "China's Navy Is Already Challenging the US in Asia."

²⁹⁶ Gertz, "China Military Buildup Shifts Balance of Power in Asia in Beijing's Favor: Congressional Report Warns the Danger of U.S.-China Conflict Is Rising."

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