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THESIS

COST AS A FACTOR IN CHINA'S RESEARCH, DEVELOPMENT, AND ACQUISITION (RDA) CYCLES AND DECISION-MAKING

by

Adam J. Dickson

March 2022

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Considerable attention is paid each year to costing Chinese weapons systems and then aggregating individual system estimates into total Chinese defense costs. Aggregate figure costs are then compared against those of the United States as a guidepost for assessing the adequacy of U.S. defense spending and as a substitute in planning for the Chinese military threat. These standard treatments of cost might gloss the depth and breadth of risk associated with the U.S. defense spending profile. The future of the Department of Defense is toward the INDOPACOM theater, and China is our peer threat. There is very little academic research into how China conducts defense spending and, most importantly, how it intends to invest in future capabilities. This study will continue the 2018 NPS thesis *Comparison of Naval Acquisition Efficiency between the United States and China*; however, it will focus on Marine Corps–specific investments. The findings of this thesis will help inform how the influence of cost on Chinese weapon acquisition decision-making informs Force Design 2030 decision-making.

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COST AS A FACTOR IN CHINA'S RESEARCH, DEVELOPMENT, AND ACQUISITION (RDA) CYCLES AND DECISION-MAKING

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ABSTRACT

Considerable attention is paid each year to costing Chinese weapons systems and then aggregating individual system estimates into total Chinese defense costs. Aggregate figure costs are then compared against those of the United States as a guidepost for assessing the adequacy of U.S. defense spending and as a substitute in planning for the Chinese military threat. These standard treatments of cost might gloss the depth and breadth of risk associated with the U.S. defense spending profile. The future of the Department of Defense is toward the INDOPACOM theater, and China is our peer threat. There is very little academic research into how China conducts defense spending and, most importantly, how it intends to invest in future capabilities. This study will continue the 2018 NPS thesis *Comparison of Naval Acquisition Efficiency between the United States and China*; however, it will focus on Marine Corps–specific investments. The findings of this thesis will help inform how the influence of cost on Chinese weapon acquisition decision-making informs Force Design 2030 decision-making.

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LIST OF ACRONYMS AND ABBREVIATIONS

CADD	Central Military Commission Armament Development Department
CCP	Chinese Communist Party
CJCS	Chairman of the Joint Chiefs of Staff
CMC	Central Military Commission
CRS	Congressional Research Service
DOD	Department of Defense
DON	Department of the Navy
EABO	Expeditionary Advanced Basing Operations
GAO	General Armament Department
GLD	General Logistics Department
ICD	Initial Capabilities Document
IPT	integrated product team
JCIDS	Joint Capabilities Integration and Development System
JROC	Joint Requirements Oversight Council
MOF	Ministry of Finance
MROC	Marine Corps Requirements Oversight Council
NDS	National Defense Strategy
NED	Naval Equipment Department
NMS	National Military Strategy
NSS	National Security Strategy
O&S	operations and support
PLA	People’s Liberation Army

PLAN	People's Liberation Army Navy
PLARF	People's Liberation Army Rocket Force
POM	Program Objective Memorandum
PPBE	Planning, Programming, Budgeting, and Execution
PRC	People's Republic of China
R&D	research and development
SECDEF	Secretary of Defense
S&T	science and technology
SPC	State Planning Commission
STIC	Study of Innovation and Technology China
USMC	United States Marine Corps
USN	United States Navy

ABOUT THE AUTHOR

Captain Adam J. Dickson was born and raised in Fowler, Ohio. The youngest of three children, Captain Dickson graduated from Tiffin University in Ohio with a bachelor's in Homeland Security and Cyber Defense and was commissioned through the Platoon Leadership Course in 2012.

After completing The Basic School in 2013, Captain Dickson attended the Aviation Supply Basic Officers Course in Newport, Rhode Island. Upon completion, he was assigned as a supply officer to the Marine Aviation Logistics Squadron 14 at Marine Corps Air Station Cherry Point, North Carolina, where he served from 2013 to 2017.

Upon completing his first successful tour, Captain Dickson was assigned to Headquarters Marine Corps, Programs and Resources, Program Analysis and Evaluation directorate. He served as a program analyst from 2017 to 2020, where he was in charge of both the Training and Education and Headquarters portfolios. Captain Dickson was selected on the Commandant's Career Level Education Board to attend the Naval Postgraduate School to study defense management. After graduation, Captain Dickson will be assigned to Headquarters Marine Corps, Programs and Resources, where he will be a defense systems analyst.

Captain Dickson's personal awards include the Navy Commendation Medal (two awards) and a Navy Achievement Medal. He is married to his husband, Cole Staudt, and they have two wonderful dogs, Izzy and Charlie.

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I want to thank my advisors, Dr. Simona Tick and Raymond Jones, who have been instrumental in making this process as painless as possible. Thank you both for making sense of a complicated and broad subject; your advice helped narrow the scope and steer this thesis in the right direction.

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I. INTRODUCTION

A. PURPOSE OF RESEARCH

There is a concern that the return of investment (ROI) for the U.S. Department of Defense's (DOD) capability is not as high as it should be. China appears to maintain a positive glideslope with its warfighting capabilities by increasing capacity and defense spending, yet the U.S. spends trillions of dollars on large-scale, exquisite systems to maintain a competitive edge. The DOD's Acquisition System, or The Big "A," must continue the efforts to avoid the U.S. to lose its competitive advantage against peer threats. The Defense Acquisition Process (DAP), Joint Capabilities Integration and Development System (JCIDS), and the Planning, Programming, Budgeting, and Execution (PPBE) process must effectively synchronize to deliver capabilities to the warfighter. Sounds simple enough on paper, but each element of the DAP consists of sub-processes that contain several other sub-processes.

Additionally, Congress funds our government and military; thus, the DAP must answer their prerogatives. If the character of war is increasingly dynamic, how can America outpace its enemies if the DOD cannot field a weapon quickly? Members of Congress even believe the DAP is "overly bureaucratic and too slow to deliver a capability to the warfighter" (GAO, 2019, p. 5). Moreover, the cost to fund warfighting capabilities increases each year for many reasons like schedule delays, supply chain constraints, contract issues, etc. Yet, China seems to field capabilities more rapidly. Furthermore, China will outpace the U.S. because we consistently spend money on expensive, exquisite systems, while the Chinese government leverages technology transfers to gain a competitive edge.

The future of the DOD is towards the INDOPACOM theater, and China is our peer threat. There is very little prior research into how China conducts defense spending and, most importantly, how they intend to invest in future capabilities. Understanding how cost plays a factor in China's decision-making is important to assess the sufficiency of U.S. defense spending towards the Chinese military threat. Considerable attention is paid each year to costing Chinese weapons systems and then aggregating individual system estimates into total Chinese defense costs. Moreover, attention is spent each year costing Chinese weapons systems and then compiling the aggregate cost information into total Chinese defense expenditures. Aggregate figure costs are then compared to the U.S. to assess the sufficiency of defense spending towards the Chinese military threat. These standard treatments of cost might gloss the depth and breadth of risk associated with the U.S. defense spending profile. This study will continue the NPS thesis *Comparison of Naval Acquisition Efficiency between the United States and China* (Lorge, 2018); however, it will focus on Marine Corps specific investments.

B. RESEARCH QUESTIONS

This thesis aims to determine the extent to which cost plays a factor in China's Research, Development, and Acquisition (RDA) cycle by examining the connection between cost and operational capability. To meet this study's objective, the following research questions will be answered:

(1) Primary research question:

- How do China's military expenditures compare to the United States?

(2) Secondary Research Questions:

- What frameworks can be used to compare cost and capability at the program level?
- What is the cost comparison at the program level for USMC and PLARF weapons?

Comparing cost to operational capability is one way to assess the overall efficiency of China's RDA cycle. Applying those results to an American weapons system will help decision-makers realize how much utility is gained with every dollar spent. By reviewing the funding profiles of large-scale DOD programs and comparing them to similar Chinese weapons systems, one could deduce where we are either lacking in capability or excelling. Regardless of the outcome, this thesis is one way to help assess our overall cost efficiency through a macro-level analysis of the U.S. and China's military expenditure profile and a micro-level analysis of operational systems at the program level. This thesis will help inform those with a background in acquisitions and cost estimation and cover several areas of study, but primarily focus on acquisition and cost.

C. SCOPE AND LIMITATIONS

The research is limited to GDP and military expenditure information between the U.S. and China for the macro-level analysis. The scope of this study for the micro-level analysis is limited to United States Marine Corps (USMC) and the People's Liberation Army Rocket Force (PLARF) programs. The aim is to provide a more scaled approach to determine if cost plays a factor and analyze the cost efficiency in each country's acquisition process.

My thesis continues the work of Lorge (2018), who developed a framework to compare the acquisition efficiency between several countries. Lorge used this framework to score the overall battleship acquisition efficiency between the United States Navy (USN) and the People's Liberation Army Navy (PLAN). The scope of the data analyzed in this report will be limited to the anti-ship missile programs currently utilized by the USMC and the PLARF in China. These programs were selected for several reasons. First, the anti-ship missile program contributes directly to the INDOPACOM theater's operations. Second, the Commandant of the Marine Corps (CMC) has made anti-ship missile operations one of his top enablers in the future fight against China. Third, both the USMC and the PLARF have very similar capabilities, thus making it easier to compare. The anti-ship missile program offers a robust acquisition footprint, making the cost implication critically significant in budgetary and mission risks.

Similar to Lorge (2018), there are several limitations concerning the "veracity of the data that is available" regarding Chinese defense expenditures (p. 2). First, the People's Republic of China (PRC) underreports defense budget numbers significantly. Due to these data inconsistencies, all of China's defense expenditures come from independent researchers' open-sourced estimates, which will be discussed in the literature review section. Second, due to the complexity and secrecy of both anti-ship missile programs, only unclassified data will be analyzed, void of any capability analyses.

D. METHODOLOGY

This study is conducted using quantitative and qualitative data mixed methods. It leverages preexisting metrics used to measure the cost efficiency between the U.S. and China outlined in LCDR Lorge's 2018 NPS thesis. The scope is limited to more extensive USMC programs that require robust acquisition systems or those deemed critical investments based on the authoritative documentation listed below. A literature review gathers knowledge from prior studies on China's and the U.S.'s defense spending and RDA cycles, to support the development of the analysis used in my thesis.

Financial data are reviewed from relevant Headquarters Marine Corps (HQMC) and DOD reports to quantitatively analyze and compare the U.S defense investment profile to China. Additional data are gathered from open-source financial reporting documentation to derive China's defense investment profile. Moreover, this study focuses on defense investments corresponding with authoritative policy documents like the National Security Strategy (NSS), National Defense Strategy (NDA), Commandants Planning Guidance (CPG), and the Force Design 2030 (F.D. 2030) directive for the USMC. The literature review identifies the necessary authoritative documentation used by China that guides their defense spending. The findings of this thesis help inform how the influence of cost on Chinese weapon acquisition decision-making informs Force Design 2030 decision-making.

E. ORGANIZATION OF REPORT

The rest of the thesis is organized as follows. Chapter II provides the background information on the United States and China's acquisition systems, explicitly addressing each country's requirements generation process, acquisition process, budgetary process, resource allocation system, and weapons development system. Chapter III presents the literature review, which discusses peer-reviewed reports, thesis, papers, and articles on the acquisition process of both the United States and China. Chapter IV discusses the methodology used to analyze the available data, identifies the metrics used to assess the relationship between cost and operational capability, and leverages preexisting frameworks to compare the USMC and PLARF weapons systems. Chapter V presents the analysis and demonstrates how cost affects China's RDA cycle by comparing China's defense expenditure profile to the United States and the anti-ship missile programs between the USMC and PLARF. Chapter VI concludes with an overall summary of the findings and provides suggestions for areas of future research.

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II. BACKGROUND

This chapter discusses defense acquisition at a macro level and then compares the individual processes between the U.S. and the PRC. It starts with defining defense acquisition and discusses the three critical steps of the DOD's acquisition process in detail. These steps will set the foundation of how the DOD provides operational capabilities to the warfighter. Next, this section will overview how the PRC is organized and discuss its acquisition process. Finally, the PRC's weapons development process and resource allocation system will be discussed in detail and compared to the U.S. defense acquisition process.

A. DEFENSE ACQUISITION SYSTEMS

A defense acquisition system is defined as a "set of processes and procedures that a country will use to assign resources to requirements that will satisfy national security objectives" (Lorge, 2018; Marcum, 2013). The DOD implements three processes in its defense acquisition system to manage resources and acquire weapons systems. The first is the PPBE process, which is the DOD's primary resource allocation system. The second is the JCIDS process covering the requirements development process. Finally, the DAS incorporates milestones to deliver resources to the warfighter. These processes are discussed further in the following few paragraphs.

1. The Planning, Programming, Budgeting, and Execution Process

The PPBE process is DOD's primary resource allocation system (McGarry, 2020). Developed in 1961 by Robert S. McNamara, the PPBE process is an annual procedure that identifies which programs align to strategic objectives and assigns resources to those programs based on a five-year cycle called the Future Years Defense Spending Plan (FYDP). The output of the PPBE cycle is called the program objective memorandum (POM), which is a document required from every defense-related agency that consumes any financial appropriation. The POM is the authoritative document that informs the presidential budget submission to fund the DOD.

The first phase of the PPBE cycle is Planning, which generally begins after the President releases the NSS, the Secretary of Defense releases the NDS, and the Chairman of the Joint Chiefs of Staff (CJCS) releases the National Military Strategy (NMS). These three strategic documents inform the planning phase by establishing objectives to preserve and protect national interests. Each service will conduct capabilities gap analyses to ensure they have the adequate resources to meet the requirements laid out in the NSS, NDS, and NMS. Once all the services have completed their requirements review, the results are laid out in the Defense Planning Guidance, and each service will leverage that document to conduct its internal planning process. For the Marine Corps, the Commandant releases the annual CPG, the outlook in the next decade, and the Combat Development and Integration (CD&I) branch is the sole source for developing requirements to meet the CPG. The requirements generation process will be discussed further under the JCIDS section.

The next phase in the PPBE cycle is the Programming phase, which assesses programmatic risk in each services portfolio to inform the POM. This is done by each service conducting a thorough program review of their respective portfolios. In the Marine Corps, the program evaluation board (PEB) chair will initiate the program review, and each program manager will physically brief the health of their portfolio. The brief consists of reviewing the basic overview of what the program does, the current funding profile in the FYDP, any future additive capabilities, and the various levels of risk incurred if that program took a funding reduction. Once all program reviews are complete, the PEB chair will release the results to the Deputy Commandant of Programs and Resources (DC, P&R), who will ensure the entire USMC investment portfolio is balanced and able to meet the requirements outlined in the CPG.

Next, DC, P&R will brief the program review results to the Marine Resource Oversight Council (MROC) to build the Tentative POM (T-POM). The MROC is chaired by the Assistant Commandant of the Marine Corps (ACMC) and the other Deputy Commandants. After the MROC approves the T-POM, it will then go to the CMC for final approval before submitting it as the last POM to the Office of the Secretary of Defense Cost Analysis and Program Evaluation (OSD CAPE).

The third phase of the PPBE process is the Budgeting phase which ends with the final presidential budget submission. After OSD CAPE gathers each POM from its respective service, the comptroller will review the entire submission and ensure the appropriate fiscal controls are in place before final submission to Congress (McGarry, 2020). Once complete, OMB will include the budget submission in Congress's annual Presidential budget request to inform the National Defense Authorization Act (NDAA).

The final phase is the Execution phase used to track the budget and evaluate the program results. The data gathered from this phase will forecast the cost of future requirements and help determine programmatic risk. Essentially, the execution phase is like a report card that helps identify which programs are under-executing their allotted budget over executing the money given. It is intended to compare the program's actual performance to its forecasted or planned performance (McGarry, 2020).

2. The Joint Capabilities Integration and Development System

The JCIDS encompasses the statutory rules for the DOD's requirements generation process, and it is the authoritative source for the Joint Resource Oversight Council (JROC) exercise its Title X responsibilities to the CJCS (CJCS, 2021). The JCIDS is the needs identification arm of the triad in the DAP, and it begins with a service agency conducting a Capabilities Based Assessment (CBA). The CBA helps identify gaps between the requirements outlined in the NDS and the available capabilities which make up a service's warfighting portfolio. These gaps are then translated into different resource requirements and prioritized by the service chiefs to consider additive capabilities or new defense systems.

After completing a CBA, the service will follow up with other analyses such as the Doctrine, Organization, Training, Materiel, Leadership and Education, Personnel, and Facilities (DOTMLPF) analysis, Operational Planning Team (OPT) assessments, or other experiments to ensure the CBA is valid. Once the results are finalized, the CBA will inform the Initial Capabilities Document (ICD), initiating the acquisition process. The ICD captures the services' initial need for an identified capability gap and provides traceability to the operational doctrine, threats, and other relevant factors that inform joint requirements

(CJCS, 2021). The ICD will also inform the Material Development Decision (MDD) once a capability need has been identified (CJCS, 2021). The MDD will be the formal interface with the next leg of the DAP, called the Defense Acquisition System (DAS).

3. The Defense Acquisition System

The DAS is the actual acquisition or the procurement of the new or additive capability. The DOD uses the DAS in terms of milestones to oversee the management of the acquisition process (Schwartz, 2014). Milestone A is the first phase of the DAS, and it consists of the Materiel Solution Analysis (MSA) and Technology Maturation & Risk Reduction (TMRR) events. The MSA signals the analytical rigor needed to select the appropriate concept, and connects the capability gaps to system-specific requirements that will inform the overall acquisition strategy (OUSD (A&S), 2015). The output of the MSA event is the draft Capabilities Development Document (CDD), which feeds the TMRR event.

The TMRR event helps realize the risk associated with the new capability and validates the CDD draft. The major priorities in the TMRR event include reducing technology, engineering, integration, and life-cycle cost risk, demonstrating critical technologies on prototypes, and developing an acquisition strategy to support the decision to proceed into development, production, and sustainment (OUSD (A&S), 2015). The final output is a complete and validated CDD that will inform the activities in the next phase of the DAS. Milestone B consists of the Engineering & Manufacturing Development (EMD) phase, and its purpose is to "develop and test a product to verify all operational and derived requirements are met" (OUSD (A&S), 2015). Several key events in the EMD must be completed to move on to Milestone C. These events include developmental testing and evaluation, integrated logistics assessments, critical design reviews, and other planning documents required to outline and support the logistics and sustainment plans for the program's life cycle. The final output of Milestone B is a formal program initiation or Program of Record (POR), which means that funding has been secured to build and test the new or additive capability.

The final phase of the DAS is Milestone C, which consists of two events, Production and Deployment (P&D) and Operations and Support (O&S). The P&D phase is where the rubber meets the road because the new or additive capability has a prototype ready for low rate initial production that will be used for operational test and evaluation (OUSD (A&S), 2015). Once the prototype has met all user requirements, the O&S event will test the product support strategy to ensure the DAP can sustain the actual program. Once material readiness and operational support requirements are met, the program will enter the final phase of Full-Rate Production, where the predetermined quantity will be produced and delivered to the user (OUSD (A&S), 2015).

B. CHINA'S RESEARCH, DEVELOPMENT, AND ACQUISITION CYCLE

Lorge (2018) discusses China's RDA process through a Strengths, Weaknesses, Opportunities, and Threats (SWOT) analysis. By leveraging a 2018 paper written for the Acquisition Research Symposium by Tai Ming Cheung, titled *Strengths and Weaknesses of China's Defense Industry and Acquisition System and Implications for the United States*, Lorge (2018) breaks down China's RDA cycle into two separate parts, the requirements generation process, and the resource allocation process.

Beginning with China's requirements generation process, Lorge (2018) describes the process by starting at the top of the Chinese Government since they do not recognize different political parties (p. 9). Since the CCP is the ruling political party, the leader of that party sets the political direction of the entire country through a five-year development plan, similar to the DOD's FYDP (Lorge, 2018, p. 9). Currently, China is on its 14th Five-Year Plan, which spans 2021–2025 and outlines its strategic direction and goals (UNDP, 2021). The National People's Congress (NPC) officially approved the plan in March 2021 and outlined 20 major economic development indicators, including safety and security (UNDP, 2021).

Lorge (2018) points out that the People's Liberation Army (PLA) is not politically neutral yet acts as an arm for the Chinese Communist Party (CCP) and not the Chinese Government (p. 10). The PLA executes the CCP's Five-Year Plan via white papers that focus the defense requirements generation process to the strategic vision of the CCP

(Lorge, 2018, p. 10). Lorge (2018) discusses the most recent white paper, the Chinese Military Strategy (p. 10).

China's military strategy has been updated since 2015 and includes a robust framework to modernize its military in both technological innovation and warfighting capabilities that will outpace the U.S. Some macro-level examples include leveraging the whole gambit of its diplomatic, economic, and military power to thrust China into the forefront of global dominance. Other micro-level examples include the proliferation of long-range precision strike technology and accelerating the expansion of China's nuclear forces (DOD, 2021a).

Once the white papers are released, military leaders develop a list of capability requirements needed to achieve the strategic goals laid out by the CCP. These requirements are then reviewed by political representatives, military leaders, and industry to finalize which programs will receive resources (Lorge, 2018). Once the list of approved programs is completed, they will be included in the Five-Year weapons construction plan, according to Lorge (2018). The design and technical requirements are drafted by a coordinated effort of military end-users and industry through a comprehensive feasibility study which sets the stage for the research and development phases (p. 11).

Lorge (2018) uses the PLAN's shipbuilding process as a use case for the requirements generation process. He states that a "feasibility study conducted by the Naval Equipment Department (NED) would determine the fleet's needs for propulsion, storerooms, berthing, and so forth, to meet this new mission," which follows the similar process to the United States (p. 12). Once the design specifications are approved by the CMC Armament Developing Department (CADD), the ship will formally enter production (p. 12).

1. PRC's Resource Allocation Process

In a report titled *Defense Acquisition in Russia and China,* the authors discuss several key stakeholders in China's RDA process (Ashby et al., 2021). The first is the civilian-controlled State Administration for Science, Technology, and Industry for National Defense, which drafts and disseminates policy and plans for national defense. The authors then identify the military-controlled Equipment Development Department (EDD), which manages the weapons development life cycle for the PLA. Finally, under the PLA service branches, the General Armament Department (GAD) is responsible for manning, training, and equipping the forces (Ashby et al., 2021). Before 2016, the GAD and EDD worked together to manage the weapons procurement process, but after 2016, president Xi Jinping reorganized both departments into the Central Military Commission (CMC) (Ashby et al., 2021, p. 17). This reform decision enabled the Chinese RDA process to be less bureaucratic and provided president Xi Jinping with more direct oversight over the PLA, thus increasing efficiency (p. 17).

According to the authors, China has a five-step RDA process similar to the JCIDS process used by the United States: Feasibility Study; Project Design; Engineering and Development; Experiment and Design Finalization Phase; Production Phase. The most significant defense contractors in China are state-owned enterprises (SOEs) which the authors define as:

> Non-corporation economic units where the State owns the total assets and is registered in accordance with the Regulation of the People's Republic of China on the Management of Registration of Corporate Enterprises. Not included from this category are solely State-funded corporations in the limited liability corporations. (p. 19)

Additionally, China conducts suboptimal contracting within the SOE construct. The authors stated the following regarding China's contracting practices:

> China also practices a cost-plus pricing regime—a holdover of the command economy—which guarantees a 5-percent profit for contractors on top of their incurred costs. Contracts are single-sourced for most military equipment, with only non–combat-related contracts undergoing a formal bidding process. PLA leadership admitted as recently as 2014 that these institutional features—more than funds or technology—are the biggest impediments to China's RDA process. (Ashby et al., 2021, p. 23)

In his thesis, Lorge (2018) states that "the PRC resource allocation process overlaps significantly with its requirements generation process" (p. 14). Once the Five-Year plan has been released, the Ministry of Finance (MOF) leverages it to develop the Five-Year budget outlook for China. Additionally, Lorge (2018) states that "the Defense Bureau at the civilian State Planning Commission is responsible for developing the portion of the budget dedicated to the defense department" (p. 14).

The General Logistics Department (GLD) submits the budget plan to the Defense Bureau containing a complete list of all defense programs in the construction plan that require funding (Lorge, 2018, p. 14). Then, the defense budget gets wrapped up in the domestic budget by the MOF and submitted to the NPC for approval. The CCP's job is to determine the appropriate balance of resources between the military and domestic program submissions compared to those approved in previous budget cycles. According to Lorge (2018), the MOF and State governments decide on a "topline military expenditure number or allocation plan," and that number will be sent to the CMC and funneled down to individual military districts via the GLD (p. 15). The unique military districts will take that allocation plan and route their requirements via "investigation and augmentation reports" or "bids" to the regional commands then to the CCP for consideration into the defense budget (Lorge, 2018, p. 15). Once the bids are received, the GLD will draft a budget to the CMC, making any revisions and adjustments before forwarding the final draft to the MOF. The MOF will report the official budget globally, but the numbers are not always accurate, according to multiple sources discussed later in this thesis.

2. PRC's Weapons Development Process

The PRC's weapons development process consists of seven steps, which resemble our DAS, specifically the JCIDS process with some differences. The GAD was previously responsible for the weapons acquisition process, but the CADD replaced the GAD due to its narrow scope and the CCP's naval proliferation plan. According to Lorge (2018), the CADD was created to "provide centralized management over all the services and is now responsible for oversight over the PRC weapons development system" (p. 18).

C. CONCLUSION

This chapter provides the background on defense acquisition by identifying the U.S.'s three main processes currently used in acquisitions. It discusses the similarities and differences between the U.S. and PRC's acquisition process, weapons development process, and resource allocation. The next chapter reviews the relevant research associated with this topic.

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III. LITERATURE REVIEW

The chapter presents an analysis of a 2018 NPS study and several peer-reviewed articles to discuss the frameworks used to measure efficiency in acquisition systems. Then, this section reviews the relevant research associated with the PRC's weapons development process. Finally, this chapter concludes with a discussion on previous studies of the PRC's economic outlook, mainly how much money they spend on defense expenditures.

A. ACQUISITION EFFICIENCY BETWEEN THE U.S. AND CHINA

In a thesis written at the Naval Postgraduate School, Lorge (2018) assesses several countries' acquisition efficiency, including the U.S and the PRC. In his abstract, he states,

> The People's Republic of China has emerged as the most significant long-term strategic competitor to the United States on the world stage. To accomplish this, China has made substantial investments in modern naval systems. Understanding its acquisition system is required to know how successful China has been in this effort. (p. 1)

Lorge (2018) claims that most countries use different acquisition processes, and finding a standardized assessment framework is next to impossible; thus, he develops his own. Focusing on USN shipbuilding, Lorge (2018) identifies 10 key factors that affect a country's acquisition efficiency. His findings suggest that while U.S.'s shipbuilding program outpaces China, China has a superior cost and schedule performance. Lorge's primary research question aims to answer, "how can the differences in efficiencies of the acquisition systems for naval vessels in the United States and China be identified and measured?" (p. 2). He has two secondary questions, and they are as follows: "What are the critical acquisition processes used by the United States and China?" and "Can the total life-cycle costs (development, procurement, and operations and support [O&S] costs) for similar acquisitions be compared?" (p. 2).

He uses a gap analysis to determine the delta between current capabilities and those needed to satisfy strategic guidance. The results of that analysis then inform future strategic guidance, and capabilities are baked into the requirements documentation. After conducting a thorough literature review of previous analysis, Lorge derives metrics that he believes could measure efficiency. The final list of Lorge's acquisition efficiency factors are depicted in Table 1 and are used to help narrow the scope of his thesis. My thesis will leverage the cost and O&S cost acquisition efficiency factors for the micro-level analysis portion.

Table 1. Final List of Acquisition Efficiency Factors. Source: Lorge (2018).

Acquisition Efficiency Factor	U.S. Acquisition Efficiency	Comparison of Acquisition Systems	The PRC Acquisition System
Cost	X		X
Schedule	X		X
Performance	X		X
Acquisition Workforce	X	X	X
Contracting	X	X	X
Resource Allocation	X	X	
Innovation	X		
Industrial Base	X	X	X
Requirements System	X		X
O&S Costs			

Lorge's next step was to apply scoring criteria for each efficiency factor used in his analysis to determine the overall acquisition efficiency rating. Lorge (2018) develops a simple scoring method that can be used "to capture a country's performance in that particular area" (p. 52). A fundamental category of "poor, neutral, and good" is assigned an arbitrary number from zero to four depending on that particular country's acquisition performance. These numbers are summed at the end to determine the country's overall acquisition performance rating or score. Lorge's (2018) intent for the scoring criteria to be scalable by allowing the user to examine each criteria's weight and determine the appropriate score for that specific efficiency rating. Lorge then defines the metrics that were used to score each efficiency factor. For example, he describes the cost metric in the following way:

> Comparable systems of this country have the lowest production cost. Unlike some cost performance metrics identified in the research, this metric does not judge cost performance on the initial baseline. This is because baseline

> accuracy is widely varied. Instead, this metric reflects the direct costs incurred by countries in the production of similar systems. (p. 57)

Next, he outlines the definition of the cost scoring criteria in the following way:

> Good: Superior overall and in the majority of programs
> Neutral: Superior overall or in the majority of programs
> Poor: Neither superior overall nor in the majority of programs (p. 59)

The intent behind the scoring metric and its respective scoring criteria is to normalize each efficiency factor and show the differences in how each factor impacts the acquisition process. To capture those efficiency factors, which proved challenging to analyze quantitatively, Lorge applies a qualitative analysis based on relevant and available literature. For example, the Industrial Base efficiency factor is identified as being challenging to use a quantitative metric to; therefore, Lorge states in his scoring criteria of this efficiency factor that:

> This metric is assessed using qualitative data. The user of this framework should assess the processes and results of each country's requirements system. A determination should be made whether the requirements documents produced by the system are influenced solely by the country's strategic objectives or whether there are other factors. (p.62)

Lorge then applies the acquisition efficiency framework to the battle force shipbuilding programs of the United States Navy (USN) and China to "determine which country is more efficiency in their acquisition of naval vessels" (p. 65). Next, Lorge collects data to analyze each efficiency factor quantitatively and qualitatively. For example, to assess the cost performance criteria, he gathers data on the USN's shipbuilding budget from 2012 to 2016 and selects USN vessels comparable to vessels found in China's fleet (p. 68). He applies the scoring criteria in comparative analysis, and whichever country has the lowest cost per ship scores higher in cost performance (p. 65). My thesis will adopt the same methodology and use it towards a comparison between the Marine Corps' and the PRC's anti-ship missile programs.

For the qualitative comparative analysis, like the O&S cost factor, he applies more subjectivity to assess if the "O&S costs are considered when developing a new weapon system" (p. 62). Although this efficiency factor is scored using some subjectivity, I would argue Lorge does an excellent job reviewing relevant and available literature, synthesizing the information, and scoring the O&S cost factor this manner. My thesis will leverage qualitative data to inform the analysis for the O&S cost factor.

Lorge concludes that the U.S. scored higher is in its acquisitions process than China; however, China outperforms the United States in Cost and Schedule Efficiency. This is primarily due to how China uses the absorption method for new technologies, and the U.S. spends much more on research and development than China (p. 84). Additionally, Lorge finds that using Operation and Support (O&S) costs to derive China's O&S efficiency score proved difficult due to the lack of available data.

Lorge recommends that to maintain a "strategic advantage" over China, the United States must consider an accelerated acquisition process, improve contracting methods, and increase capacity in their industrial base (p. 85). Additionally, he recommends assessing the feasibility of procuring a smaller Littoral Combat Ship (LCS) comparable to the Corvette Class Vessel used by China (p. 86). Lorge states that "an analysis should be conducted to determine whether such a vessel would benefit the USN" (p. 86). Lastly, Lorge recommends that applying China's absorption method that would not violate intellectual property laws could prove beneficial to acquire technology from private industry quickly.

Lorge's thesis informs this report through the use of the cost and O&S cost factors, along with their respective scoring criteria. Lorge's analysis of the USN and the PRC's shipbuilding programs prove to be beneficial for decision-makers because it is an evidenced-based approach towards assessing acquisition efficiency. Additionally, one could leverage his framework for any defense program as a report card to inform future funding decisions towards that program.

B. FRAMEWORKS TO ASSESS ACQUISITION EFFICIENCY FACTORS

This section discusses various methodologies to assess acquisition efficiency proposed by several authors in peer-reviewed reports and journals. First, this section defines the RDA cycle and then link innovative factors to the RDA process. Next, this section discusses cost as a factor in the RDA process and provide a framework for assessing it.

1. Innovation as a Factor

In a report titled *Developing a Framework to Identify Innovation in the Defense Research, Development, and Acquisition Processes,* the author develops a methodology to identify and categorize certain innovation factors in an RDA cycle (Marcum, 2013). This RDA framework "provides a systematic, interdisciplinary approach to analysis by benchmarking past experiences to gain insight into future defense industrial capabilities" (p. 2). In the brief, Marcum (2013) vignettes a generic RDA processes framework and how most bureaucratic processes are similar across several western countries (p. 2). She states that "decision-makers may choose any number of acquisition strategies, including indigenous development, copying, co-development, licensing, purchase, or a hybrid mix of approaches based on a country's national science and technology (S&T) capability" (Marcum, 2013, p. 2). Depending on who is in charge may dictate how research and development are addressed, specifically technological development (p. 2).

Next, Marcum (2013) discusses the innovation RDA processes framework and seeks to adopt a model that enables "analysts to take a systematic approach to evaluate change over some time by identifying the overlapping observable phenomena of hard and soft innovation capabilities found in the stages of a generic RDA process" (p. 2). She discusses the common RDA elements in her analysis. For example, some of the common RDA elements include pre-program activities, requirements, research and design, development and demonstration, production, and operations and maintenance (Marcum, 2013, p. 3). Additionally, she lists the innovative factors associated with the common RDA elements. The list includes but is not limited to political and military organizations, research labs and investitures, human capital level of experience, manufacturing facilities, and skill set for maintenance (p. 3). Marcum (2013) generates a table of Common RDA Elements and Innovative Factors seen below.

She then synthesized each RDA element and the respective innovation factor to derive the hard and soft innovations that may "signal a change in the development process" (p. 2). Marcum leverages these hard and soft innovative factors, illustrated in Table 2, to derive a list of questions that would assist the analyst in directing the objective research process.

Table 2. Linkages between Common RDA Elements and Innovative Factors. Source: Marcum (2013).

Pre-program activities	Requirements/ Needs	Research and design	Development and demonstration	Production/ manufacturing	Operations and maintenance
Basic/Basic applied research *Development facilities* *Defense funding of civil-related technology research* *Organizations creating a "DARPA effect"* *Entrepreneurial skills to market technology advances* *Degree of foreign involvement*	The identification of equipment needs based on capability gaps and strategic priorities. Concepts are developed and submitted for consideration. *Political and military organizations* *Budgets for investment in defense programs* *Perceived threats* *Recent events that trigger a military response* *Contract mechanisms* *Import/export approval mechanisms* *Organizations approving program start-up* *Degree of foreign involvement*	The government accepts a design concept. A feasibility study is conducted. Plans are made to develop or acquire technology and insert into the program. Final specifications are accepted by the government. *Research laboratories and institutes* *Development facilities* *Design organizations* *Leading design personalities* *Defense funding of civil-related technology research* *Organizations creating a "DARPA effect"* *Regulations*	A program manager sets a development, industrial production schedule with milestones. Designs are finalized, demonstrated, and approved for production. Contracts are selected and a systems integration plan is set in place. *Human capital—level of expertise* *Production facilities* *Contributing enterprises* *Technical know-how* *Systems integration skills* *Funding sources* *Approval processes and organizations* *Demonstration*	A manufacturing plan is executed. All production-related activities are defined and monitored. Equipment is tested for final production and acceptance. *Manufacturing facilities and locations* *Approval processes* *Technical skills* *Oversight and approval for fielding* *Culture for presenting finished products* *Interaction between organizations* *Role of political and military leadership* *Degree of foreign involvement*	System is presented to the service for acceptance. Failures to meet performance requirements may result in rejection and modification. Systems are delivered for operational use. At the end of the spectrum, equipment is maintained and eventually disposed of according to the life-cycle plan. *Services involvement in acceptance and retirement of systems* *Skill set for maintenance* *Degree of foreign involvement*

The intent behind this list of questions is to move away from the generic RDA framework and develop a more narrowed scope that would assess future development strategies. Marcum's work informs this report by showing different alternatives to assess innovation in acquisition.

In a policy brief titled *Innovation in China's Defense Research, Development, and Acquisition System,* Cheung (2011) discusses technology's effects on the RDA process over the last 80 years. Cheung observes the three basic steps of the RDA process as basic research, applied research, and development and production, which was the process flow for most of the 1950s into the 1970s (p. 2). Emerging technology advances the RDA process into a "coupling model," observed in the 1990s. This coupling model combines the basic linear acquisition process and injects feedback loops which achieve a more dynamic and interdisciplinary approach to acquisitions. Cheung discusses how the DOD uses the current systems-oriented system because it decreases compartmentalizing, causing issues with innovation.

The next area of focus was China's RDA cycle and aligning more with a coupling model due to the Chinese Government's control over the industrial base. Cheung states that "the Chinese Defense RDA process resembles the five key phases of the U.S. approach," although there are some differences (p. 5). For example, the first phase of the U.S. Defense RDA framework contains a comprehensive feasibility study, while the Chinese framework is called pre-concept. The U.S. conducts a joint capabilities analysis to capture all necessary end-user requirements during the first phase, while the first phase of the Chinese framework is more unilateral.

The Chinese RDA framework, specifically the R&D process with industry, is more restrictive, according to Cheung (2011). The Chinese Government primarily conducts the pre-concept design and testing before it is released to the industry as they prefer to keep a tight lid on design plans. Cheung (2011) concludes that the Chinese RDA process is not ideal for long-term innovation. The Chinese Government's strict control over industry stifles the innovative process and thus inhibits China's modernization efforts. This study shows several overlaps between the PRC's RDA cycle and the U.S. acquisition process. Moreover, it demonstrates how the U.S. is less restrictive towards long-term innovation while China focuses on short-term which stifles its innovation.

C. THE PRC'S RDA PROCESS

This section discusses how China procures and assimilates technology into its economy. First, this section discusses the importance of how foreign technology transfers affect China's RDA process. Next, this section provides an overview of China's economy. Finally, China's financial reporting inconsistencies will be discussed.

1. The PRC's RDA Process

China is making impressive progress in developing its science and technology (S&T) capabilities, especially in the defense domain, but it remains a considerable distance from the global technology frontier. One of the most effective ways to close this gap is to leverage the technology possessed by advanced S&T powers. China, however, faces high barriers to gaining access to this technology and expertise because of long-standing Western export restrictions on defense and dual-use transfers. Along with increasing its investment in imported technology, China collaborates with foreign entities to locate and seize research and development opportunities. Covertly, China is conducting industrial and cyber-espionage and reverse engineering. Understanding how China obtains, absorbs, and transforms foreign defense technology and knowledge into its local adaptations is crucial in assessing its defense technology rise and its long-term innovation prospects.

In a policy brief titled *The Role of Foreign Technology Transfers in China's Defense Research, Development, and Acquisition Process,* Cheung (2014) lists the defining operational attributes of China's defense innovation in the following ways. First, imitation is the primary means of innovative technology. Second, leadership is top-down. Third, the intentional restricted access to the outside world. Fourth, the state sets the priorities and manages the system (Cheung, 2014, p. 2). These attributes help explain how China develops its acquisition strategy, but it does not explain how it acquires new technology. China's technological development and acquisition process is called introduce, digest, absorb, and re-innovate, or IDAR for short (p. 2).

Additionally, Cheung (2014) describes IDAR as how China absorbs or turns foreign technology into a usable defense capability and explains their absorption model in four stages; acquisition, assimilation, transformation, and exploitation (p. 3). The four stages of absorption combined with the four elements of the IDAR strategy are how Cheung (2014) describes the overall RDA cycle in China (p. 3).

Acquisition/Introduction

> Gaining access to external knowledge is the key component to China's RDA process (Cheung, 2014). There are several ways China tries to gain access to emergent technologies. The most common are arms transfers, foreign investments, espionage, open-source information, human capital transfers, and foreign R&D centers. The author concludes that espionage and open-source information are the most critical factors in China's RDA cycle because they are the most successful in acquiring the technology. (p. 3)

Assimilation/Digestion

> Cheung (2014) outlines the central government entities contributing to IDAR's assimilation aspect, including "the Institute of Scientific and Technical Information of China" and "the Ministry of Science and Technology. These entities contribute to China's information analysis and dissemination (IAD), which is how China "digests" the illegally acquired technology. The author concludes that the Chinese Government has increased its IAD system through the proliferation of these entities since the 1990s. (p. 3)

Information Analysis and Dissemination (IAD)

> Cheung claims that China possesses 400 analysts and diffusion centers with 50,000 personnel. Thirty-five of the centers belong to the Central Government; the rest belong to lower provincial governments. This shows that China is building a robust dissemination network, capable of rapidly processing new technology and informing its industrial base at a higher rate than its competitors. (p. 3)

Transformation/Absorption

> China uses IDAR to bridge current capabilities and external technology. They accomplish this mainly through corporate espionage, intellectual property theft, and unauthorized reverse engineering (p. 4). China has gained extensive absorption capabilities by investing heavily in its technology transfer initiatives. According to the author, the Chinese Government is expanding its national engineering research centers, enterprise-based technology centers, state key labs, national technology transfer centers, high-technology service centers, and recruitment of foreign technical experts. (p. 4)

Exploitation Re-Innovation

> China lacks a robust S&T manufacturing capability, thus restricting it from leveraging foreign-produced technology. The ability to gain access to foreign technology is critical to their defense industrial base as they are in the process of expanding their defense-related technology development (Cheung, 2014). Like the NDS, China has developed a five-year outlook in 2012 that details their plans to build their technology industry, including investments in skilled labor dedicated to advancing their domestic technology. Ultimately, China intends to reduce its reliance on foreign technology and focus on innovating organic defense-related technology. (p. 4)

The author concludes that the IDAR model is a more precise way to understand how China acquires technology. Additionally, the IDAR model assesses how China innovates its defense-related technology solutions through absorption and marrying foreign technology with domestic products (Cheung, 2014, p. 4).

2. The PRC's Economy

Taplin (2019) analyzes China's economy in a Wall Street Journal article titled *China's Economic Data: A Guide for the Dazed and Confused.* China ranks number two, right below the U.S., in the global balance of economic and military power, yet most of the data reported by the PRC is often misunderstood. Most of the PRC's financial data provides little justification for its massive growth over the last several decades, and this could be attributed to political leaders underreporting actual data. Taplin (2019) claims that when "an economic data point becomes a political target, the incentive for officials to report that information increases falsely." A notable example is how the PRC overstated the Inner Mongolia Province's industrial growth by 40 percent, while government revenue only inflated 26 percent to mask the effects of the housing and commodity market downturn in 2015 (Taplin, 2021).

Moreover, the author suggests that official statisticians use questionable judgments to capture industrial growth, specifically adjusting to "real" growth. Unlike the U.S., the PRC does not use accurate inflation indices to account for industrial development in its national accounts. Instead, officials rely on the PPI, which gauges the price of goods over time by domestic producers. The author claims that only using PPI will not provide a holistic snapshot of other commodities such as pharmaceuticals or electronics (Taplin, 2021).

3. Measuring Gross Domestic Product in China

In a journal article titled "Is China Fudging its GDP Figures? Evidence from Trading Partner Data" the authors sought to find a group of indicators highly correlated to GDP, but it is not subject to manipulation. The authors begin with the following research question, "how can we reliably estimate fluctuations in economic activity when official statistics are of questionable quality?" (Fernald et al., 2021, p. 1). The authors claim that even though China is notorious for using unreliable economic statistics, their data is increasingly becoming more reliable in the previous decade, but still have a long way to go

(p. 2). Assessing GDP itself lends little perspective to capturing China's economic growth rate.

China is no doubt using questionable economic statistics, particularly in the realm of their local and provincial output figures, and the authors claim that even prominent Chinese officials have expressed concern over corruption and data manipulation (p. 2). The main challenge is assessing reporting data quality by finding an independent output benchmark. One suggested benchmark is leveraging light emissions to determine real GDP growth. Capturing light emissions is done through satellite imagery and scanning certain areas at night to produce an accurate snapshot of night-time light to monitor actual GDP growth (p. 2). Other suggested benchmarks include assessing electricity consumption, rail cargo volume, and loan disbursements. Electricity consumption is pretty self-explanatory, less manipulation, and confirmed through light emissions. Rail cargo volume is another objective indicator and could be measured through fees charged for each unit of weight reported externally. The loan disbursements are also more accurate due to regulatory oversight and strict reporting rules (Fernald et al., 2021).

Imports are among the best-measured components of GDP because they are externally reported and could be used to track domestically reported Chinese activity because they are unexposed to Chinese manipulation (p. 2). Moreover, imports and measured GDP move closely for countries with sound statistical systems, like the U.S. Most notably, soybean crops grown in the U.S. and imported to China are reported by the U.S. and thus less subject to manipulation by China. Alternatively, imports from countries with poor statistical methods could be manipulated, but the authors argue that these represent a small portion of their sample (p. 2). They use imports as a baseline indicator but needed other hands to assess trends and compare the economic output of imports.

The authors conclude through statistical analysis that the following indicators have the highest correlation to economic activity: "the consumer index, electricity, exports, fixed asset investment, floor space, industrial production, rail freight, and retail sales" (p. 2). Many analysts have tried to capture China's actual GDP growth; however, local and provincial governments potentially distorted many of China's GDP outputs (Fernald et al., 2021). The authors tie the aggregate data of each indicator to an overall variable called

China's Cyclical Activity Tracker (C-CAT), which accurately captures China's overall economic growth rate. They used the Root Mean Squared Error (RMSE) Average and compared fourth-quarter growth rates from 2000 to 2020. Finally, they reached the C-CAT to the imports indicator, and they determined that the C-CAT and imports moved the closest together.

4. China's Financial Reporting Inconsistencies

In an article titled *China's Economic Data: An Accurate Reflection, or Just Smoke and Mirrors,* the authors state that "in the 1970s, China transitioned from a Command Economy to a market economy, allowing individuals to own companies and opening four coastal cities for foreign investment" (Owyang & Shell, 2017). Since 1978, China's economic growth has risen from 2.3 percent to nearly 18 percent. The authors claim that due to this rapid expansion, the Chinese Government developed the National Bureau of Statistics (NBS) "to track agriculture and production in the state-owned enterprises to capture GDP" (Owyang & Shell, 2017). However, the NBS maintained the Command Economy approach and only focused on display, accurately capturing growth.

In 1993, China transitioned to the United Nation's System of National Accounts and retroactively published their GDP under these methods; however, understanding and adopting these methods took time, thus resulting in inaccurate reporting of GDP data (Owyang & Shell, 2017). The authors review the history of China's statistical capacity score by comparing it to that of other developing countries. The score is based on an aggregate of 25 individual variables developed by the World Bank (Owyang & Shell, 2017). The authors conclude that China has scored below the median in the 38th percentile in the past, but they have improved and scored well into the 80th percentile (p. 3). The improvement is derived from more concise reporting methodologies, increased frequency of data releases, and adopting the International Monetary Fund's Special Data Dissemination Standard, which validates the accuracy of capital market data (p. 3).

The authors point out the varying methodologies used by researchers to capture China's real GDP growth. These methods include electricity output, construction indices, stock market health, and production and manufacturing. Similar to Fernand et al. (2021), the authors conclude that the most accurate methodology to assess China's GDP is Li's model, which captures the outputs of electricity production, rail cargo volume, and loan disbursement (p. 4). The results are very similar by comparing China's GDP growth output from 2000 to 2009 to Li's indices. However, Li's model does not capture agriculture, which makes up 49 percent of Chinese out (p.4). Another alternative method to capture China's real GDP growth includes luminosity or the tracking of light-emitting pixels at night to track economic changes done by economists J. Vernon Henderson, Adam Storeygard, and David N. Weil in 2012. The three economists seek to compare the effects of luminosity on income and found that there was, in fact, a strong correlation between the two (p. 4).

Owyand and Shell (2017) conclude that there are varying methods for capturing China's actual economic growth, but no one is better than the other. Until China becomes more transparent with its financial reporting data, the analyst will have to rely on what is available to predict China's economy accurately.

D. CONCLUSION

This section discussed previous work on assessing the RDA process by providing an overview of various frameworks used to evaluate acquisition efficiency. Additionally, it provided a review of multiple peer-reviewed articles covering the PRC's RDA process and how they acquire technology and assimilate it into their economy. This section also provided an overview of the PRC's economy and discussed several financial reporting inconsistencies with how China reports its GDP growth to the rest of the world.

Overall, there is insufficient literature which quantitatively analyzes how China acquires weapons systems. There are multiple reports showing overviews of the PRC's acquisition process and recent reform efforts to streamline it; however, these reports lack quantitative analyses needed to inform decision-makers. Additionally, China shrouds most information from the public which makes it difficult to assess the validity of information being analyzed. Frameworks developed by Lorge (2018), and Marcum (2013) are beneficial to this report because they provide tangible procedures to assess acquisition efficiency. Analyses conducted by Cheung (2011 & 2014) enable the reader to gain substantial knowledge regarding China's nuanced approach towards weapons development, yet there are very few similar reports from alternative sources. This suggests that other authors may have to rely on conjecture to formulate future opinions surrounding China's RDA cycle.

Alternatively, Owyang & Shell (2017) are able to quantitively analyze China's economic history despite China's secretive reporting tactics. The authors explain China's recent reform efforts to improve its financial reporting statistics, which is confirmed by Fernald et. al (2021). Furthermore, these reports suggest alternative ways to assess China's economic posture and will inform the analysis portion of this report.

IV. METHODOLOGY

A. SUMMARY

This chapter discusses the methodology used to assess the cost efficiency between the U.S. and the PRC in two ways. First, a macro-level analysis shows the overall economic posture between the two countries. Second, a micro-level analysis is conducted to assess the overall cost efficiency between two comparable defense programs. This analysis leverages the cost efficiency framework developed by Lorge (2018) to score each country's overall cost performance.

GDP and military expenditure data will be analyzed from the past 20 years for the macro-level analysis. This portion of the study intends to gather a holistic snapshot of each country's economic posture and compare them to each other to determine which country spends more on defense. Relevant indicators to be considered include per capita spending and overall defense budget profiles leveraging historical information. Data from two comparable weapons systems will be analyzed from the USMC and PLARF's arsenal for the micro-level analysis.

B. EFFICIENCY FACTORS AND METRIC SELECTION

The next step is to identify which efficiency factors from Lorge's (2018) model assess efficiency rating and cost performance. Lorge's (2018) framework ultimately had a list of 10 efficiency factors used to assess the acquisition efficiency between several countries. To maintain the scope of this thesis, only the factors associated with cost are selected for the analysis.

1. Efficiency Factors

These factors are identified by Lorge (2018) as having the most impact on the acquisition cycle (p. 52). Moreover, each factor had a scoring metric to derive the overall efficiency rating. The metrics that are used to score the cost performance of the Marine Corps investment portfolio are similar to the Lorge (2018) model as they are a simple Likert Scale of zero to four points. Once each metric is used to assess the ACAT 1 program, the score for that program will be added together to determine the overall efficiency rating. After selecting the efficiency factors and metrics, the scoring criteria follows the Lorge (2014) model, and the economic data will be used to reflect the current funding profile for an ACAT 1 program used by the Marine Corps and China.

2. Cost Factor Selection

Lorge (2018) developed ten efficiency factors in his framework, but to maintain this study's scope to assess cost, this report will only include those factors used to evaluate the cost-efficiency of each entity's acquisition systems. These include the cost efficiency and operational and support (O&S) cost efficiency factors. Both seem the same, but they are different. The cost-efficiency factor is defined by Lorge (2018) as "comparable systems of this country have the lowest cost to produce" (p. 76). This definition is commensurate with the purpose of this research and, therefore, will be included in the methodology. Next, the cost scoring criteria is discussed by Lorge (2018), and he states that:

> This metric is assessed using quantitative data. The framework user should choose to evaluate either the acquisition system as a whole or a specific sector of it (in the case of this paper, shipbuilding is chosen). An assessment should be made of that sector as a whole and five comparable systems. A comparable system does not mean they have the same capabilities, only in the same class (e.g., destroyer). The capability will be assessed in the performance factor. (p. 77)

To maintain the scope of this study, the cost metric will compare only one comparable system; in the case of this paper, the anti-ship missile programs between the USMC and PLA are chosen. When assessing the cost factor, specific scoring criteria will be leveraged using numerical scores. Lorge (2018) defines the scoring criteria in the following way (p. 77):

- Good: Superior overall and in the majority of programs
- Neutral: Superior overall or in the majority of programs
- Poor: Neither superior overall nor in the majority of programs

This study accepts the same scoring criteria Lorge (2018) outlined to grade the overall cost efficiency between the anti-ship missile programs. For example, a score of "good" receives the number four, "neutral" gets the number two, and "poor" gets the number zero. The efficiency factors and scoring criteria are listed in Table 3.

Table 3. Cost Efficiency Factors and Scoring Criteria. Source: Lorge (2018).

Acquistion Efficiency Factor	United States	China
Cost: Comparable Systems of this country have the lowest cost to produce	Cost performance on programs in this country is:	Cost performance on programs in this country is:
	4 Points: Superior overall and in the majority of programs	**4 Points:** Superior overall and in the majority of programs
	2 Points: Superior overall or in the majority of programs	**2 Points:** Superior overall or in the majority of programs
	0 Points: Neither superior overall nor in the majority of programs	**0 Points:** Neither superior overall nor in the majority of programs
O&S Costs: This country considers all O&S costs when developing a new weapons system	This country's acquisition system:	This country's acquisition system:
	4 Points: Considers all O&S costs when developing systems	**4 Points:** Considers all O&S costs when developing systems
	2 Points: Considers some O&S costs when developing systems	**2 Points:** Considers some O&S costs when developing systems
	0 Points: Neither superior overall nor in the majority of programs	**0 Points:** Neither superior overall nor in the majority of programs

C. PRC'S DEFENSE EXPENDITURES

In addition to the cost-effectiveness at the program level, this study will discuss the factors that influence China's RDA process at the macro level. As stated previously, there are discrepancies in China's budget reporting data, and conflicting reports and studies raise questions about the veracity of how China reports its budget information. To demonstrate the effects cost has on China's RDA cycle, a model will be developed that uses time-series data to depict government expenditures. These data will be pulled from multiple sources and aggregated to demonstrate discrepancy trends in China's budget submissions.

The first source includes GDP data from the International Monetary Fund (IMF), which "developed in the 1940s to foster economic cooperation" (IMF, 2019). According to the IMF's website, its membership spans 190 countries, financed through capital subscriptions based on that country's global economic position (IMF, 2019). The specific data set is used from the IMF's International Financial Statistics (IFS) database. According to the website, the IFS "covers 184 countries and areas" and bases its data collection on member countries' major Fund accounts, including government and public sector financial information (IMF, 2022a). The query used for data collection incorporated time series data for China and its regions, including Mainland China, Hong Kong, and Macao.

The next data source used in the macro-level analysis is the Stockholm International Peace Research Institute (SIPRI), "an independent research think-tank that provides global data on conflict, armaments, arms control, and disarmament" (SIPRI, 2022). According to their website, SIPRI's Military Expenditure Database " contains consistent time series on the military spending of countries for the period 1949 to 2020" and is the premier military expenditure analysis tool used that sources from national government financial data, budget documents, white papers, and public finance statistics (SIPRI, 2022). These data are then aggregated by year and country to display trends in overall military expenditures.

Expenditures are expressed in several ways providing the user with various options to analyze the data. For example, SIPRI displays military spending as a percentage of general government expenditures to express the share of defense costs as a public good. As stated previously, SIRPI leverages different government sources to aggregate the data, including the IMF, NATO, and the United Nations Statistical Yearbook (SIPRI, 2022).

1. Data Inconsistencies

China provides limited transparency to the public when reporting military expenditures, specifically with RDT&E related spending. These data are impossible to identify in China's overall military expenditure output; thus, only estimates of these numbers will be provided.

D. USMC ANTI-SHIP MISSILE CAPABILITY

The EABO concept was developed to respond to current and merging threats in the INDOPACOM theater; although there are applications to the European Theater, the scope of this thesis is limited to that theater. China has maintained a force posture in the South China Sea (SCS) and is developing anti-access, area denial, anti-ship capabilities (A2/AD) against adversarial forces. In his latest Force Design guidance, the CMC intends to establish capabilities in concert with the Navy that provides a Ground-Based Anti-ship Missile Capability (GBASM) that will successfully conduct A2AD operations. To realize this capability, one of the key enablers is the Navy and Marine Corps Expeditionary Ship Interdiction System (NMESIS). The NMESIS program mixes preexisting weapon systems with emergent technologies that will ultimately seek and destroy enemy ships inside the Weapons Engagement Zone (WEZ) within the SCS and meet the GBASM requirement.

Still under development, the NMESIS program integrates established, proven subsystems, such as the Joint Lightweight Tactical Vehicle (JLTV) Chassis, the Naval Strike Missile (NSM), and the Fire Control System (FCS) used by the Navy for the NSM (MCSC, 2021). The benefits of the NMESIS program include leveraging proven missile technology already procured by the Navy and a new launcher capability under development by the Marine Corps, called the Remote Operated Ground Unit Expeditionary (ROGUE) Fires Vehicle. The ROGUE Fires Vehicle is intended to be an unmanned platform, teleoperated by artillery Marines, that will fire a mix of preexisting anti-ship missiles.

Since the NMESIS program is still under development and the ROGUE Fires vehicle is still being tested, gathering data on a new system may not provide a thorough analysis of the USMC's anti-ship program. Additionally, the Marine Corps has very few capabilities that can be considered a one-for-one comparison to the PRC. Thus, the High Mobility Artillery Rocket System (HIMARS) is analyzed because it possesses similar capabilities to the PRC's anti-ship missile program. The data used to analyze the HIMARS program is sourced from the DON FY22 Budget submission. Time series funding data derives the requested quantity of the HIMARS subcomponents and their respective costs. The HIMARS subsystems and their respective descriptions are depicted in Table 4. A qualitative analysis is conducted leveraging the cost factor and scoring criteria from Lorge (2018), which determines the cost-efficiency rating of the HIMARS program. The results of the scores are then be compared to the Chinese equivalent explained later in this section.

Table 4. Description of HIMARS Subsystems. Adapted from DON (2022).

System	Description
The High Mobility Artillery Rocket Launcher	Mobile rocket battery that is capable of medium to long-range precision strike and is interoperable with USMC command and control (C2) systems.
Family of Medium Tactical Vehicles (FMTV) 5-ton Carrier (M142)	Multi-purpose tactical truck used to carry the HIMARS launcher, rockets, and C2 system.
Guided Multiple Launch Rocket System (GMLRS)	Guided rocket capable of precision strike and is launched from the HIMARS.

E. PRC'S ANTI-SHIP MISSILE PROGRAM

During the PRC's recent reform efforts, the PLA reorganized the Second Artillery Corps into the People's Liberation Army Rocket Force (PLARF), which is tasked and organized to focus mainly on ballistic and land-based missile threats (DOD, 2021a). These reform efforts brought innovation to the Chinese missile development process, including missile modernization efforts to promote A2AD. The specific capability used in the analysis section is the Dong Feng 21D (DF-21) CSS-5 Mod-5 Anti-Ship Ballistic Missile (ASBM) program.

The DF-21D ASBM variant can achieve medium to long-range anti-ship missions, up to 1,550 km, and destroy a CVN class U.S. Navy aircraft carrier with 20-meter accuracy (Hendrix, 2013). Very few quantitative sources contain budget data on China, which must be less actual programmatic information. To derive the funding profile for China's DF-21D, data will be adapted from various peer-revied reports and government documents. A qualitative analysis is conducted to measure the cost efficiency of the DF-21D, and the scoring criteria is applied and compared to the Marine Corps' HIMARS program. The method behind this analysis measures the total cost of one DF-21D ASBM. The description of DF-21D subsystems are listed in Table 5.

Table 5. Description of DF-21D Subsystems. Adapted from Hendrix (2013).

System	Description
Wanshan WS2600	Transportable Erected Vehicle (TEL) equipped with a missile launcher
Dong-Feng 21D CSS-5 Mod-5	Anti-Ship Ballistic Missile capable of medium-range precision strike
System Software	Unknown

F. COMPARISON

These two systems show a micro-level analysis of the overall cost efficiency between these two warfighting enablers. The DF-21D and the HIMARS programs were chosen to measure the cost efficiency because both programs possess the similar operational capability, their respective funding profiles are comparable, and each program is listed as a high priority capability by their respective services. The DF-21D and the HIMARS contain a family of systems nested within the operational capability; thus, the cost efficiency comparison will be more accurate. For example, the DF-21D and the HIMARS are transported and launched on a Transportable Erected Launch (TEL) system.

G. CONCLUSION

With all the metrics and data sources identified, the methodology to assess the cost efficiency between China and the United States is complete. This thesis will provide a macro-level analysis of the Chinese and U.S. RDA process through total military expenditures to assess how cost plays a factor in decision making. Next, this thesis examines the cost efficiency between two similar warfighting capabilities being considered for anti-ship operations leveraging preexisting metrics provided by Lorge (2018).

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V. ANALYSIS

In this chapter, a macro-level analysis of the U.S. and the PRC's overall economic posture is conducted using GDP data in the following ways. First, the overall economic comparison between the two countries is illustrated using real GDP data from 2000 to 2020. Analyzing and displaying the data in this way demonstrates the PRC's consistent economic growth in the past two decades and clarify which country is growing more. Second, military expenditure data presents the overall defense spending profile regarding real GDP per capita and percent of the overall GDP. This analysis is intended to determine which country spends more per capita on its defense programs.

Next, a micro-level analysis is conducted to show which country is more cost effective at the program level. Funding data from each country's anti-ship missile programs will be analyzed to accomplish this. The data is derived from several sources and provides the overall program-level funding profile for each anti-ship missile program. Next, the cost efficiency factors developed by Lorge (2018) are applied to the anti-ship missile programs of the USMC and PLARF. This analysis is intended to demonstrate the use of the cost efficiency framework and determine which country is more cost-efficient with its large-scale defense programs.

A. ECONOMIC POSTURE

Military expenditure data is reflected in several ways within the SIPRI database; however, this analysis will use expenditure data as share of GDP and per capita. Analyzing military expenditures as a share of GDP provides an alternative to depict how each country prioritizes defense costs. Analyzing military spending per capita offers a normalized alternative to compare each country's defense spending based on total population size. The share of GDP is reflected as a percentage of GDP, and per capita reflects SIPRI estimates for 173 countries in 2019 in constant U.S. dollars and current U.S. dollars for 2020 (SIPRI, 2022).

1. A Comparison of Real GDP Growth

The U.S. outranks China in real GDP growth; however, the Chinese economy continues on an upward trend finishing in 2021 with 14.7 trillion dollars. On the contrary, the U.S. experienced a two percent decrease in GDP primarily due to the crisis involving COVID-19, although it has shown signs of normalizing in fourth-quarter projections, according to the Bureau of Economic Analysis (BEA, 2022a). The BEA states the following in its fourth-quarter GDP news release:

> The acceleration in the fourth quarter was led by an upturn in exports as well as accelerations in inventory investment and consumer spending. In the fourth quarter, COVID-19 cases resulted in continued restrictions and disruptions in the operations of establishments in some parts of the country. Government assistance payments in the form of forgivable loans to businesses, grants to state and local governments, and social benefits to households decreased as provisions of several federal programs expired or were tapered off. The full economic effects of the COVID-19 pandemic cannot be quantified in the GDP estimate for the fourth quarter because the impacts are generally embedded in source data and cannot be separately identified. (BEA, 2022a)

China experienced similar economic woes resulting from the pandemic. The IMF released the following statement regarding the effects of the pandemic on China's economy:

> China's recovery is well advanced, but it lacks balance, and momentum has slowed. The slowdown is attributed to the rapid withdrawal of policy support, the slow recovery of consumption amid recurrent COVID-19 outbreaks despite a successful vaccination campaign, and slowing real estate investment following policy efforts to reduce leverage in the property sector. GDP growth is projected at 7.9 percent in 2021 and 4.8 percent in 2022, with the deceleration in 2022 partly reflecting the fading of base effects, while subdued private consumption and real estate investment are adding headwinds. (IMF, 2022b)

According to the World Bank, China continues to achieve an average of 10 percent GDP growth annually, despite the trade tariffs imposed by Donald Trump in 2019 and the global pandemic in 2020 (The World Bank, 2021). Although they achieve a high growth percentage, China still has an imbalanced economy. A statement released on the World Bank in China's webpage said the following:

> China's high growth based on resource-intensive manufacturing, exports, and low-paid labor has largely reached its limits and has led to economic, social, and environmental imbalances. Reducing these imbalances requires shifts in the structure of the economy from low-end manufacturing to higher-end manufacturing and services, and from investment to consumption. (The World Bank, 2021)

China realizes that the weight of its economy is unsustainable and reforms must take place to provide a prosperous nation for its citizens, and Chinese officials are shifting focus to tackle income inequality (The World Bank, 2021). Both the U.S. and China remain the highest-ranking contributors to the global economy and will stay such as long as both do not try to go to war with each other (Taplin, 2021). Figure 1 depicts the annual real GDP growth from 2000 to 2020 below.

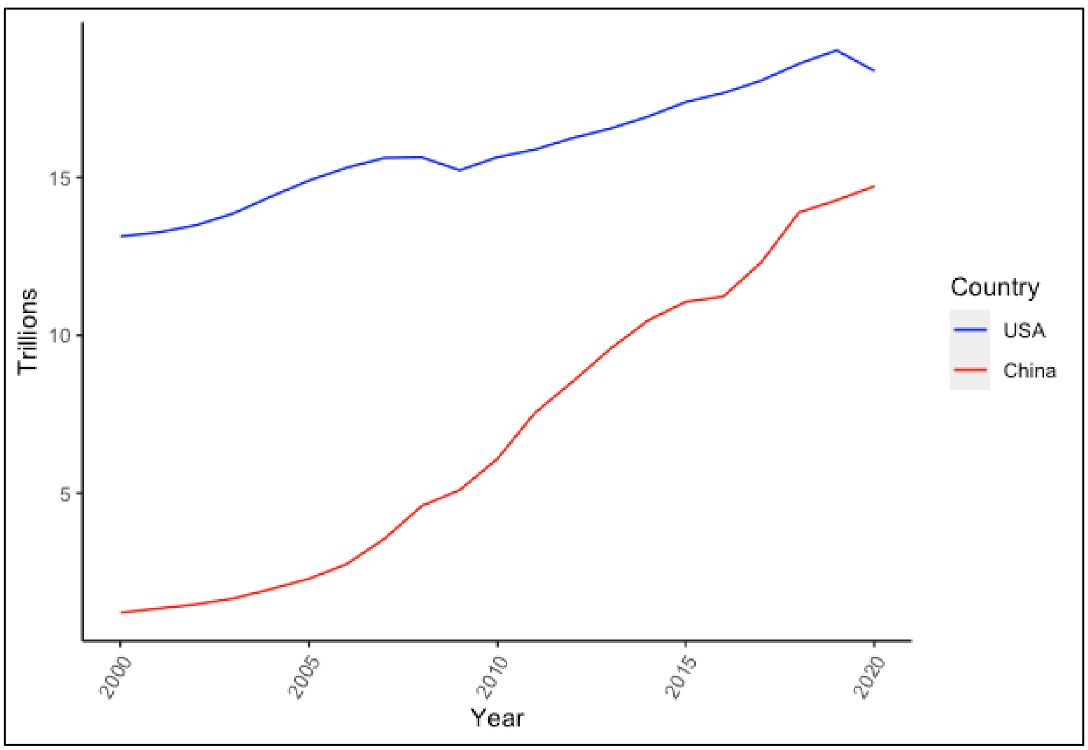

Figure 1. Total Real GDP Growth between the U.S. and China, 2000 to 2020 (Current Trillion USD). Adapted from BEA (2022b); World Bank (2022).

China is on a constant glideslope and appears to be closing the gap with the U.S. Both countries are vital trading partners, and both economies are heavily intertwined with one another, but China appears to be on a trajectory that could surpass the U.S. A forecast analysis was not conducted, but if one were, the projections would clearly state the obvious; China will outpace the U.S. economy.

2. U.S. and PRC Military Expenditures

The U.S. ranks the highest in global military expenditures as the U.S. defense budget reached 778 billion dollars in FY2022 (not depicted in Figure 2), increasing for the third straight year. This translates to approximately 2,000 in current FY19 dollars spent for every American citizen from FY2000 to FY2020 on defense-related activities. Additionally, military expenditures as a share of GDP rose slightly in the past three years. Figure 2 represents the SIPRI data output.

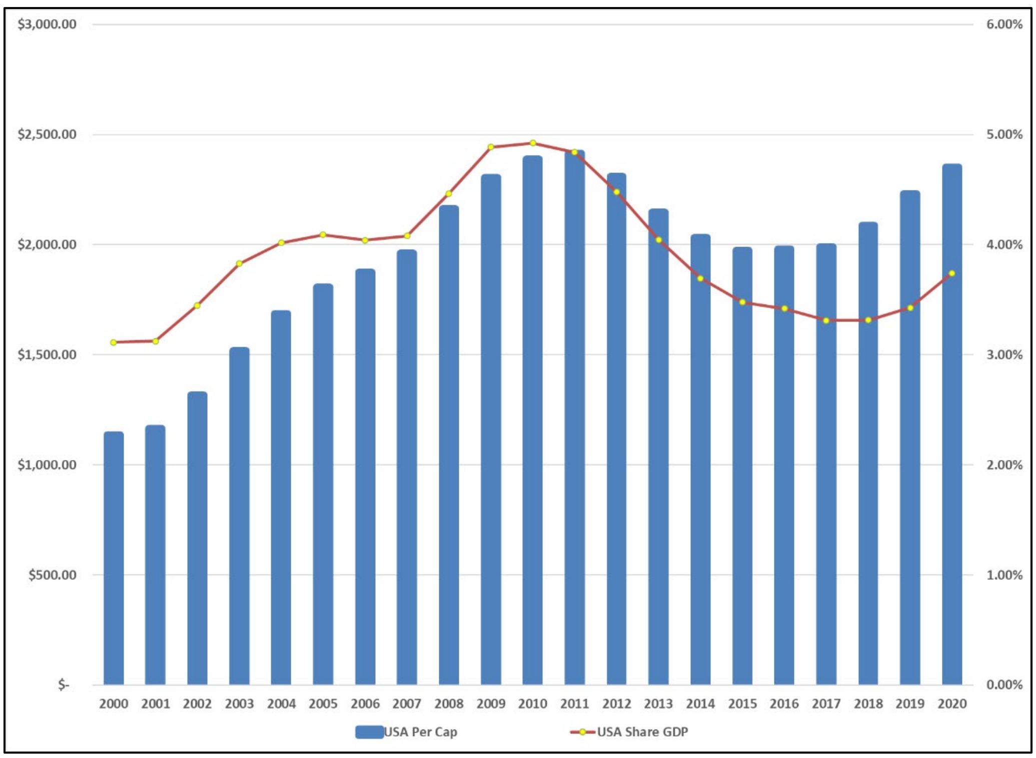

Figure 2. U.S. Official Defense Budget, 2000 to 2020. Adapted from SIPRI (2022).

The fluctuations result from several variables not explicitly captured in the expenditure data; however, one could deduce that historical events such as the global war on terrorism have influenced the steady increase in defense spending. Additionally, the fluctuations also represent political variables that are not explicit in this analysis. A noteworthy example is certain political entities who control the majority of the Executive and Legislative branches determine the defense budget.

The cost drivers associated with the budget increase from 2017 to 2020 include growth in research and development, upgrading the U.S. nuclear arsenal, and procurement costs associated with large-scale defense programs like the Joint Strike Fighter. Moreover, the share of defense spending for the U.N. and NATO is reflected in the numbers but not explicitly stated in the SIPRI estimates. Another notable observation is the steady decrease in defense spending as a share of GDP from 2009 to 2015 resulting from the global financial crisis during that time frame. Conversely, other global events such as the COVID-19 pandemic have not affected U.S. defense expenditures.

3. PRC's Military Expenditures

The PRC has some of the highest defense expenditures globally, with an estimated 252 billion dollars in 2020. This represents a two percent increase in the last two years and a seven percent increase in the previous ten years. Moreover, China has aggressively increased defense spending from 2000 to 2020, as depicted in Figure 3.

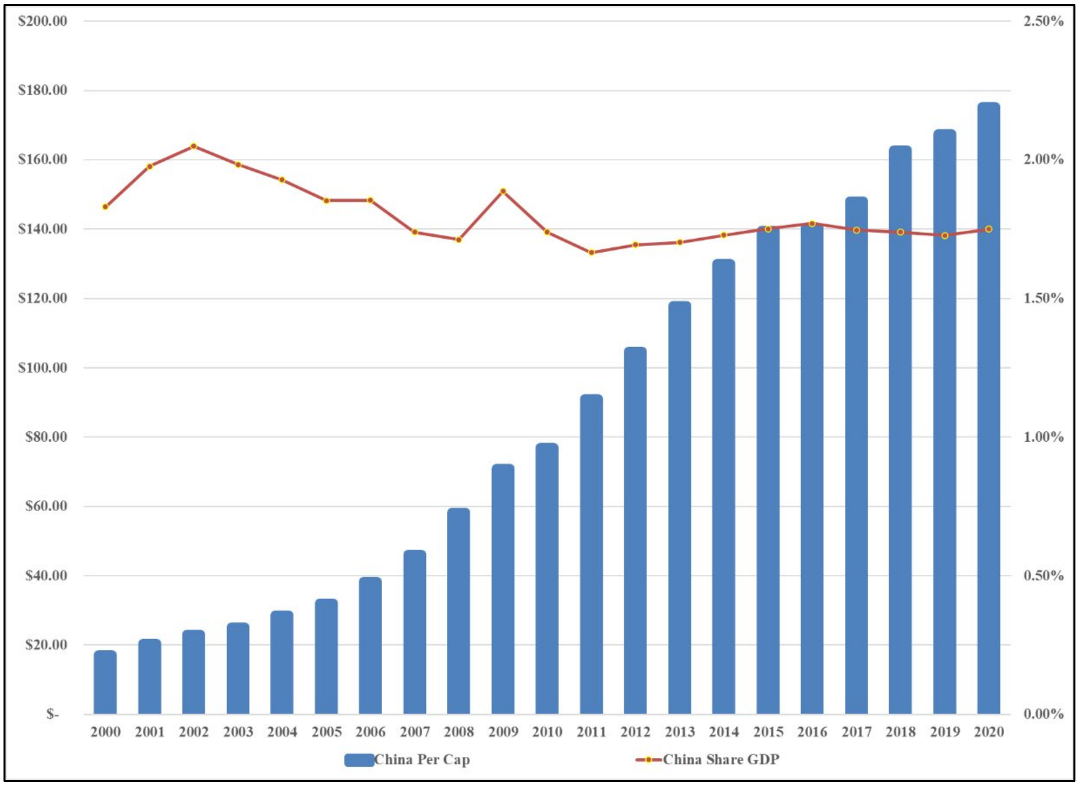

Figure 3. China's Official Defense Budget, 2000 to 2020 (Share of GDP and Per Capita). Adapted from SIPRI (2022).

On average, the PRC spends approximately 85 in the current FY19 dollars per Chinese citizen on defense from 2000 to 2020. A notable observation is a sharp and consistent increase in the PRC's military expenditures per capita, which is not commensurate with its share of GDP percentage. Moreover, the PRC has consistently increased its defense-related expenditures for the past 26 years, the longest uninterrupted increase by any country. This observation ties to one potential assumption, the veracity of the PRC's financial reporting, which indicates either an improvement of economic statistics or the PRC overstating their growth. One could assume that the PRC does not contribute to overall global security like the U.S. or some of its allies and possibly underreports its numbers.

4. Comparison

In assessing overall military expenditures for both share of GDP and per capita, the U.S. ranks higher based on the number of dollars spent per American citizen on defense. The U.S. outspends its counterpart significantly, not excluding the steady and sharp growth of the PRC's military expenditures, which is no surprise. The U.S. emphasizes innovation and carries the most financial burden in global security. Moreover, the U.S. has a more robust defense industrial base decentralized and loosely regulated, comparable to the PRC's privatized defense infrastructure.

Furthermore, the PRC leverages technology transfers as one of their primary means of defense spending, consisting of most research and development costs. Technology transfers are achieved mainly by exploiting intellectual property and industrial espionage. Consequently, the U.S. possesses the highest defense budget globally due to its defense industrial innovation, spending more money on RDT&E and O&S costs. Figure 4 illustrates each country's defense budget for the last 20 years.

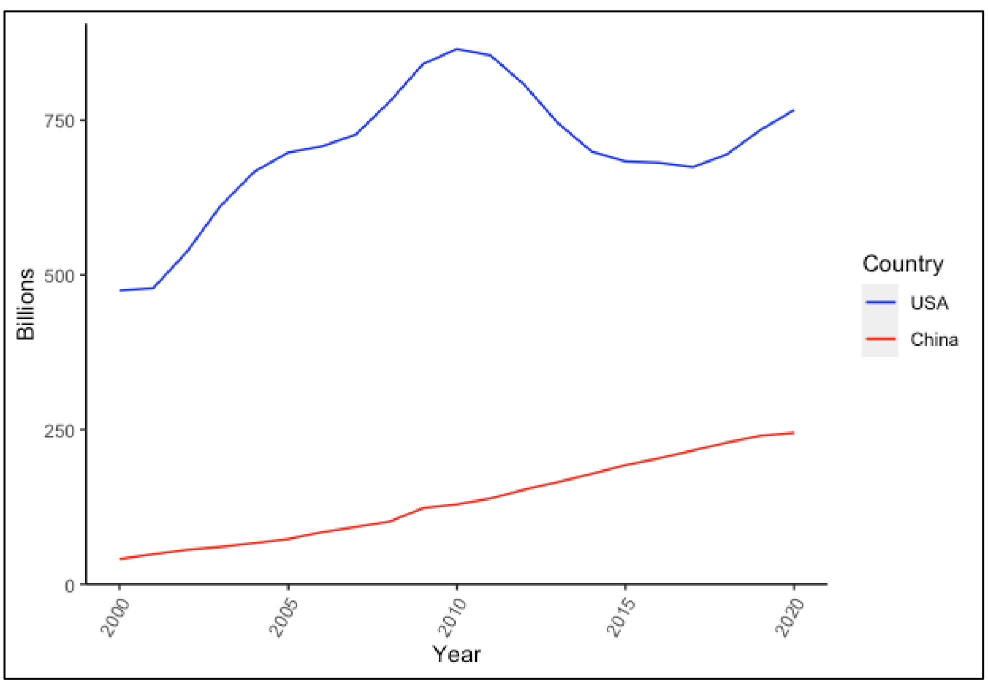

Figure 4. U.S. and the PRC's Official Defense Budgets in Constant 2019 Dollars. Adapted from SIPRI (2022).

Both the U.S. and PRC have increased their overall defense budgets. The U.S. has been on a steady incline since 2017, while the PRC consecutively increased its topline. The political variables mentioned above are more fleshed out in Figure 4. For the U.S., one could argue that national objectives during the Bush administration (Jan 2001 to Jan 2009) influenced the sharp increase in the overall topline. Most notably, force modernization in ground equipment and personnel. In contrast, the Obama administration (Jan 2009 to Jan 2017) focused more on unmanned, exquisite systems and a leaner force.

B. COST FACTOR

To analyze the cost factor, a program-level comparative analysis is conducted on the anti-ship missile budget for each country from 2018 to 2021. This budget is compared to the total number of anti-ship missiles and subsystems added to that country's arsenal each year. Leveraging the same methodology used by Lorge (2018), each country with the lowest dollar amount spent per anti-ship missile system is scored as having better cost performance.

1. USMC

This section discusses the micro-level analysis of the anti-ship missile program used by the USMC. The HIMARS is selected for this analysis for several reasons. First, it has been in the USMC's arsenal since 1996, making data easier to locate and analyze. Second, it is comparable to the PRC's DF-21D rocket system, discussed in the next paragraph. Third, the HIMARS could be leveraged in the USMC's future GBASM capability by fitting the NMESIS to the HIMARS transport vehicle according to (DON, 2021). The DOD's FY22 Budget Justification Book defines the M142 High Mobility Artillery Rocket System (HIMARS) as:

> A C-130 transportable, wheeled, indirect fire, rocket/missile system capable of firing all rockets and missiles in the current and future Multiple Launch Rocket System (MLRS) Family of Munitions (MFOM). (p. 72)

The HIMARS program consists of three subsystems: the launcher, two MTVR re-supply vehicles, and the rockets used to fire out of the launchers. The USMC spent approximately 651 million in FY21 procurement dollars to purchase 53 more HIMARS launchers, 53 carriers, and 1,914 rockets for the HIMARS program. Table 6 shows the calculations used to derive the procurement cost information.

Table 6. Total HIMARS Program Procurement Cost from 2018 to 2021. Adapted from DOD (2018–2020, 2021b).

	2018	2019	2020	2021	Grand Total
High Mobility Artillery Rocket System (HIMARS) Launcher Qty	26	10	10	7	53
HIMARS Launcher Procurement Unit Cost (TY$K)	$ 6,404.90	$ 6,533.00	$ 7,378.00	$ 4,254.00	$ 24,569.90
Then Year $ > 2021$ Inflation Factor (JIC)	1.0612	1.0404	1.02	1	
HIMARS Launcher Procurement Unit Cost (FY21$K)	$ 6,796.88	$ 6,796.93	$ 7,525.56	$ 4,254.00	$ 25,373.38
HIMARS Launcher Total Procurement Cost (FY21$K)	**$ 176,718.93**	**$ 67,969.33**	**$ 75,255.60**	**$ 29,778.00**	**$ 349,721.86**
FMTV Carrier (M142) Qty	26	10	10	7	53
FMTV Carrier (M142) Procurement Unit Cost (TY$K)	$ 585.94	$ 597.66	$ 642.63	$ 661.90	$ 2,488.13
Then Year $ > 2021$ Inflation Factor (JIC)	1.0612	1.0404	1.02	1	
FMTV Carrier (M142) Procurement Unit Cost (FY21$K)	$ 621.80	$ 621.81	$ 655.48	$ 661.90	$ 2,560.99
FMTV Carrier Total Procurement Cost (FY21$K)	**$ 16,166.82**	**$ 6,218.05**	**$ 6,554.78**	**$ 4,633.32**	**$ 33,572.97**
GMLRS Qty	342	238	312	1022	1914
GMLRS Procurement Unit Cost (TY$)	$ 124.53	$ 120.37	$ 136.44	$ 146.10	$ 527.44
Then Year $ > 2021$ Inflation Factor (JIC)	1.0612	1.0404	1.02	1	
GMLRS Procurement Unit Cost (FY21$K)	$ 132.15	$ 125.24	$ 139.17	$ 146.10	$ 542.65
GMLRS Total Procurement Cost (FY21$K)	**$ 45,195.00**	**$ 29,805.94**	**$ 43,419.71**	**$ 149,314.20**	**$ 267,734.84**
Total HIMARS Program Procurement Cost (FY21$K)	**$ 238,080.74**	**$ 103,993.32**	**$ 125,230.09**	**$ 183,725.52**	**$ 651,029.67**

Funding amount is depicted in current FY21$K PMC.

2. PLARF

This section discusses the micro-level analysis of the PLARF's anti-ship missile program costs and will leverage funding data from congressional reports and open-source information. According to the *Annual Report to Congress: Military and Security Developments Involving the People's Republic of China 2021,* the PLARF's mission statement is defined in the following way:

> …organizes, mans, trains, and equips the PRC's strategic land-based nuclear and conventional missile forces as well as associated support forces and missile bases. (p. 12)

Newly developed, the PLARF has grown its missile inventory in the past several years and continues to be a formidable adversary. This analysis focuses on the DF-21D, the PLARF's version of the anti-ship missile. Like the HIMARS program, the DF-21D consists of three subsystems: the launcher, the Transportable-Erected Launch (TEL) vehicle carrier system, and the rocket itself. Each subsystem possesses capabilities commensurate with the HIMARS program. Starting with the launcher system, the available funding data suggests that the PLARF has expanded its inventory over the past four years by 150 systems totaling approximately 106 million in FY21 dollars. Next, the PLARF added about 40 TELs to its inventory over the past four years totaling 34.1 million in FY21 dollars. Finally, the total missile inventory is ambiguous. Latest reports estimate approximately 900 missiles added to the PLARF's inventory over the past four years, totaling about 10 million FY21 dollars (DOD, 2021a; Hendrix, 2013). Table 7 shows the calculations used to derive this information.

Table 7. Total DF-21D Program Procurement Cost from 2018 to 2021. Adapted from DOD (2018–2021a) and Hendrix (2013).

	2018	2019	2020	2021	Grand Total
DF-21D Launcher Qty	25	25	0	100	150
DF-21D Launcher Procurement Unit Cost (TY$K)	$ 700.00	$ 700.00	$ 700.00	$ 700.00	$ 2,800.00
Then Year $ > 2021$ Inflation Factor (JIC)	1.0612	1.0404	1.02	1	
DF-21D Launcher Procurement Unit Cost (FY21$K)	$ 742.84	$ 728.28	$ 714.00	$ 700.00	$ 2,885.12
DF-21D Launcher Total Procurement Cost (FY21$K)	**$ 18,571.00**	**$ 18,207.00**	**$ -**	**$ 70,000.00**	**$ 106,778.00**
Wanshan WS2600 Carrier Qty	10	10	10	10	40
Wanshan WS2600 Carrier Procurement Unit Cost (TY$K)	$ 828.35	$ 828.35	$ 828.35	$ 828.35	$ 3,313.40
Then Year $ > 2021$ Inflation Factor (JIC)	1.0612	1.0404	1.02	1	
Wanshan WS2600 Carrier Procurement Unit Cost (FY21$K)	$ 879.05	$ 861.82	$ 844.92	$ 828.35	$ 3,414.13
Wanshan WS2600 Carrier Total Procurement Cost (FY21$K)	**$ 8,790.45**	**$ 8,618.15**	**$ 8,449.17**	**$ 8,283.50**	**$ 34,141.27**
DF-21D Missiles	100	200	150	450	900
DF-21D Missile Procurement Unit Cost (TY$K)	$ 11,000.00	$ 11,000.00	$ 11,000.00	$ 11,000.00	$ 44,000.00
Then Year $ > 2021$ Inflation Factor (JIC)	1.0612	1.0404	1.02	1	
DF-21D Procurement Unit Cost (FY21$K)	$ 11,673.20	$ 11,444.40	$ 11,220.00	$ 11,000.00	$ 45,337.60
DF-21D Total Procurement Cost (FY21$K)	**$ 1,167,320.00**	**$ 2,288,880.00**	**$ 1,683,000.00**	**$ 4,950,000.00**	**$ 10,089,200.00**
Total DF-21D Program Procurement Cost (FY21$K)	**$ 1,194,681.45**	**$ 2,315,705.15**	**$ 1,691,449.17**	**$ 5,028,283.50**	**$ 10,230,119.27**

The funding amount is depicted in current FY21$K.

3. Comparison

In the assessment used to compare overall anti-ship missile cost performance between the USMC and the PLARF, two items were looked at closely; the amount of inventory added to each country's arsenal and the unit cost each year. This section will break down and compare the three subsystems individually.

a. Launcher System

In the assessment of the launcher subsystem, the PLARF scored higher due to their average inventory and fewer procurement costs compared to the USMC. China has added an average of 37.5 launch systems over the past four years, and even though reliable data is not available for 2020, the PLARF still outpaces the USMC with its launcher inventory by nearly three times more launch systems on average. The USMC leverages preexisting missile capabilities developed by the Army and Navy, thus offsetting some procurement costs; however, the USMC still provides a portion of procurement funding to test and evaluate its launcher systems.

The USMC procured 26 more launchers in 2018 to support the operating forces and offer additional assets to critical HIMARS units previously under its allowance (DOD, 2018). Moreover, the launchers procured in 2019 and 2020 were used to test and evaluate the NSM in support of the USMC's GBASM program (DOD, 2019, 2020). The PLARF leverages technology transfers for its launcher systems and thus, does not have to spend as much compared to the USMC, the difference of approximately 200 million dollars. Table 8 illustrates the comparison of the launcher subsystem.

Table 8. Comparison of Launcher System Costs

	2018	2019	2020	2021	Grand Total
High Mobility Artillery Rocket System (HIMARS) Launcher Qty	26	10	10	7	13.25
DF-21D Launcher Qty	25	25	0	100	37.5
HIMARS Launcher Total Procurement Cost (FY21$K)	$ 176,718.93	$ 67,969.33	$ 75,255.60	$ 29,778.00	$ 349,721.86
DF-21D Launcher Total Procurement Cost (FY21$K)	$ 18,571.00	$ 18,207.00	$ -	$ 70,000.00	$ 106,778.00

b. Vehicle Transport System

The USMC possesses more than the PLARF and spends slightly less in assessing the vehicle transport system. Over the past four years, the USMC has procured an average of 13 vehicle transport systems and spent approximately 33.5 million dollars in procurement costs on those vehicles. Since the launcher system sits on top of the vehicle transport system, the quantity procured each year is commensurate with the launcher quantity. The USMC leverages the FMTV re-supply vehicle to provide logistics support; however, it was not used in this analysis since it is a general-purpose vehicle and not organic to the HIMARS program.

The PLARF added an average of 10 TELs to its inventory over the past four years totaling approximately 34.1 million dollars. The TEL comparison in Table 9 suggests that the PLARF does not necessarily achieve cost savings with its technology transfer model. It does, however, provide fewer overhead costs in terms of inventory management. The TELs are expensive to maintain, and fewer of them cut down on maintenance costs.

Table 9. TEL Comparison

	2018	2019	2020	2021	Grand Total
FMTV Carrier (M142) Qty	26	10	10	7	13.25
Wanshan WS2600 Carrier Qty	10	10	10	10	10
FMTV Carrier Total Procurement Cost (FY21$K)	$ 16,166.82	$ 6,218.05	$ 6,554.78	$ 4,633.32	$ 33,572.97
Wanshan WS2600 Carrier Total Procurement Cost (FY21$K)	$ 8,790.45	$ 8,618.15	$ 8,449.17	$ 8,283.50	$ 34,141.27

c. Missiles

The data suggests that the USMC outpaces the PLARF's missile quantity, and the USMC spends less compared to the PLARF. Over the past four years, the USMC has procured an average of 479 GMLRS and spent 267 million dollars. Moreover, the USMC leverages preexisting anti-ship missile capabilities developed for the Navy and Army in its HIMARS program, thus demonstrating some cost savings, yet this data is not reflected in this analysis. The PLARF developed the DF-21D variant to provide an anti-ship capability; therefore, the added quantities are significantly lower than the USMC. Moreover, the available data suggests that China is underreporting its missile inventory based on the high low ranges provided in the *Annual Report to Congress: Military and Security Developments Involving the People's Republic of China 2021*. The data provided in Table 10 shows the conservative estimates or the high range.

Table 10. Missile Comparison

	2018	2019	2020	2021	Grand Total
GMLRS Qty	342	238	312	1022	479
DF-21D Qty	100	200	150	450	225
GMLRS Total Procurement Cost (FY21$K)	$ 45,195.00	$ 29,805.94	$ 43,419.71	$ 149,314.20	$ 267,734.84
DF-21D Total Procurement Cost (FY21$K)	$ 1,167,320.00	$ 2,288,880.00	$ 1,683,000.00	$ 4,950,000.00	$ 10,089,200.00

The PLARF spends significantly higher in missile costs due to the 11 million dollar price tag on the DF-21D MRBM; therefore, the PLARF scored lower in this category.

C. O&S COST FACTOR

The O&S cost factor is scored by reviewing the overall life-cycle costs associated with the anti-ship missile programs from each country. Attention is paid to which country considers O&S costs in the total life-cycle costs of the DF-21D and the HIMARS programs. Each country is assigned a score, and the final results are discussed in the comparison section.

1. USMC

The USMC achieves its life-cycle cost estimates by factoring in R&D, procurement, and O&S. O&S costs consist of costs not associated with R&D or procurement, but rather the maintenance, sustainment, logistics support, and disposal funding required execute a defense program. According to the OSD CAPE's *Operating and Support Cost Estimation Guide (2020),* O&S costs are defined as:

> …all sustainment costs incurred from the initial system deployment through the end of system operations. This would include all costs of operating, maintaining, and supporting a fielded system. Specifically, this consists of the costs (organic (government civilian and military) and contractor) of personnel, equipment, supplies, software, and services associated with operating, modifying, maintaining, supplying, and otherwise supporting a system in the DOD inventory. These costs include those associated with the system-specific personnel training necessary to support the system. (p. 6)

The above definition alone proves that the majority of costs associated with the life cycle are O&S costs. According to OSD CAPE's *Cost Estimation Guidebook*, depending on the program funding level, O&S costs generally make up most life-cycle costs or are considered the most significant cost driver (p. 17). For example, the USMC's total obligation authority (TOA) is approximately 44 billion dollars, and O&S costs make up roughly 20 percent of it, or nine billion dollars (DOD, 2021b).

The PPBE, JCIDS, and DAS processes are structured so that all life-cycle costs are captured and documented appropriately. A notable example is developing and implementing the OSD CAPE's *Operating and Support Cost Estimation Guidebook,* an authoritative document used to capture O&S cost in every program. The JCIDS manual is a Congressionally mandated document that outlines how to conduct affordability analysis, capturing O&S cost in every program's life cycle. Moreover, Milestone C in the DAS is solely dedicated to capturing O&S costs in every program before reaching FOC. Moreover, Lorge (2018) states that "because each program office is responsible for that system throughout its life cycle, the DOD does not hand off the system's support responsibility to another organization once it is purchased" (pp. 79–89). The USMC achieves a "good" score under the O&S cost scoring factor for the reasons stated above.

2. PLARF

Although its mission set is not new, the PLARF was reorganized and elevated from an independent branch to full service after the PRC's reform initiatives in 2015 (Department of Defense, 2020). These reforms resemble the U.S.'s decentralized command structure; however, the PLARF's structural reforms still fall victim to bureaucratic and program office stove piping. Lorge's (2018) assessment of the PLAN's O&S cost scoring is commensurate with the PLARF. The PLARF's weapons development process does consider O&S costs, but the splintering effect of different program offices concentrating on one portion of the program's life cycle causes unnecessary ambiguity.

The PLARF is a full service; therefore, the CMC's CADD is directly responsible for weapons development and procurement, while the operating forces manage the O&S costs (Lorge, 2018). Moreover, the PRC's practice of absorption in the form of intellectual property theft enabled the PLA to advance more capabilities without factoring in O&S costs, thus resulting in poor program performance. A noteworthy example is Lorge's (2018) claim that Chinese officials "have blamed problems such as equipment not meeting its expected life on failure to maintain it throughout its life cycle properly" (p. 80).

An argument could be made that the PLARF falls victim to poor program performance resulting from O&S costs being unrealized in the program's life cycle. Furthermore, the inability to locate exact O&S cost estimates from available sources affirms the assumption that the PLARF does not necessarily consider all O&S costs in the program's life cycle. For the reasons previously stated, the PLARF receives a score of “neutral” because it assumes some O&S costs when developing weapons systems.

3. Comparison

In the assessment to compare the O&S cost factor between the USMC and the PLARF, the USMC scored better at factoring in O&S cost when developing weapons. Several items were taken into account for this assessment. First, the availability of research supports the assumption that O&S expenses are factored into each organization’s program life cycle. Second, a review of each organization’s overall command hierarchy and service level guidance was conducted. Finally, historical O&S cost information was researched, and reliable data was located for the USMC, yet the PLARF’s information remained ambiguous.

The USMC and the PLARF share similar bureaucratic pitfalls in the weapons development process. The USMC captures O&S costs more organized than the PLARF because of the authoritative requirements baked into the DOD’s DAS. The PLARF does factor in O&S costs when developing weapons, yet there is little evidence to prove that assumption; however, the PRC’s recent reforms may enable the PLARF to achieve a better score in the future.

4. Conclusion

This chapter presented data supporting the macro-level analysis comparing the U.S. and the PRC in two ways. First, a study of each country’s overall economic postures was conducted by depicting Real GDP growth from 2000 to 2020. Second, data showed each country’s overall military expenditure profile from 2000 to 2020.

Next, this chapter presented data supporting the micro-level analysis comparing the USMC’s and the PLARF’s anti-ship missile programs. Two factors from the acquisition efficiency framework developed by Lorge (2018) were used to assess the overall cost performance of the anti-ship missile programs. The summary of scores is depicted in Table 11. The USMC received an overall score of 8, while the PLARF received a 4, indicating that the USMC is more efficient in costing weapon systems. The next chapter analyzed the scoring results, and answers to this report's research questions are provided.

Table 11. Summary of USMC and PLARF Cost Efficiency

Acquistion Efficiency Factor	USMC	PLARF
Cost: Comparable Systems of this service have the lowest cost to produce	Cost performance on this program is: **4 Points:** Superior overall and in the majority of the program	Cost performance on this program is: **2 Points:** Superior overall or in the majority of programs
O&S Costs: This service considers all O&S costs when developing a new weapon system	This service's acquisition system: **4 Points:** Considers all O&S costs when developing systems	This service's acquisition system: **2 Points:** Considers some O&S costs when developing systems
TOTAL POINTS	**8**	**4**

VI. CONCLUSION AND RECOMMENDATIONS

This thesis aimed to determine if cost plays a factor in China's RDA cycle and leverage a preexisting framework to assess the cost efficiency between the USMC and PLARF. Specifically, this thesis sought to answer the following questions:

(1) Primary research question:

- How do China's military expenditures compare to the United States?

This is accomplished through a macro-level analysis of real GDP data from the BEA and IMF and military expenditure data from SIPRI. These databases enable a more objective and independent analysis because of the quality and availability. U.S. military expenditures ebb and flow for various reasons. Cost drivers include increased research and development for ley warfighting enablers, specifically during the early 2000s and well into the 2010s with the global war on terrorism. Moreover, the fluctuations are consistent with the political party in control of the Executive Branch at the time. For example, during George W. Bush's Presidency and directly following the terrorist events of September 11, 2001, military expenditures increased sharply from 2001 to 2008. During Barack Obama's Presidency, the global war on terrorism had almost reached the culmination point, but various enablers such as UAVs and counter improvised explosive devices capabilities were the main cost drivers from 2008 to 2011. Shortly after 2011, the data show that military expenditures decreased until Donald Trump took office.

The PRC did not show signs of fluctuation; it was the exact opposite. From 2000 to 2020, the PRC's military expenditure profile increased at an impressive rate, seven percent on average in the past ten years. Data depicted was in military expenditures as a share of GDP per capita. Although the PRC has a larger population than the U.S., seeing how much the PRC increased spending is still impressive. Cost drivers include research and development, science, and technology achieved through the absorption method.

(2) Secondary Research Questions:

- What frameworks can be used to compare cost and capability at the program level?

In this thesis, I leveraged the acquisition efficiency framework developed by Lorge (2018) and chose programs specific to the USMC and compared them to the PLARF's anti-ship missile program using his framework. By conducting a one-for-one comparison, I demonstrated the effectiveness of the scoring criteria and overall acquisition efficiency between the U.S. and PRC. The framework consisted of ten efficiency factors and scoring criteria to drive the acquisition efficiency rating. In my thesis, I used two factors associated with assessing the cost efficiency: cost and O&S cost.

- What is the cost comparison at the program for USMC and PLARF weapons?

The CMC's strategic guidance has shifted to focus on precision strike capabilities in the past several years, and the USMC is set to achieve the GBASM requirement via the NMESIS program. The HIMARS was chosen for this analysis for several reasons, mainly the length of time it has been in the USMC's arsenal, and it is the closest comparable system to the PLARF's DF-21D. Additionally, strategic guidance like the NDS and CPG discusses expanding the HIMARS program to bridge the capability gap while developing the NMESIS program.

Two comparable anti-ship missile programs used by the USMC and the PLARF were analyzed, and each score was compared to determine which service is superior in each factor. The USMC scored higher in both cost and O&S price, and the scores are depicted in Table 11. Other factors could have been selected, such as scheduling, contracting, and defense industrial base; however, those factors remain outside the scope of this analysis and could be considered for areas of future USMC research.

The USMC and the PLARF share similar bureaucratic pitfalls in the weapons development process. The USMC captures O&S costs more organized than the PLARF because of the authoritative requirements baked into the DOD's DAS. The PLARF does factor in O&S costs when developing weapons, yet there is little evidence to prove that assumption; however, the PRC's recent reforms may enable the PLARF to achieve a better score in the future.

B. RECOMMENDATIONS

The analysis conducted in this thesis shows that cost plays a factor in China's RDA process and that USMC is more efficient when factoring in cost in its acquisition cycle than the PLARF. The PRC remains a global power competitor both in operational capability and economic posture, and the U.S. continues to spend more per capita on defense. The PRC relies heavily on technology transfers through its absorption method enabling more rapid production of operational capabilities compared to most of the world. Moreover, the PRC's acquisition reform efforts coupled with the consistent upward spending trend could potentially skyrocket the PRC's defense posture ahead of the U.S. The following areas of concern should be considered to ensure the U.S. remains at the forefront of global defense:

- Accelerated Acquisition via Absorption: Lorge (2018) listed accelerated acquisition as the number one recommendation and the utilization of the absorption method as number five (p. 86). A review of DOD's rapid acquisition framework and leveraging preexisting technology where possible will fill capability gaps for defense programs. Cheung (2017) claims that the absorption method is the leading driver for the PRC's rapid technology production, so the writing is on the wall. If the character of war is increasingly dynamic, how can America outpace its enemies if the DOD cannot field a weapon quickly? Members of Congress even believe the DAP is "overly bureaucratic and too slow to deliver a capability to the warfighter" (GAO 19–439, p. 5). The U.S. already has a robust defense industrial base; it is time U.S. officials rethink how to achieve speed in its slow acquisition process and start assimilating preexisting technology.

- Evolve the Defense Industrial Base: The United States defense industrial base possesses unmatched capabilities in the commercial sector, yet the DOD chooses to build unique, exquisite systems from scratch and fiercely resist change. One could argue there are rare circumstances where a brand-new capability needs to be built from the ground up, and sometimes an exquisite material solution is not the answer.

- Inexpensive over Exquisite: The USMC's solution for the GBASM requirement is to build an entirely new platform, NMESIS, via the ROGUE Fires vehicle. The cost of this program already exceeds 190 million dollars in both RDT&E and procurement funding (DOD, 2021b). Moreover, the USMC requested 48 million dollars to purchase NSMs that would be used to test NMESIS via the ROGUE Fires prototype for the Marine Littoral Regiment (DOD, 2021b). This thesis analyzed the HIMARS because it has been a constant force multiplier for several decades and could potentially be an inexpensive alternative for the GBASM requirement. The USMC should reexamine its approach to building the NMESIS and consider the HIMARS as a platform to realize the GBASM requirement.

C. FUTURE RESEARCH

The scope of this thesis focused primarily on measuring cost efficiency in the acquisition process between the U.S. and the PRC. The framework developed by Lorge (2018) drove most of the discussion and can be leveraged for virtually any defense program. Some suggestions for future research involving the acquisition process include the following:

- Classified Data: All data referenced in this thesis were derived from open sources; however, there were inconsistencies about the PRC data. Gaining access to classified information on the PRC would improve the veracity of the data. Moreover, access to classified information would narrow the scope of future analyses about China's RDA process.

- Program Level Analysis: Leverage the framework developed by Lorge (2018) and apply it to any defense program. Most DOD organizations possess organic performance metrics to assess efficiency within a portfolio, but each program is different. Scaling the efficiency factors in this report and the thesis produced by Lorge (2018) may provide a more consistent product or identify areas where the efficiency framework could be improved.

- Narrow the Topic: Any topic involving China and cost is very broad, especially since the PRC does not accurately report its budget information. Finding topics that focus on trends in specific economic indicators such as GDP, Household Income, and Defense Spending may be more digestible for the reader.

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