Defense Acquisition in Russia and China

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Preface

This report documents research and analysis conducted as part of a project entitled *Prototyping a New Business Model: Quantitative Decision Support for Army Decisions*, sponsored by the Assistant Secretary of the Army (Acquisition, Logistics, and Technology). The purpose of the project was to provide short-notice analytic support to the Assistant Secretary of the Army (Acquisition, Logistics and Technology) to address questions and issues that require quick-turn results.

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Summary

The research reported here was completed in April 2020, followed by security review by the sponsor and the Office of the Chief of Public Affairs, with final sign-off in June 2021.

In the 1970s and 1980s, the U.S. military's Second Offset Strategy led to the development of key technologies, such as the Global Positioning System, precision-guided munitions, and stealth, marking the start of a decades-long period of U.S. technological dominance over its adversaries. Since the Second Offset, U.S. defense acquisition has focused on sophisticated technologies, such as precision-guided weapons and stealth. Meanwhile, Russia and China have sought to modernize their legacy equipment while concurrently developing new and increasingly sophisticated systems of their own.

This report discusses recent RAND Arroyo Center research into the research, development, and acquisition (RDA) processes of Russia and China—both doctrinally and in practice—and identifies areas in which each country excels and where each country has challenges. Assessing the current state of and future prospects for Russian and Chinese acquisitions provides valuable insight to policymakers who are responsible for ensuring that the United States maintains an advantage over these pacing threats.

On paper, the RDA processes used in both Russia and China are comparable to those of the United States. Although terminology may differ slightly, there is common agreement among the three countries on certain essential steps. In practice, the outcomes of these broad RDA frameworks hinge on the people and institutions who are tasked with their implementation. Russia maintains a large arms export market but struggles to produce its most sophisticated systems in strategically significant quantities. China's reliance on intellectual property theft means its weapons are years behind, but the Chinese recognize that shortcoming and are investing in and growing organic capabilities through joint ventures and acquisition of foreign technology.

Unsurprisingly, graft in Russia continues to be an issue, and the relative influence of individuals over strategic needs or military requirements frequently drives outcomes. Adding to this tension is Russia's apparent focus on arms sales, which comprise nearly 40 percent of the country's export of manufactured goods.

Russia's State Armament Program–2020, promulgated in 2011, marked the first time in the post-Soviet period that the Russian military received adequate funding to reach the program's targets, which include a stated goal of providing "70 percent modern equipment" by 2020. In recent years, Russia has focused on building weapons for export and meeting attainable requirements, such as the modernization of legacy ground equipment and aircraft. The

performance of new weapon systems, such as the T-14 Armata tank and the 2S35 Koalitsiia self-propelled howitzer, purportedly exceeds those of their U.S. counterparts, which might give the impression that the Russians are able to develop sophisticated military hardware on a compressed schedule. But in actuality, the timetable from requirements specification to initial operating capability for the Russian defense sector is comparable to the timing in the United States. Moreover, the high cost of these systems may forestall the Russian military from ever procuring them in more than token quantities.

Russia still faces a number of internal and external hurdles because of its poor economic outlook. This includes stagnation in the size and talent of its research and development (R&D) workforce, relatively low wages, outdated manufacturing facilities that are incapable of producing high-tech equipment in large quantities, and an import substitution program that is unlikely to remediate all the effects of Western sanctions.

Although Russia's technical workforce has stagnated, China is rapidly building its organic R&D capacity. The Chinese government is urging Chinese nationals who are studying abroad to return home after earning their degrees. In 2016, almost 80 percent of the foreign-educated workers returned to China, likely because of the relatively high wages and other incentives China offered the students. However, these young people lack the managerial experience to execute large system integration projects and the technical skills to manufacture some high-end technologies. An approach China has taken to address this problem is investing in acquisitions of foreign technology and in joint-venture partnerships. This has the twofold benefit of developing the skills of junior tech talent and increasing their access and exposure to foreign technologies.

China's reliance on theft of intellectual property for its weapon development has helped keep it competitive but has pegged it several years behind the cutting edge. A copy-replace model, such as China's, tends to emphasize the value of reverse engineering over foundational R&D work. However, China has begun rectifying that deficiency by increasing its national spending on R&D at a compound annual growth rate of almost 15 percent since 2010. The nexus of China's R&D activities is its state-owned enterprises, which, despite still existing under government auspices, have thrived in the more market-based economy of the 21st century. For a sense of scale, of the top 22 highest-grossing defense firms worldwide, nine are from the United States and eight are from China.

This points to China being on a path to mitigating some of its historical shortcomings in RDA execution. In some areas, such as ballistic missiles, the People's Liberation Army (PLA) has already made substantial gains. In others, such as aircraft, recent results have accrued from decades of development. Overall, the PLA has overcome many technological barriers, but this progress has often been based on the assimilation of foreign processes and technology through intellectual property theft and, most recently, acquisitions and joint ventures. The PLA is still struggling to spur domestic innovation and close the gap on a few glaring technical deficiencies, such as high-end chips, silent submarines, and aircraft engines. Even as it strives to clear these technical hurdles, the PLA must address the institutional inefficiencies and barriers related to management and quality assurance that continue to frustrate its efforts at reform.

Acknowledgments

We wish to thank Bruce D. Jette, Assistant Secretary of the Army for Acquisition, Logistics, and Technology, for sponsoring this analysis.

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Abbreviations

AI	artificial intelligence
AVIC	Aviation Industry Corporation of China
CMC	Central Military Commission
EDD	Equipment Development Department
GAD	General Armaments Department
IOC	initial operating capability
MCF	military-civil fusion
MIC	Military-Industrial Commission
PLA	People’s Liberation Army
R&D	research and development
RDA	research, development, and acquisitions
SAP	State Armaments Program
SDO	State Defense Order
SIPRI	Stockholm International Peace Research Institute
SOE	state-owned enterprise

1. Introduction

In the 1970s and 1980s, the U.S. military's Second Offset Strategy led to the development of key technologies, such as the Global Positioning System, precision-guided munitions, and stealth, marking the start of a decades-long period of U.S. technological dominance over its adversaries. The conflicts of the 1990s and 2000s presented numerous challenges for the United States, but rarely were they direct products of inferior technology. Rather, transitioning from a force structure designed for major theater war to one that could address smaller contingencies most often required nonmateriel solutions because new tactics, techniques, and procedures were needed to conduct counterinsurgency and counterterrorism missions.

In the past decade, the threats the United States faces have multiplied, and the geopolitical environment is once again defined by great-power competition between technologically capable adversaries. China and Russia have become more formidable and antagonistic toward the United States and its allies. The 2017 *National Security Strategy* and 2018 *National Defense Strategy* have identified this as a new era of "long-term, strategic competition" with "revisionist powers" that calls for renewed commitment to maintaining technological overmatch.[1] Although these strategies make little distinction between China and Russia as revisionist powers, the roles of the two nations on the international stage are, in fact, quite different. Russia is a rogue state with a relatively weak economy but a formidable military that actively seeks to undermine the international order with force. China—a rising peer competitor—aspires to dominate the international order in the long term.[2]

Since the Second Offset, the United States has focused on fielding highly sophisticated technologies, such as fifth-generation fighter aircraft, synthetic aperture radars, and unmanned vehicles. Meanwhile, China and Russia have aimed to modernize their legacy military equipment to a comparable level while also developing some sophisticated systems of their own. Evidence in recent years suggests that these efforts to catch up have been at least moderately successful, and, by some measures, the capabilities of certain Chinese and Russian systems are starting to surpass those of the United States. For example, within the next few years, Russia expects to begin fielding such systems as the T-14 Armata main battle tank and the 3M22 Tsirkon antiship hypersonic cruise missile—neither of which has a direct U.S. analogue.

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[1] The White House, *National Security Strategy of the United States of America*, Washington, D.C., December 2017; James Mattis, *Summary of the 2018 National Defense Strategy of the United States of America: Sharpening the American Military's Competitive Edge*, Washington, D.C.: U.S. Department of Defense, 2018.

[2] James Dobbins, Howard J. Shatz, and Ali Wyne, *Russia Is a Rogue*, *Not a Peer; China Is a Peer*, *Not a Rogue: Different Challenges*, *Different Responses*, Santa Monica, Calif.: RAND Corporation, PE-310-A, October 2018, p. 2.

Looking even further ahead, some argue that artificial intelligence (AI) will be the next major breakthrough in military research and development (R&D). Both China and Russia are devoting vast government resources toward autonomous weapons. China released an AI national development strategy in 2017 with the stated goal of becoming the world leader in AI by 2030,[3] and Russia followed suit by releasing its own AI strategy in October 2019.[4] Some speculate that this could be the start of an AI arms race, one that the United States is at risk of losing if China or Russia has superior research, development, and acquisition (RDA) processes.

In light of these concerns, this report unpacks how China and Russia acquire weapons, both doctrinally and in practice, and how these processes compare with the process in the United States. It identifies areas where these countries excel and where they may be at a disadvantage and considers development timelines, funding mechanisms, capital constraints, and other systemic factors. In sum, this report attempts to answer the following research questions:

1. How do Russia and China approach defense acquisitions according to doctrine?
2. How do Russia and China approach defense acquisitions in practice?
3. What limits Russia's and China's ability to acquire new weapon systems?
4. How do Russia and China excel with respect to developing new weapon systems?

Chapters 2 and 3 address each of these questions directly in separate sections. However, in Chapter 2, Russia's limitations and strengths are presented in the opposite order of the list above and in Chapter 3. Russia's acquisition enterprise is crucial to its continued global relevance, but the difficulties it faces, especially with regard to capital and production capacity, far exceed its recent successes. Conversely, China's RDA process, although not without its own limitations, is trending in a more positive direction and is the most serious pacing threat in the long term. For this reason, we conclude Chapter 2 with a discussion of Russia's limitations, while we reverse this structure in Chapter 3 by ending with China's strengths.

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[3] State Council of the People's Republic of China, "Full Translation: China's 'New Generation Artificial Intelligence Development Plan' (2017)," trans. Graham Webster, Rogier Creemers, Paul Triolo, and Elsa Kania, New America website, August 1, 2017.

[4] Office of the President of the Russian Federation, "Decree of the President of the Russian Federation: On the Development of Artificial Intelligence in the Russian Federation," trans. Etcetera Language Group, Inc., Center for Security and Emerging Technology website, October 2019.

2. Russia

How Does Russia Approach Defense Acquisitions According to Doctrine?

It appears Russia has retained the same overarching RDA framework that it used in the Soviet era, which consists of five major stages: (1) scientific research projects, (2) preliminary design, (3) system development, (4) system adoption, and (5) serial production.[5] In the Soviet system, weapon system R&D was guided by the State Armament Program (SAP), a largely classified document that outlined the focus areas of research and the procurement plan for a period of about a decade.[6] The SAP still exists today and serves fundamentally the same role as it did in Soviet times. The SAP is used as a guideline to form tactical and technical requirements that specify the objectives of different research projects. Subsequently, research institutes and companies are given tactical and technical assignments describing the desired specifications for components of new weapon systems they are tasked to design. See Figure 2.1.

This appears to be an iterative process between the governing authority (likely the head of the "priority technology area" that the project falls under) and the chief designer of the design firm. At this point, preliminary designs are evaluated, and new direction may be given, depending on progress and perceived feasibility.[7] Eventually, the state decides whether to move a project into system development or to end it. In the Soviet system, the Military-Industrial Commission (MIC) had the final say. If the project was approved for continuation, the MIC would also name the primary contractor at this time.

This marked the project's entry into the development stage. This stage had a number of substages: "preparation of a draft design, preparation of engineering plans and design documents, creation and experimental testing of system components, combined tests, production of models, and use of the system by troops."[8] In today's system, as in the Soviet era, improvements are made iteratively during testing, and in at least some instances, a test batch of prototypes is produced for field testing. Today, field testing takes about one or two years.[9] In the Soviet system, an independent state commission consisting largely of officials from the Ministry of

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[5] Russian military sources still use this terminology, indicating that the RDA framework has not undergone drastic changes since the Soviet era. See, for example, A. N. Petrunin, A. A. Protasov, and V. N. Bobrik, "O soprovozhdenii opytno- konstruktorskikh rabot v promyshlennosti po sozdaniyu avtomatizirovannykh sistem voyennogo naznacheniya [On the Support of Experimental Design Work in Industry to Create Automated Military Systems]," *Voennaia mysl [Military Thought]*, No. 8, 2019.

[6] Pavel Podvig, ed., *Russian Strategic Nuclear Forces*, Cambridge, Mass.: The MIT Press, 2004, pp. 45–47.

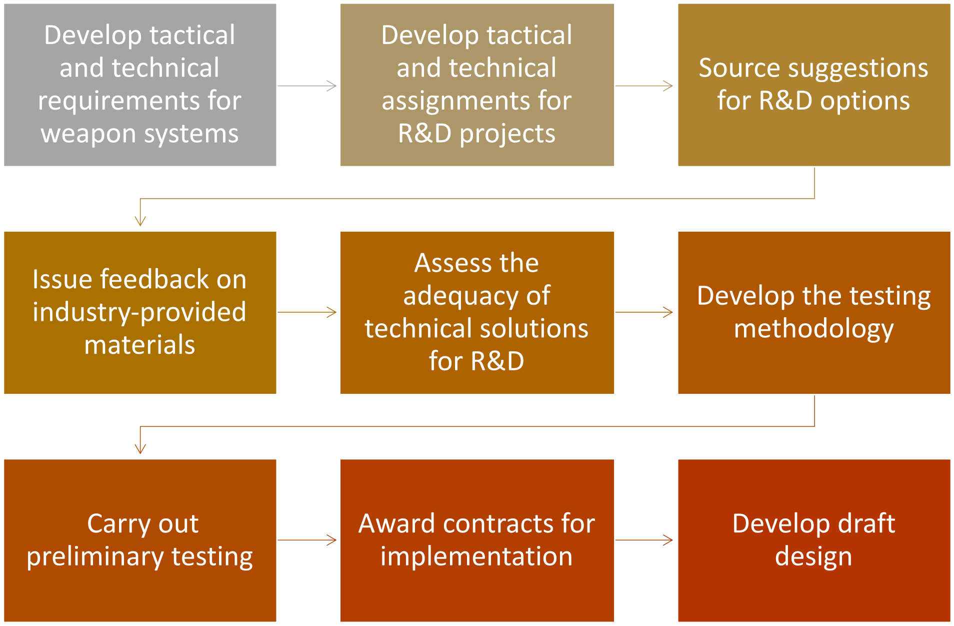
[7] Petrunin, Protasov, and Bobrik, 2019.

[8] Podvig, 2004, p. 47.

[9] Lester Grau and Charles K. Bartles, "Factors Influencing Russian Force Modernization," Changing Character of War Centre website, September 2018.

Defense would evaluate the system’s readiness for serial production based on its performance in testing.[10] If approved, the system would be adopted, and serial production would begin.

Figure 2.1. First Steps in Russia’s Defense Research and Development Process



SOURCE: Adapted from Petrunin, Protasov, and Bobrik, 2019.

How Does Russia Approach Defense Acquisitions in Practice?

Although it seems to have retained the nominal characteristics of the Soviet model, Russian RDA has in fact undergone a significant transformation in the past decade. As with so much else in contemporary Russia, the *de jure* aspects of the budgetary and procurement process and the way it operates *de facto* correlate only loosely. Personalities, rather than institutions, form the basis of power and determine what is and is not funded. The post-Soviet Russian defense complex has cultivated institutions whose primary purpose is to manage and direct these interpersonal contests. The most important of these are the Russian Security Council and the MIC. The former comprises mostly cabinet ministers and other senior government officials. Its duties encompass not just military security but also domestic and international security broadly defined. The MIC, in contrast, exists specifically to manage relationships between the Russian

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[10] Podvig, 2004, p. 47.

government and the defense industry.[11] It became a part of the Russian Presidential Administration in 2014.

The most important personality, of course, is President Vladimir Putin himself. Putin is the head of both the Security Council and the MIC and decides Russia's defense and spending priorities. Putin chairs meetings of these institutions and serves as the ultimate kingmaker within them; however, given his other responsibilities, he cannot devote all that much attention to their day-to-day operations. Until 2018, Putin delegated the duties of MIC head to Deputy Prime Minister Dmitrii Rogozin. After Rogozin fell out of favor, the former Deputy Defense Minister for Procurement, Iurii Borisov, took over this role.[12]

As previously mentioned, Russian defense procurement is guided by the SAP, which not only plans defense expenditures and weapon purchases but also R&D investments. The SAP is updated about every five years, although the current plan, SAP-2027, was delayed and only completed in 2018 rather than in 2015.[13] The first post-Soviet SAP was developed in the late 1990s, during the presidency of Boris Yeltsin, but until the promulgation of SAP-2020 in 2011, every SAP was an aspirational document whose objectives went totally unfulfilled. Even SAP-2020, the first SAP to actually generate significant results, has not been fully realized. The original plan was premised on sustained high oil prices and strong economic growth, neither of which proved to be accurate prognostications.[14] Furthermore, the loss of critical defense inputs from Ukraine crippled some planned development areas, such as shipbuilding. As a consequence, SAP-2020 had to be reworked on the fly to adjust to new geopolitical and budgetary realities following the annexation of Crimea. Even if adequate funding had been available, some of the SAP's goals, such as the acquisition of over 2,000 T-14 Armata tanks by 2020, were unrealistically ambitious. Even so, SAP-2020 marked the first time in the post-Soviet period that the Russian military received adequate funding for procuring modernized equipment. According to a statement in 2018 by Defense Minister Sergei Shoigu, leadership expected to meet its target of providing the Russian military with "70 percent modern equipment" by 2020.[15]

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[11] Jakob Hedenskog, Gudrun Persson, and Carolina Vendil Pallin, "Russian Security Policy" in Gudrun Persson, ed., *Russian Military Capability in a Ten-Year Perspective—2016*, Stockholm: Swedish Defence Research Agency, 2016, p. 102.

[12] "Borisov Has Replaced Rogozin as Deputy Chairman of the Military-Industrial Commission of Russia," TASS Russian News Agency, June 25, 2018.

[13] Richard Connolly and Mathieu Boulègue, *Russia's New State Armament Programme: Implications for the Russian Armed Forces and Military Capabilities to 2027*, London: Chatham House, The Royal Institute of International Affairs, 2018, p. 4.

[14] Center for Analysis of Strategies and Technologies,"Gosudarstvennyeprogrammy vooruzheniia Rossiyskoi Federatsii problemy ispolneniia i potentsial optimizatsii" ["The State Armaments Programs of the Russian Federation: Problems of Implementation and Potential for Optimism"], Moscow, 2015, p. 15.

[15] "Russian Army Gets 1,500 Weapon Titles, 80,000 Pieces of Equipment, 2018," TASS Russian News Agency website, December 24, 2018.

The specifics of Russian defense procurement are determined not by the SAP but by the annual State Defense Order (SDO).[16] Because available funds almost invariably fall far short of what was envisioned in the ongoing SAP, a politically fraught rebudgeting process is required. The Russian parliament plays almost no role in the development of the SDO, which is itself a classified document about which only broad details are generally released. The Russian president exercises final authority about what is and is not funded, but this takes place only at the end of a semiformal process in which different individuals and interest groups attempt to intervene to protect their interests. The largest players are the Ministry of Defense and the defense industry, but these are far from monolithic and encompass contradictory interests. The Ministry of Finance also has an opportunity to offer input about the SDO but does not have a direct veto. The Ministry of Finance seems to play a significant role in constraining the ambitions of the military and industry in procurement by injecting a measure of fiscal reality into the budgetary process.[17] Federal target programs are another flexible source of funds aimed at addressing goals that Russian leadership identifies as especially critical.[18] Although these programs sometimes have a national security focus, they are not limited to defense areas. The most germane of ongoing federal target programs is the "Development of the Defense Industrial Complex up to 2020," which was launched in 2012 as a stimulus in support of SAP-2020 efforts.[19]

Russia's rather opaque and undemocratic defense budgeting process has some advantages but also has major deficiencies compared with its U.S. counterpart. The absence of meaningful oversight from the legislature avoids some things, such as the geographic diversification of supply chains to try to increase political support for particular systems. But with an estimated 70 percent of the SDO being classified,[20] it has also been more difficult to shine light on graft, incompetence, and corruption on the part of officials or defense enterprises. Because the influence of individuals, rather than concrete strategic needs or military requirements, drives outcomes, projects can be perpetuated even if the military does not want them and even if they are failing to reach their technical objectives. The elimination in 2015 of the government agencies that had been responsible for investigating corruption in defense procurements further exacerbated this issue.[21]

The annual SDO is the primary funding mechanism for R&D and for procurement and modernization. Since 2010, an average of about 10 percent of the SDO has been devoted to

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[16] Susanne Oxenstierna, "Russian Military Expenditure," in Persson, 2016, pp. 135–141.

[17] Oxenstierna, 2016 pp, 145, 150.

[18] Ministry of Economic Development of the Russian Federation, "Federal'nyye tselevyye programmy rossii [Federal Target Programs of Russia]," website, undated.

[19] Tomas Malmlöf and Roger Roffey, "The Russian Defence Industry and Procurement," in Persson, 2016, p. 151.

[20] Susanne Oxenstierna and Fredrik Westerlund, "Arms Procurement and the Russian Defense Industry: Challenges Up to 2020," *Journal of Slavic Military Studies*, Vol. 26, No. 1, 2013.

[21] Malmlöf and Roffey, 2016, p. 156.

R&D; although this figure grew in the mid-2010s, it now seems to be receding.[22] Unfortunately, the breakdown of R&D spending within each annual SDO is not publicly available, so we can only speculate about what projects are being prioritized. Russia has a diverse assortment of institutions that engage in defense R&D. These include scientific-technical research institutes, which, in some cases, are actually design bureaus. Some of these research institutes have been absorbed into state holding companies or defense manufacturers, while others retain a degree of institutional independence inherited from the Soviet era. Russian universities also carry out defense-related research, albeit on a much smaller and less systematic scale than in the United States. The Russian Academy of Sciences and its Soviet predecessor historically played an outsized role in defense R&D, particularly in basic research, but the waning influence and funding of the Academy of Sciences in the Putin era is eroding its ability to play this role. Finally, the Russian government established the *Fond perspektivnykh issledovanii* [Foundation for Advanced Research] in 2012. Modeled after U.S. Defense Advanced Research Projects Agency, the foundation was a pet project of Dmitrii Rogozin. What Rogozin's deflating political stature will do to the organization remains to be seen, but Iurii Borisov's assumption of Rogozin's former position as its head suggests it may have staying power.

How Does Russia Excel with Respect to Developing New Weapon Systems?

For much of the post-Soviet period, state funding for R&D was limited or nonexistent, and most R&D activity has been undertaken by defense manufacturers with a partial view toward arms export sales. Because of the opacity of both the SDO and the budgets of individual defense enterprises, it is difficult to ascertain the relative importance of arms exports as a funding source. That said, developing weapons for export may come at the expense of R&D activities and production of weapon systems that align with Russia's military needs. Some Russian companies' production lines do not have the tools, materials, and human capital necessary to provide everything that its customers want. For example, the limiting factor in Russia's procurement of long-range strike and air defense systems—some of which are designed for export—is in production capacity, not cost.[23] If Russian companies must balance production of weapons designed for export against weapons made exclusively for Russia's armed forces, its military modernization could be delayed further. Nonetheless, Russian assessments consider these arms

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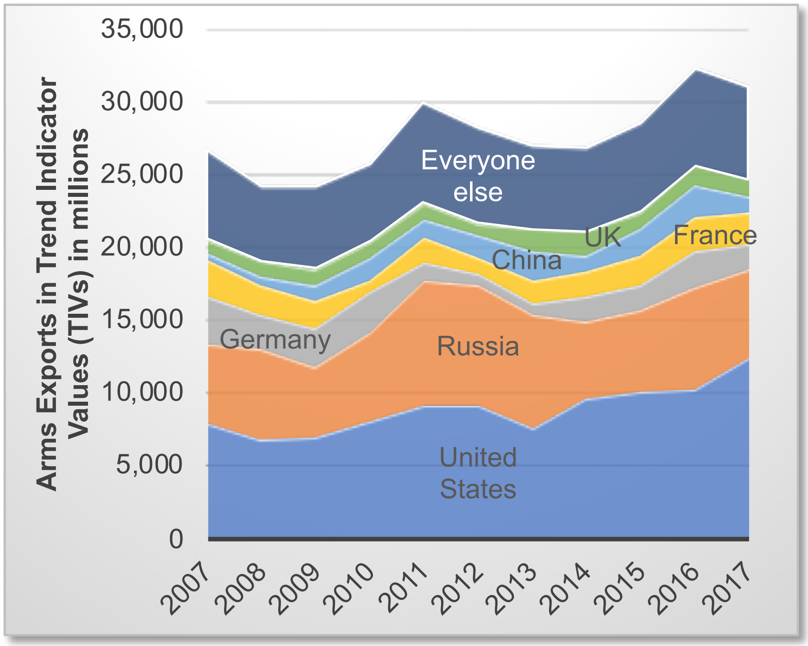
[22] Stolypin Institute of Economic Growth, "Rol' oboronnogo-promyshlennogo kompleksa v obespechenosti ekonomicheskogo rosta v RF [Role of the Defense-Industrial Complex in Facilitating Economic Growth in the Russian Federation]," November 2017, p. 4.

[23] See both Edward Geist, "Long-Range Strike," Appendix G, and Clinton Reach, "Russian Air Defense," Appendix J, in Andrew Radin, Lynn E. Davis, Edward Geist, Eugeniu Han, Dara Massicot, Matthew Povlock, Clint Reach, Scott Boston, Samuel Charap, William Mackenzie, Katya Migacheva, Trevor Johnston, and Austin Long, *The Future of the Russian Military: Russia's Ground Combat Capabilities and Implications for U.S. Russia Competition: Appendixes*, RR-3099/1-A, 2019b.

exports an important economic success story for their country; in fact, some Russian companies relied heavily on exports for their survival when the Russian armed forces were procuring little military equipment in the 1990s and 2000s.[24]

Although Russia's natural resources dominate their total exports, arms comprise nearly 40 percent of the country's export of manufactured goods.[25] As shown in Figure 2.2, Russia is second only to the United States in global arms exports and sells more than the next three countries combined. In particular, it has dominated the air defense market (Figure 2.3), although these numbers have dropped precipitously in recent years because of the sanctions following Russia's annexation of Crimea.[26]

Figure 2.2. Global Arms Export Market, 2007–2017



SOURCE: Data from Stockholm International Peace Research Institute (SIPRI), "SIPRI Arms Transfers Database," webpage, undated b.
NOTE: Amounts are in Trend Indicator Values (TIVs). TIVs are not financial values. See Paul Holtom, Mark Bromley, and Verena Simmel, "Measuring International Arms Transfers," fact sheet, SIPRI website, December 2012.

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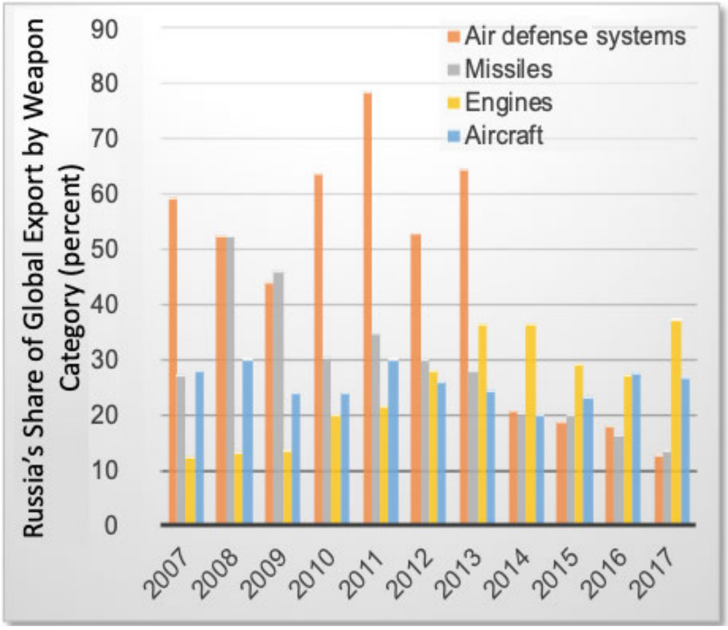
[24] Edward Geist, "Indirect Fires," Appendix F in Radin et al., 2019b, p. 102.

[25] U.S. Department of State, "Value of Arms Deliveries and Total Trade by Country, 2005–2015," Table II.d in "WMEAT 2017 Tables II IV Arms Transfer Deliveries, 2005 2015," Excel workbook, World Military Expenditures and Arms Transfers 2017 website, 2017; UN Comtrade Database, Russian Federation, 2017 (data as of October 30, 2018). Total exports of manufactured goods used commodity code 84-96; see Richard Connolly and Cecilie Sendstad, *Russia's Role as an Arms Exporter: The Strategic and Economic Importance of Arms Exports for Russia*, London: Chatham House, The Royal Institute of International Affairs, March 2017.

[26] SIPRI, undated b.

Figure 2.3. Russia's Share of Global Export by Weapons Category, 2007–2017



SOURCE: Data from the SIPRI, undated b.

Aside from air defense systems, arms exports have remained fairly steady in spite of sanctions. However, if sanctions remain in effect, the inability to import dual-use products, such as machine tools and electrical subcomponents, from the West could prove problematic down the line. Russia has little internal capacity to compensate for this lack of supply, although it has undertaken an import substitution program to replace foreign components with proprietary versions of its own.[27] This initiative is targeted at helping meet production quotas in the short term while enabling Russia to manufacture high-tech equipment in the long term. Sanctions aside, if Russia is unable to indigenously develop high-tech components and tools, it could trigger a vicious cycle in which Russian companies are forced to buy small quantities of ready-made machinery at premium prices, suffer losses as a result, and invest even less in domestic production in the future.[28] So far, import substitution has been successfully replacing Ukrainian components because of their similar technological basis, but substitution of products from European Union and North Atlantic Treaty Organization countries has been more complicated, which, in the meantime, may cause Russia to lean on Asian suppliers.[29]

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[27] Malmlöf and Roffey, 2016, p. 154.

[28] Paul Goble, "Import Substitution in Russia Failing as Moscow Buys Products Not Technologies," *Eurasia Daily Monitor*, Vol. 16, No. 44, March 28, 2019.

[29] Malmlöf and Roffey, 2016, p. 155.

What Limits Russia's Ability to Acquire New Weapon Systems?

The lack of diversity and dynamism in Russia's defense-industrial complex has exacerbated the import substitution effort. Following a period of privatization in the post-Soviet era, the Russian defense industry under Putin has been increasingly consolidated into a handful of state-owned holding companies. Although many Western analysts view this monopolistic structure as a major weakness, the extreme dysfunction of the privatized defense enterprises of the 1990s and 2000s was far worse than it is today. The challenge was that these firms were not designed to be competitive, and Russian defense procurements before 2010 were insufficient to keep them afloat by themselves. However, because there was only one surviving Russian manufacturer for most types of major military systems, the government was unable to credibly resort to the threat of allowing mismanaged enterprises to fail without crippling its own defense capabilities. This led to a codependent but often-adversarial relationship between the Russian government and the country's defense enterprises. Enterprises would receive payment but fail to deliver on time, and while the government often sued, it lacked effective incentives to induce better performance. The firms did not usually have cash to pay fines, and if they went bankrupt, there would be no Russian supplier of critical military hardware. Putin solved this problem by renationalizing these enterprises and placing them under the control of state-owned holding companies in the hands of his associates.[30] This measure reduced the earlier mismatched incentives, but whether it or the increased resources made available by SAP-2020 were more important for the improvement in the performance of the Russian defense industry in the 2010s is an open question.

Despite consolidation, the Russian industrial base still lacks the size and capital necessary to take on the large system integration projects to develop next-generation systems. Compared to U.S. prime contractors, top Russian defense companies earn, on average, an order of magnitude less in net profit.[31] Their productivity is low as well. Productivity is best measured by dividing total outputs by total inputs, most often formulated as net profit divided by labor costs. However, labor cost data for Russian defense companies are unavailable, so we instead define productivity

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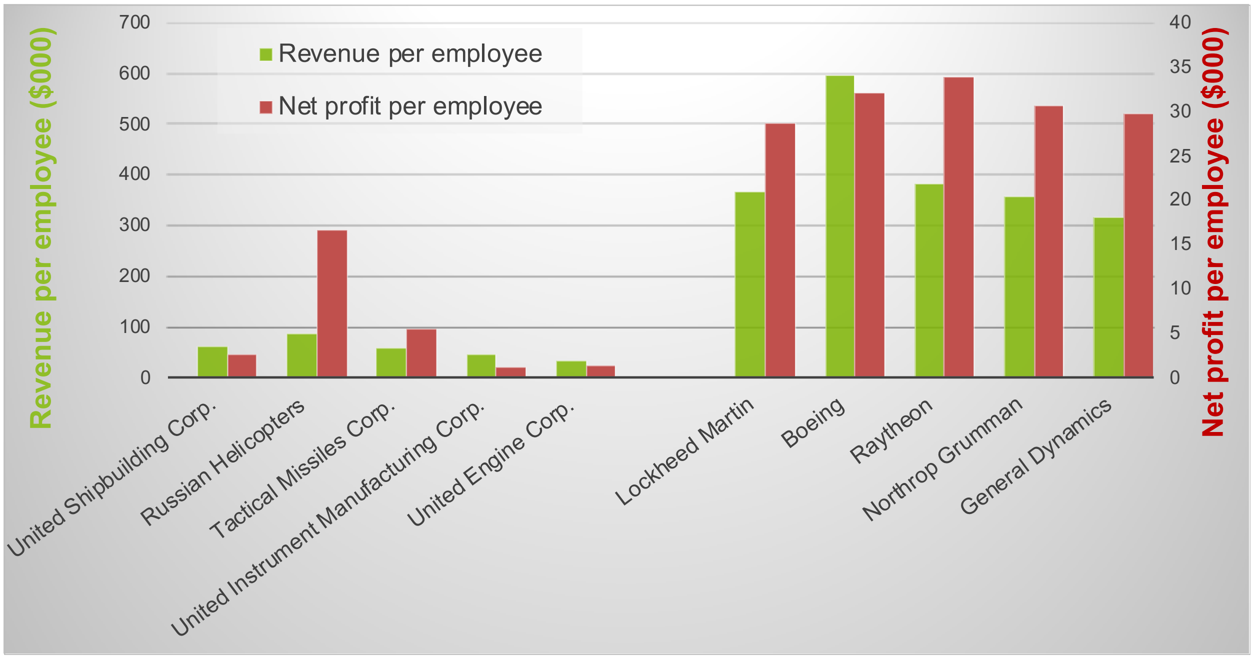
[30] Malmlöf and Roffey, 2016, p. 155.

[31] For more information about specific Russian companies, consult the very thorough analysis of Russia's defense industrial base in Radin et al., 2019b. Appendixes E–K include detailed analyses of the major firms producing weapons that enable Russia's maneuver ground forces; indirect fires; long-range strike; command, control, communications, computers, intelligence, surveillance, and reconnaissance; air defense; and electronic warfare capabilities. These appendixes include information on the staff size, production capacity, and financial health of more than a dozen firms. Some companies, such as the Kolomna Design Bureau and Concern Radio-Electronic Technologies (KRET), are performing much better than others, such as the artillery provider Uraltransmash and the cruise missile provider Novator. See also the main report, Andrew Radin, Lynn E. Davis, Edward Geist, Eugeniu Han, Dara Massicot, Matthew Povlock, Clint Reach, Scott Boston, Samuel Charap, William Mackenzie, Katya Migacheva, Trevor Johnston, and Austin Long, *The Future of the Russian Military: Russia's Ground Combat Capabilities and Implications for U.S.-Russia Competition*, Santa Monica, Calif.: RAND Corporation, RR-3099-A, 2019.

as dollars of revenue per employee and profit per employee.[32] Using these statistics, Russian defense companies measure well below their U.S. counterparts (see Figure 2.4).[33]

Figure 2.4. Productivity of Top Russian and U.S. Defense Contractors, 2015



SOURCE: Data from the SIPRI, "SIPRI Arms Industry Database," webpage, undated a.
NOTE: Note that only 29 percent of Boeing's revenue in 2015 was from defense contracts. Amounts are in 2015 U.S. dollars.

This can partly be explained by a workforce that has continued to stagnate despite its relatively strong knowledge base. The Soviet system inculcated a culture that emphasized education—particularly in science, technology, engineering, and math—and this culture has persisted in post-Soviet Russia to a certain extent. The mean years of schooling for adults has steadily increased since 1990 to its current all-time high. Russia ranks near the top tier, coming in at 31st globally, with 12 mean years of schooling. The United States is ranked 3rd with 13.4 years.[34] However, there are signs that the most educated workers in Russia are eager to leave. *The Moscow Times* reports that one-half of Russian doctoral students say they hope to relocate

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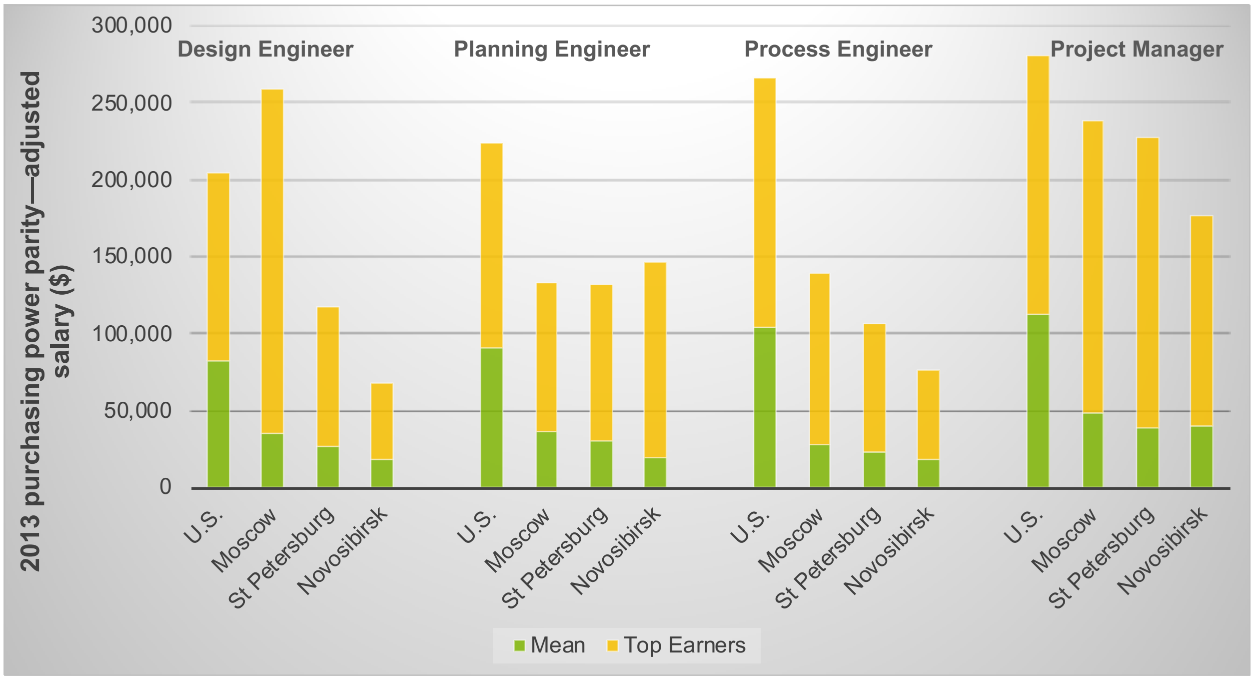
[32] Lowell L. Bryan, "The New Metrics of Corporate Performance: Profit per Employee," *McKinsey Quarterly*, February 2007.

[33] SIPRI, undated a.

[34] United Nations Development Programme, "Russian Federation: Human Development Indicators," webpage, undated.

from Russia for a "good job."[35] This could be motivated by the prospects of higher salaries and better quality of life. By one measure, Russian engineering wages fall well below U.S. standards even when adjusted for purchasing power in the two countries (see Figure 2.5).

Figure 2.5. Comparison of Engineering Salaries in the United States and Russia



SOURCE: Russian salaries are from Awara Group, "Engineers in Russia: Salary Survey," 2015; U.S. salaries are from American Society of Mechanical Engineers and American Society of Civil Engineers, *The Engineering Income and Salary Survey Standard Report: Trends Analysis*, *Policies*, *and Practices*, New York and Reston, Va.: Engineering Income and Salary Survey Publishing Group, April 1, 2013.
NOTES: PPP = purchasing power parity. Amounts are in 2013 U.S. dollars.

These trends are borne out in the immigration data as well. The Russian Presidential Academy of National Economy and Public Administration estimates that about 100,000 Russians emigrated annually to developed countries in the past few years, of whom nearly 40 percent had a college education. Conversely, it is estimated that only 13 to 17 percent of immigrants who entered Russia in 2014 had a college education.[36] This problem is likely to persist because 41 percent of Russians aged 18 to 24 say they either definitely or probably want to leave Russia to permanently live abroad.[37] Other demographic indicators also bode poorly for the economic

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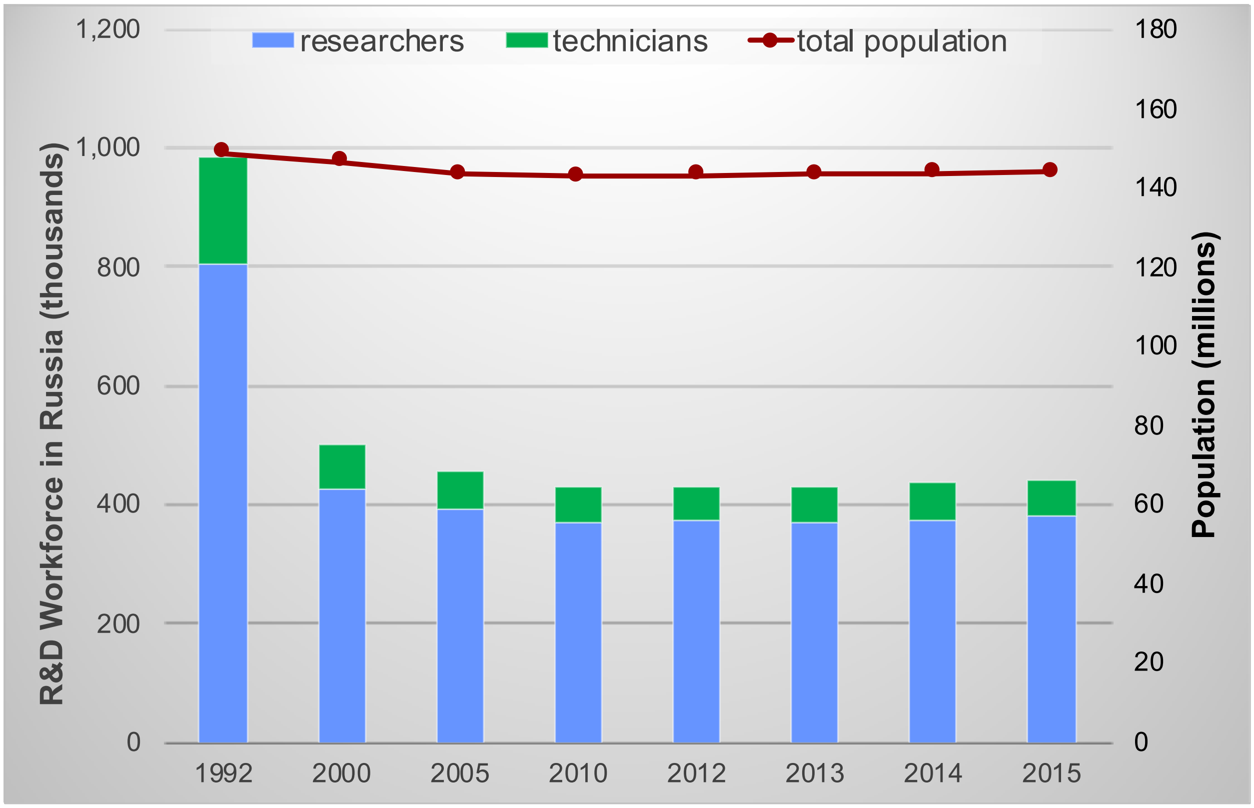
[35] "Half of Russian PhD Students Want to Move Abroad," *Moscow Times*, April 4, 2018.

[36] N. Mkrtchyan and Yu. Florinskaya, "Migration of Skilled Workers to Russia: Balance of Losses and Gains," in Vladimir Gurevich and Andrei Kolesnikov, eds., *Monitoring of Russia's Economic Outlook: Trends and Challenges of Socio-Economic Development*, No. 1(62), Gaidar Institute for Economic Policy, Russian Presidential Academy of National Economy and Public Administration, January 2018, p. 15.

[37] Levada Center, "Emigration Moods," press release, April 2, 2019.

health of the country and its prospective workforce. Russia's total population and R&D workforce growth hover near zero (Figure 2.6), and average life expectancy remains comparatively low for a developed country.

Figure 2.6. Growth of Total Population and R&D Workforce in Russia, 1992–2015



SOURCE: Data on total population are from The World Bank, "Population, Total," World Bank Russian Federation webpage, undated; data on the R&D workforce are from Federal State Statistics Service (Rosstat), *Russia in Figures 2017*, Moscow, 2017.

Despite numerous systemic drawbacks, there are what would outwardly appear to be some bright spots in Russia's recent acquisitions activity. The seemingly sudden appearance of new Russian weapon systems with claimed performance exceeding their U.S. counterparts, such as the T-14 Armata tank and the 2S35 Koalitsiia self-propelled howitzer, might give the impression that the Russians are able to develop sophisticated military hardware on an extremely compressed schedule. In actuality, the timetable from requirements specification to initial operating capability (IOC) for the Russian defense sector is comparable to its U.S. counterpart. The T-14 evolved out of a mid-1990s project to develop a next-generation main battle tank, the "Object 195." Two prototypes were built that shared many features of the later T-14, such as its automated turret. At the end of the 2000s, it was decided that this design was already outdated, and a new development program was initiated that built on lessons from the prototypes. The emerging platform became the basis for a shared chassis for the T-14; the Koalitsiia; and, potentially, a variety of other systems. But while pilot production of T-14s has been ongoing for several years and while they are featured in the Moscow Victory Day parade, state certification and IOC have yet to take place and are currently anticipated in 2020.[38] Similarly, development of the Koalitsiia self-propelled howitzer began at the Burevestnik design bureau in 2002, resulting in the construction of a highly unusual prototype with vertically-stacked twin barrels in a single turret. State-directed development began in 2006, and pilot production of a more conventional single-turret version began in 2013. These prototypes were displayed in the Victory Day parade in 2015, but they differed from the planned final version in that they were mounted on a T-90 chassis instead of the planned Armata chassis. In 2018, the Ministry of Defense stated that the Koalitsiia is anticipated to complete state trials and reach IOC in 2020.[39] These examples suggest that the Russian defense sector requires a period of close to 20 years, not much different from the U.S. defense sector, to finalize a system design and begin serial production.

The Armata and Koalitsiia are moderate design successes, but a number of modern Russian weapon systems have fared far worse, even after reaching serial production. For example, the performance of the Bulava submarine-launched ballistic missile has tested well below expectations, and the Russian media suspect that its lackluster performance could be attributed to flawed manufacturing processes.[40] Russia experts Connolly and Boulègue list a number of other sophisticated weapon systems that have been plagued by design roadblocks and delays:

> A new class of fourth-generation diesel-electric submarines—the Lada class (Project 677, NATO: St Petersburg class)—was also delayed, as the Russian shipbuilding industry was unable to produce air-independent propulsion systems. Similar delays in developing new sensors, power plants and weapons systems caused delays in the delivery of Admiral Gorshkov-class frigates (Project 22350, NATO: Admiral Gorshkov-class), the new fifth-generation Su-57 multi-role fighter aircraft (initially designated as the PAK-FA, or *Perspektivnyi aviatsionnyi kompleks frontovoi aviatsii*), and the Ivan Gren-class (Project 11711, NATO: Ivan Gren-class) landing ships.[41]

Moreover, the high cost of these systems may forestall the Russian military from ever procuring them in more than token quantities. This problem is relatively new for Russia, given that its acquisitions strategy, until very recently, has been to prioritize procurement in large quantities at the possible expense of quality. Practical realities may force Russia to revert to that low-risk procurement model if it becomes untenable to obtain enough of these more-sophisticated systems.

Russian critiques of the relative capability of the country's RDA process should give comfort to any Americans worried that they are falling behind. Not only do the Russians not believe that

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[38] Scott Boston and Matthew Povlock, "Maneuver Ground Forces," Appendix E in Radin et al., 2019b.

[39] Geist, "Indirect Fires," Appendix F in Radin et al., 2019b.

[40] Geist, "Long-Range Strike," Appendix G in Radin et al., 2019b, p. 134.

[41] Connolly and Boulègue, 2018, p. 8; italics in the original.

their process is superior, they consider it to have many glaring inadequacies. Only a few sophisticated systems have been developed and procured in significant quantities in the post-Soviet period. Given the size of the Russian economy, its RDA capability is impressive, and its products are sometimes less expensive in absolute terms. However, the per-unit cost of its next-generation systems, such as the T-14 tank and the Su-57 fighter, is still too high for the Kremlin to acquire them in significant quantities.

3. China

How Does China Approach Defense Acquisitions According to Doctrine?

Although Chinese military technology in the 1980s and early 1990s was often dismissed as weak and limited,[42] several factors help explain China's progress in defense RDA over the past 40 years. Perhaps the most significant change has been in defense spending. According to SIPRI, which draws from official People's Republic of China reporting, Chinese military expenditures grew tenfold in constant dollars over the past 25 years, with spending reaching an all-time high of $250 billion in 2018.[43] Although China has spent more on its military and gained greater access to global markets,[44] it has also sought to enact policy that will foster a closer relationship between its private sector and military.

This is part of a larger effort to shed some of the old features of the command economy and to spur innovation. Reforms over the past two decades have reshuffled the roles and responsibilities within the Chinese bureaucracy, representing an effort to centralize and standardize China's weapon system procurement strategy in the upper echelons of government, while also granting the defense industry some autonomy in production and contract fulfillment.[45]

China's current key players in RDA are the civilian-controlled State Administration for Science, Technology, and Industry for National Defense; the military-controlled Equipment Development Department (EDD); and the People's Liberation Army (PLA) service branches.[46] The first of these three is primarily in charge of drafting regulations, standards, and long-term plans for the defense industry; EDD manages PLA weapon system life cycles. The service branches are responsible for manning, training, and equipping the armed forces.[47] Prior to the most recent round of PLA reforms, initiated in 2016, the PLA's General Armaments Department (GAD), General Staff Department, and service branches would "establish operational

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[42] Bates Gill "Chinese Military-Technical Development: The Record for Western Assessments, 1979–1999," in James C. Mulvenon and Andrew N. D. Yang, eds., *Seeking Truth From Facts: A Retrospective on Chinese Military Studies in the Post-Mao Era*, Santa Monica, Calif.: RAND Corporation, CF-160-CAPP, 2001. Gill presents several arguments from literature supporting this, including obsolete aircraft, poor manufacturing, and limited training.

[43] SIPRI, "SIPRI Military Expenditure Database," webpage, undated c. Note that actual military expenditures are suspected to be even higher than official People's Republic of China figures.

[44] China joined the World Trade Organization in 2001, increasing its ability to import foreign technology.

[45] For more information, see Evan S. Medeiros, Roger Cliff, Keith Crane, and James C. Mulvenon, *A New Direction for China's Defense Industry*, Santa Monica, Calif.: RAND Corporation, MG-334-AF, 2005.

[46] Cristina Garafola, "Will the PLA Reforms Succeed?" *China Analysis*, No. 164, March 30, 2016, p. 3.

[47] Ed Francis and Susan M. Puska, "Contemporary Chinese Defense Industry Reforms and Civil–Military Integration in Three Key Organizations," San Diego, Calif.: University of California Institute on Global Conflict and Cooperation, Policy Brief No. 5, September 2010.

requirements and oversee basic preliminary research and R&D contracts, manage acquisition programs, and ensure follow-on support for newly fielded systems," with GAD taking the lead in these efforts.[48]

In 2016, GAD and EDD were reorganized, being joined to form the Central Military Commission (CMC). This is one of many PLA reforms that, together, have had the effect of reasserting Xi Jinping's control over the PLA. As chairman of CMC, he now has direct oversight over the formerly semiautonomous general departments, which are now organized into 15 separate functional departments, commissions, and offices. As a result, EDD's control over the RDA process has, arguably, diminished. For example, GAD's Science and Technology Commission now reports directly to the CMC instead of to the EDD. Although these reforms could prove problematic in the short term, they may make China's RDA process more efficient in the long term. According to the Institute for National Strategic Studies,

> [s]ince the EDD will be part of the formal CMC bureaucracy, it will likely be subject to more stringent oversight from organizations such as the Audit Bureau, Discipline Inspection Commission, and Politics and Law Commission. This could help to reduce corruption and inefficiency in the defense R&D system.[49]

Like the U.S. RDA process, the PLA's has five key steps. Although the PLA is much less open about its acquisition process and although different sources give different names for the steps, there seems to be agreement in the sources on the overall outline of the five-step process. First is a comprehensive feasibility study, which determines the technical and tactical requirements for a new system and assesses life-cycle costs. These studies form the basis for future R&D contracts and can be completed by PLA institutions, universities, other academic institutions, or defense contractors. In the project design stage, products undergo a series of iterative designs and models for validation. It also seems that some initial prototyping is done; in what used to be the PLA's Second Artillery Force, chief and deputy chief designers were appointed at this stage to oversee system integration and key subsystem development. As part of the reforms initiated in 2016, the Second Artillery became its own service branch and was renamed the Rocket Force, but some of Second Artillery practices likely carried over into the Rocket Force and may apply to the service branches more broadly.[50]

The third stage in China's RDA process is engineering and development, when full-scale design begins. This includes the technical design of the product, the building and evaluation of test models, computer modeling of production processes, and preparation for small-batch

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[48] Mark Stokes, "China's Evolving Space and Missile Industry," in Tai Ming Cheung, ed., *Forging China's Military Might*, Baltimore, Md.: Johns Hopkins University Press, 2014, p. 242.

[49] Joel Wuthnow and Phillip C. Saunders, *Chinese Military Reforms in the Age of Xi Jinping: Drivers, Challenges, and Implications*, Washington, D.C.: National Defense University, China Strategic Perspectives, No. 10, March 2017.

[50] The Second Artillery Force was the PLA arm responsible for developing most of China's nuclear and conventional long-range missiles.

production. In the Second Artillery, the engineering and development stage was when ground testing and subsequent design revisions occurred for missile prototypes. In the experiment and design finalization phase, specialized testing centers and PLA units conduct increasingly difficult tests on development and batch production systems. This includes performance, environmental, and reliability evaluations and is presumably followed by the necessary adjustments in product design. In the Second Artillery, this was referred to as the *flight test phase*, in which missiles were subjected to increasingly realistic and difficult flight tests, culminating in a design certification board review. After passing through the experiment and design finalization phase, product designs enter the batch production phase. Once a system goes into production, the process often starts over again, to develop an incrementally improved version of the same system. For some systems, this is undertaken in small batches at first, which are distributed to operational units for further evaluation, resulting in additional modifications to the product design before larger-scale production commences.[51]

To facilitate this process, the Second Artillery (and likely the Rocket Force) would create a regimental level seed unit of high-level officers early in the acquisition process to provide input on and shape the design of its new missiles. Seed unit personnel would usually be stationed at the factories and research institutes at which new weapons were being planned or produced. The officers of these units would not only provide operational perspective for the design process but would also work to develop tactics and maintenance procedures. These regiments would often receive administrative and training support from an operational brigade fielding a missile similar to the model they were helping to design. Once the missile was operational, the regiment would be upgraded to a full, operational brigade, fielding the new missile.[52] It is unclear whether the other PLA branches employ a similar approach. Given the privileged status of the Rocket Force in PLA strategy and politics, it is possible that this practice is unique to it. Other units that might adopt a similar approach would most likely be in the PLA Air Force, or perhaps the PLA Navy, where large units (regimental or brigade) are built largely around a single weapon platform.

How Does China Approach Defense Acquisitions in Practice?

As in the United States, the RDA process is usually long and difficult; it can take decades, even with the extensive use of stolen or purchased technology to cut corners in R&D. For example, China's J-20 stealth fighter, which is similar to the U.S.-developed F-22 and F-35, spent about nine years in preliminary research and nine to ten years in engineering and

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[51] Tai Ming Cheung, "An Uncertain Transition: Regulatory Reform and Industrial Innovation in China's Defense Research, Development, and Acquisition System," in Cheung, ed., 2014; Susan M. Puska, Debra Geary, and Joe McReynolds, "Commissars of Weapons Production: The Chinese Military Representative System," in Cheung, ed., 2014; Stokes, 2014; Tai Ming Cheung, "Strengths and Weaknesses of China's Defense Industry and Acquisition System and Implications for the United States," in *Acquisition Research: Creating Synergy for Informed Change, April 26–27, 2017*, Monterey, Calif.: Naval Postgraduate School, March 31, 2017.

[52] Stokes, 2014.

development, while the Y-20 transport, which is similar to the U.S.-developed C-17, took about 17 years to be fully ready for the Chinese air force. Both were high-priority programs with extensive backing from the highest levels of the Chinese Communist Party and the PLA.[53] Other programs, such as the J-15 carrier-based fighter, which is similar to the Russian-developed Su-33, had accelerated early research stages and advanced to prototyping and low-rate production quickly, but at the cost of a longer and more iterative engineering and evaluation process that found and corrected design problems. It still took the PLA 11 to 13 years to field the J-15.[54]

The entities responsible for executing many of the steps in China's RDA process are defense contractors. Unlike U.S. defense prime contractors, the largest of China's defense contractors are state-owned enterprises (SOEs). Although the SOEs have historically suffered from bloat and debt, their exposure to the market-based elements of China's 21st century economy has made them somewhat leaner and more profitable. As part of this revival, they now occupy the nexus of China's R&D efforts.[55] U.S. and Chinese firms top the charts in defense revenues worldwide. As Figure 3.1 shows, of the top 22 defense firms, nine are from the United States and eight are from China.[56] The top Chinese firms tend to be larger than their U.S. counterparts, given their sizable nondefense revenues, but U.S. firms still dominate in terms of defense revenue, with Lockheed Martin's sales almost double those of China's largest arms producers.[57]

And while they are no longer loss-makers, Chinese firms are not nearly as profitable or productive as those in the United States (see Figure 3.2).

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[53] Cheung, 2017, pp. 347–348.

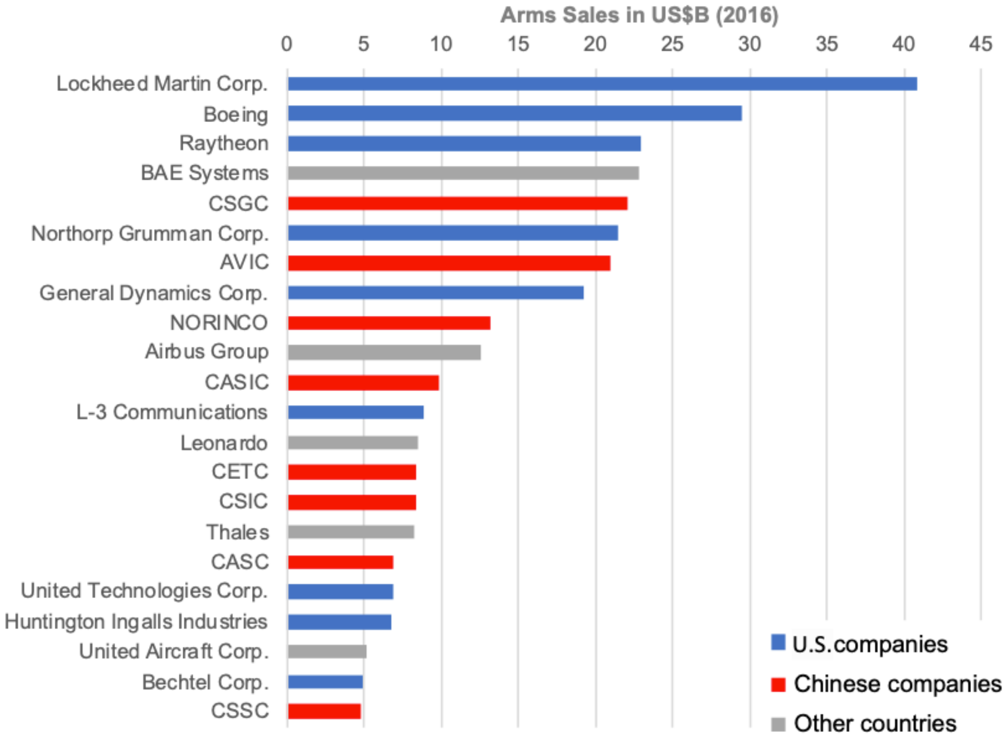
[54] Cheung, 2017.

[55] Cheung, 2017.

[56] Meia Nouwens and Lucie Béraud-Sudreau, "Global Defence-Industry League: Where Is China?" Military Balance Blog, August 28, 2018.

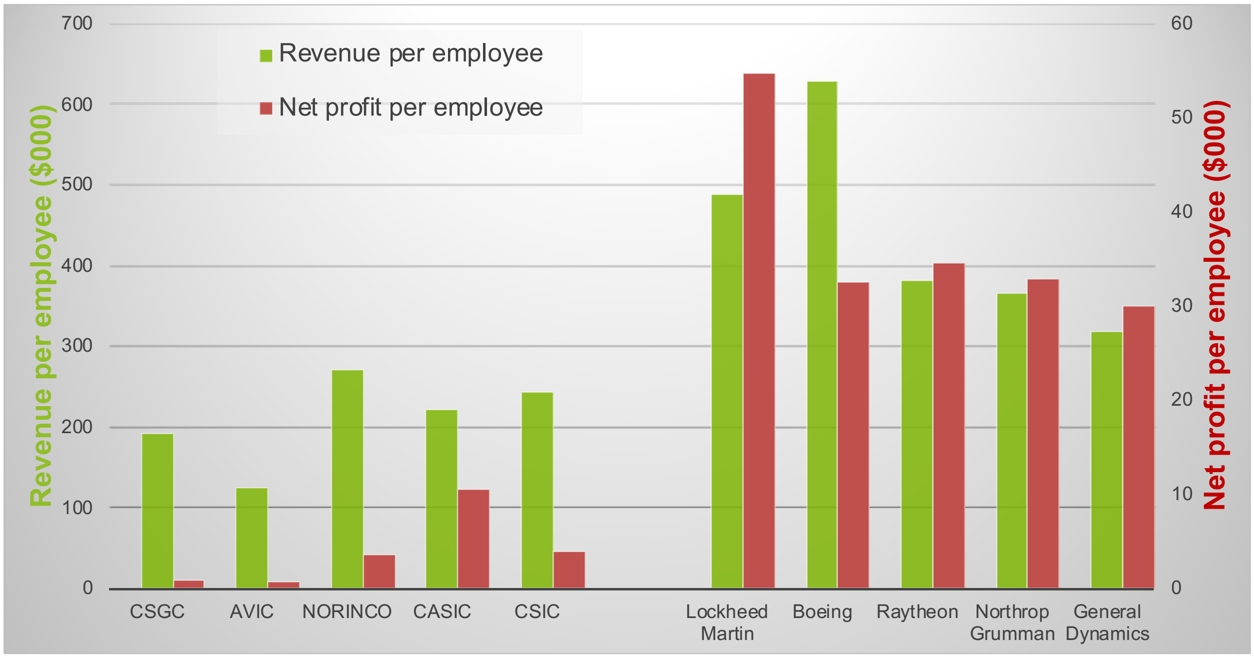
[57] Note that acquiring financial data on Chinese firms is nontrivial and requires some estimation. See Nouwens and Béraud-Sudreau, 2018, for a methodological explanation.

Figure 3.1. Defense-Related Revenues of the Largest Defense Firms Worldwide, 2016



SOURCE: Adapted from Nouwens and Béraud-Sudreau, 2018.
NOTES: BAE = British Aerospace; CSGC= China South Industries Group Corporation; AVIC = Aviation Industry Corporation of China; NORINCO = China North Industries Group Corporation Limited; CASIC = China Aerospace Science and Industry Corporation; CETC = China Electronic Technology Group; CSIC = China Shipbuilding Industry Corporation; CASC = China Aerospace Science and Technology Corporation; CSSC = China State Shipbuilding Corporation.

Figure 3.2. Productivity of Top U.S. and Chinese Defense Contractors, 2016



SOURCE: Data from SIPRI, undated a; "Global 500," *Fortune*, 2018.
NOTES: Note that this figure shows net profit from defense and nondefense sales. Many of the firms from both the United States and China have significant dealings outside the defense industry. Revenue and profit for Chinese companies are from 2018 but adjusted to 2016 U.S. dollars. Only 31 percent of Boeing's revenue in 2016 was from defense contracts.

What Limits China's Ability to Acquire New Weapon Systems?

Maintaining proper oversight and successfully rooting out corruption in the Chinese acquisitions enterprise are among its major deficiencies. The People's Republic of China exercises direct administrative control over SOEs to ensure quality and manage contracts. As in the former command economy, the PLA relies on administrative control, but since the abolition of the old economic command bureaucracies, it has not devoted the resources needed to fully monitor and control the defense industry.[58] Oversight is predominantly administered by military representatives, who are active-duty officers stationed in factories and research institutes across the country. These military representatives nominally protect government interests by ensuring production quality and contract execution but, as a practical matter, do not seem to protect the interests of their corresponding operational forces very effectively. Quality testing is often insufficient or only partially carried out. This is perhaps because most representatives are recent

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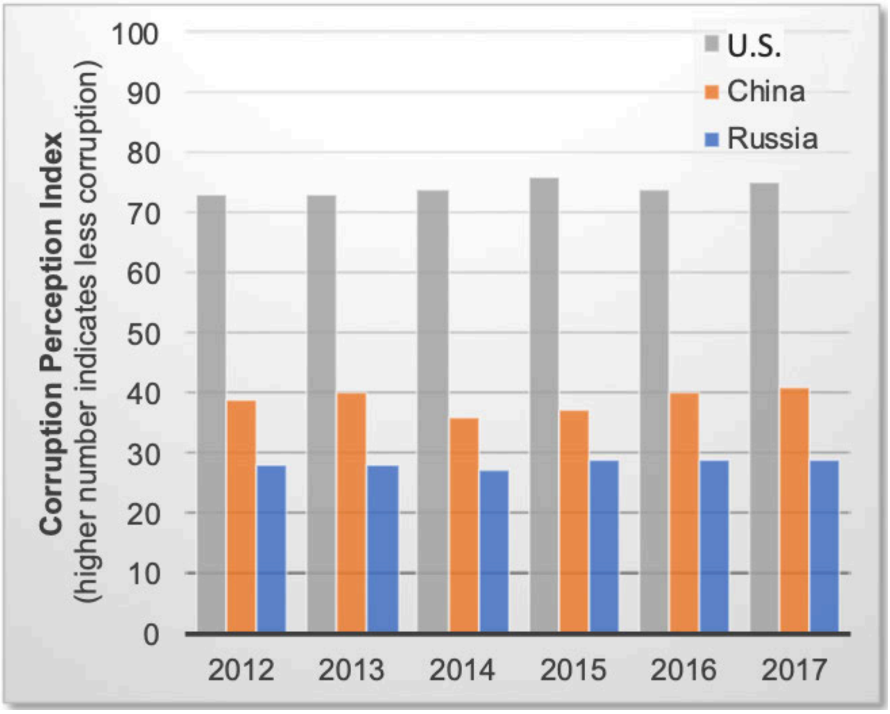
[58] Tai Ming Cheung, "An Uncertain Transition: Regulatory Reform and Industrial Innovation in China's Defense Research, Development, and Acquisition System," in Cheung, ed., 2014.

college graduates with minimal technical training and, thus, lack the expertise to monitor the activities of more-experienced contractors.[59]

Oversight is also complicated by conflicts of interest and misplaced incentives. For example, instead of receiving PLA wages, representatives are paid by the entities they are supposed to oversee. They tend to stay at the same post for long stretches of time, then to get jobs at the institutions they are supposed to be monitoring after retirement.[60] Although the use of military representatives is just one oversight mechanism in the vast Chinese administrative state, there is evidence that corruption is endemic in China's public sector more generally, as it is in Russia's (see Figure 3.3). It is possible that the sweeping PLA reforms of 2016 will curb some of the corrupt practices discussed above, although it is still too early to determine whether such changes have taken effect.

Figure 3.3. Corruption Perception Index of the United States, China, and Russia



SOURCE: Transparency International, homepage, 2018.

The design of Chinese defense contracts also does little to encourage transparency and accountability. The language of contracts is simplistic and perfunctory, without clear technical or schedule obligations, which is unsurprising given that there is no formal legal authority in the

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[59] Puska, Geary, and McReynolds, 2014.

[60] Puska, Geary, and McReynolds, 2014.

defense industry to adjudicate contract fulfillment.[61] Moreover, China has retained a compensation principle, in which the losing firm in a bid for a major defense contract still usually receives a smaller contract as consolation, stymying competition and introducing more inefficiencies.[62] China also practices a cost-plus pricing regime—a holdover of the command economy—which guarantees 5-percent profit for contractors on top of their incurred costs. This practice provides little incentive for firms to innovate or improve efficiency in their operations because higher costs translate to higher profits.[63]

The monopolistic structure of China's defense industry gives the SOEs significant bargaining power to keep this arrangement in place. Despite splitting each SOE into two separate companies in 1999, China's defense industry still lacks much real competition. SOEs dominate each of the major defense industry's sectors, and a long-established system of compartmentalization means there is little crossover of SOEs between sectors. Contracts are single-sourced for the majority of 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.[64]

China has relied heavily on theft of intellectual property for weapon development, which has helped it remain competitive but has pegged it several years behind the cutting edge. The Chinese aviation industry has leaned on this strategy for the development of fighter aircraft, largely relying on facsimiles of U.S. and Russian designs. For example, China's J-16 corresponds with Russia's Su-27. Likewise, the Chinese CH-4, J-20, and J-31 bear striking similarities to the U.S. MQ-9, F-22, and F-35, respectively. These copies vary in quality and do not necessarily perform the same as their counterparts. In particular, the production of high-quality and reliable turbofan engines has been an ongoing area of weakness. The J-20 stealth fighter is soon entering Chinese service, but it remains to be seen whether all the subsystems will deliver on their promised performance. Analysts maintain that, despite the relatively speedy introduction of the J-20, China is still 15 to 20 years behind the United States and Russia in military aviation.[65] Although intellectual property theft has surely accelerated China's development process, it does not provide the full solution.

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[61] Cheung, 2014, p. 53.

[62] Puska, Geary, and McReynolds, 2014, pp. 74–76.

[63] Cheung, 2017, p. 351.

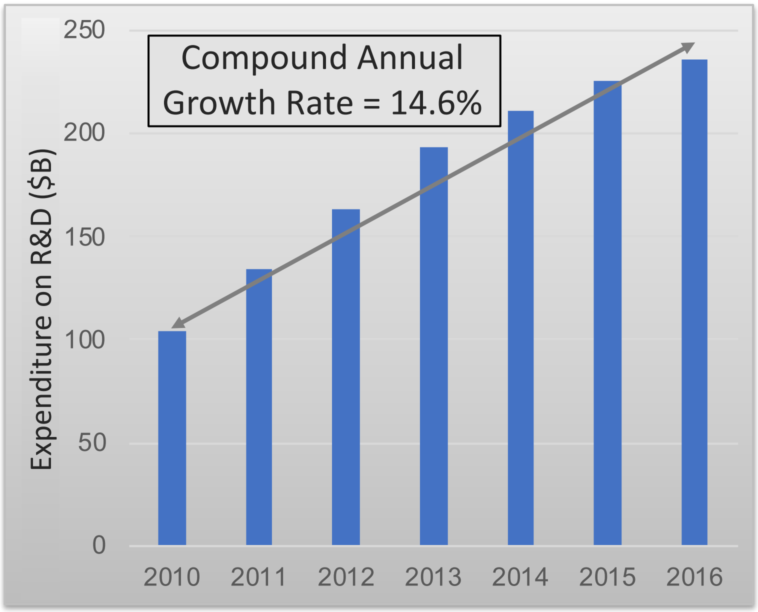
[64] Michael S. Chase, Jeffrey Engstrom, Tai Ming Cheung, Kristen A. Gunness, Scott Warren Harold, Susan Puska, and Samuel K. Berkowitz, *China's Incomplete Military Transformation: Assessing the Weaknesses of the People's Liberation Army (PLA)*, Santa Monica, Calif.: RAND Corporation, RR-893-USCC, 2015, pp. 127–128.

[65] Phillip C. Saunders and Joshua K. Wiseman, *Buy*, *Build*, *or Steal: China's Quest for Advanced Military Aviation Technologies*, Washington, D.C.: National Defense University, No. 4, December 2011, pp. 44–45.

How Does China Excel with Respect to Developing New Weapon Systems?

Where China is still lacking, it has turned to joint ventures and other investments to grow its organic R&D capacity.[66] Although a copy-replace model, such as China's, tends to emphasize the value of reverse engineering over foundational R&D work,[67] China has begun rectifying that deficiency by increasing its national spending on R&D at a compound annual growth rate of almost 15 percent since 2010 (see Figure 3.4).[68] This influx of cash has also coincided with rapid growth in the number of Chinese R&D institutions and the size of its R&D workforce (see Figure 3.5).[69]

Figure 3.4. Expenditure on Research and Development in China, 2010–2016



SOURCE: National Bureau of Statistics of China, *China Statistical Yearbook 2017*, Beijing: China Statistics Press, 2017, Tables 20-1 and 20-14.
NOTE: Amounts were converted from 2017 yuan to 2017 dollars.

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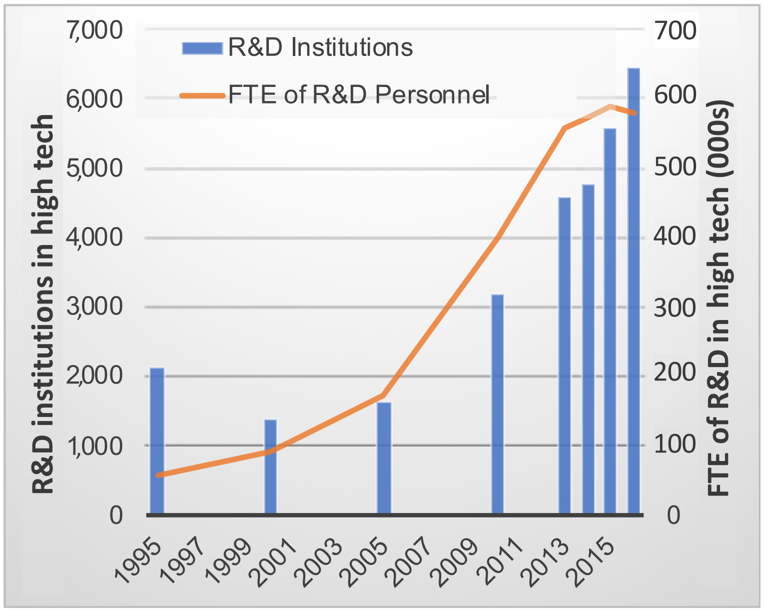
[66] Keith Crane, Jill E. Luoto, Scott Warren Harold, David Yang, Samuel K. Berkowitz, and Xiao Wang, *The Effectiveness of China's Industrial Policies in Commercial Aviation Manufacturing*, Santa Monica, Calif.: RAND Corporation, RR-245, 2014.

[67] Cheung, 2017, p. 340.

[68] National Bureau of Statistics of China, 2017, Table 20-1.

[69] National Bureau of Statistics of China, 2017, Tables 20-1 and 20-14.

Figure 3.5. Number of Research and Development Institutions and Personnel in China Over Time



SOURCE: National Bureau of Statistics of China, 2017, Table 20-14.
NOTE: Data were only available for eight years, between 1995 and 2016. FTE = full-time equivalent.

For decades, closer integration between commercial and military entities in S&T has been a goal for China. Specifically, its leadership envisioned constructing a national economy capable of mobilizing large parts of the commercial sector to meet military requirements in case of a national crisis.[70] Since Xi Jinping deemed it a national priority in 2015, military-civil fusion (MCF) has swept the nation and become a much more concretely defined concept.[71] MCF consists of a broad range of strategic initiatives, all with the goal of helping the PLA leverage the full potential of its civilian populace for defense, especially in technological innovation. MCF is motivated by the fact that, in recent years, the private sector—not the military—has been responsible for creating society's most transformative technologies. Xi said in 2017 that infrastructure, equipment procurement, training, military logistics, and defense mobilization showed the most promise for MCF.[72]

The MCF strategy includes educating the populace to be more proficient in technical fields. To continue bridging the gap in its R&D capacity, China needs to retain its top-tier engineering and managerial talent. Each year, more Chinese students are attending universities abroad, and

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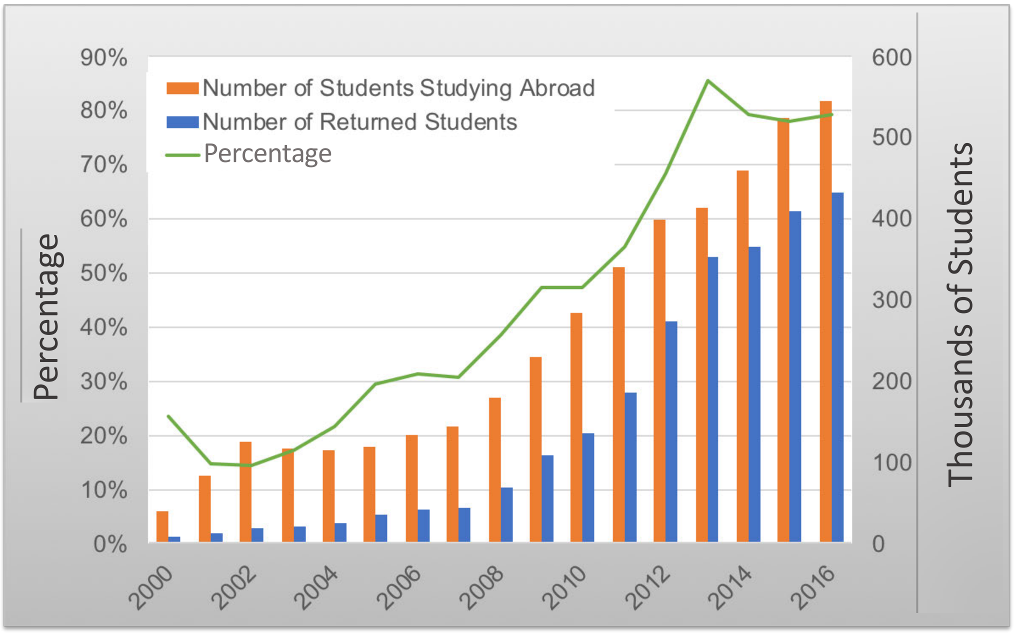
[70] Tai Ming Cheung, "Building a Dual-Use Economy," in Tai Ming Cheung, *Fortifying China: The Struggle to Build a Modern Defense Economy*, Cornell University Press, 2009, pp. 195.

[71] Tai Ming Cheung, *From Big to Powerful: China's Quest for Security and Power in the Age of Innovation*, Seoul: East Asia Institute, April 2019, p. 11.

[72] Cheung, 2019, p. 12.

China has a vested interest in these students returning home after earning their degrees. The data show that, in recent years, China has actually been quite successful at enticing these students to come back. From 2013 to 2016, around 80 percent of foreign-educated workers chose to return to China (see Figure 3.6),[73] possibly motivated by the prospect of higher wages, which, for high-tech jobs, are now becoming comparable to those in the United States (Figure 3.7).[74] As a result, the skills of China's engineering and manufacturing workforce are considered quite good. However, the same workers are usually young and lack the managerial experience to execute large system-integration projects. For example, most of the design team at the Chinese aerospace company COMAC is under 30 years old. Making matters worse, the Chinese bureaucracy and SOEs are very hierarchical in design and inhibit cross-communication between project teams at lower levels.[75]

Figure 3.6. Percentage of Chinese Nationals Who Return Home After Studying Abroad



SOURCE: National Bureau of Statistics of China, 2017, Table 21-10.

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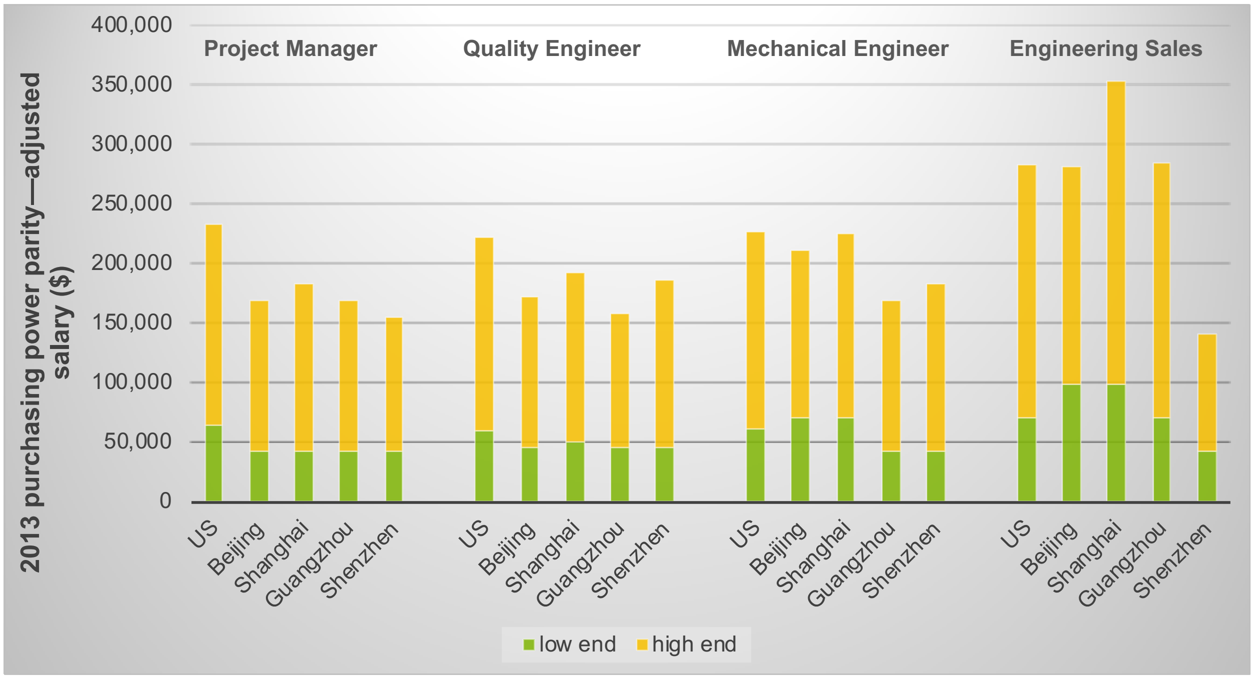
[73] National Bureau of Statistics of China, 2017, Table 21-10.

[74] Crane et al., 2014, pp. 63–64.

[75] Crane et al., 2014, p. 62.

Figure 3.7 Comparison of U.S. and Chinese Technology Salaries, 2013



SOURCE: Chinese salaries are from Michael Page, *China 2014: Salary and Employment Forecast*, 2014; U.S. salaries are from American Society of Mechanical Engineers and American Society of Civil Engineers, 2013.
NOTE: For U.S. salaries, we define *low end* and *high end* as the 10th and 90th percentiles, respectively. For Chinese salaries, we take the lower and upper bounds for non-executive level positions. Amounts are in 2013 U.S. dollars.

One approach China has taken to address this problem is investing in acquisitions of foreign technology and joint-venture partnerships. These business relationships have the twofold benefit of developing the technical and managerial skills of junior talent and also increasing their access and exposure to foreign technologies. An excerpt from a 2014 RAND report describes in greater detail how joint ventures benefit China:

> In a manufacturing joint venture, the foreign partner typically supplies the production design and management expertise, while the Chinese partner provides the facility and labor. Thus, the Chinese partner has an opportunity to learn how to efficiently produce a line of products it did not previously have the capability to produce. . . . An R&D joint venture provides an opportunity for the Chinese partner to learn not just how to produce a specific line of products, but how to design and develop entirely new product lines. From the perspective of the Chinese partner, R&D joint ventures provide a better opportunity to improve the production capabilities.[76]

Although foreign companies are aware of China's reputation for intellectual property theft, they are willing to enter these partnerships because of the access it gives them to Chinese buyers and sellers. Joint ventures can act as marketing tools to establish good will in the Chinese

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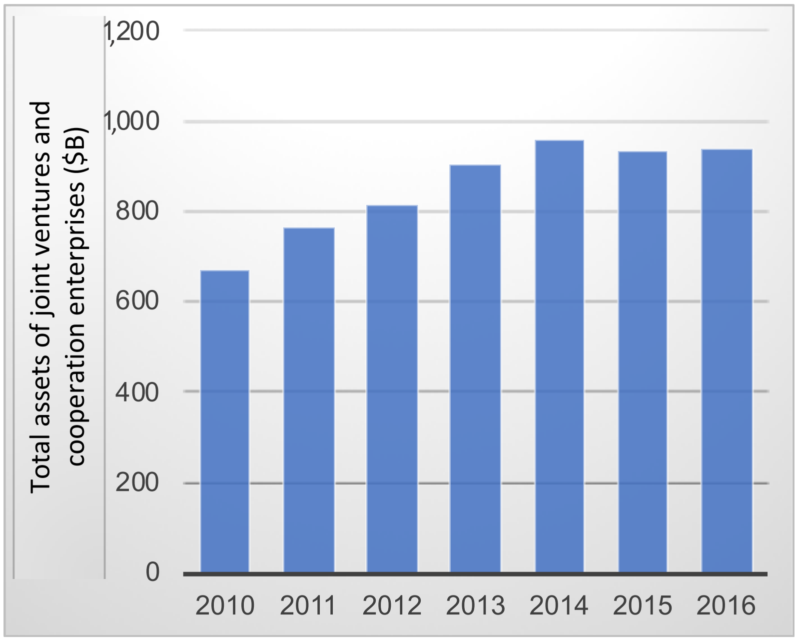
[76] Crane et al., 2014, p. 30.

market, allowing foreign companies to trade their technology and expertise for the opportunity to reach out to new customers and source low-cost components. Companies can reduce some of the risk of intellectual property theft by manufacturing key parts elsewhere before having systems fully assembled in China. For example, even Russia's United Aircraft Corporation chose to import engines for the Su-27 fighter aircraft to its assembly lines in China rather than manufacture the engines in China.[77] This is why certain high-tech parts, such as jet engines (especially turbine blades), are still difficult for China to successfully produce in large quantities.[78]

Figure 3.8. Joint Ventures and Cooperation Enterprises in China



SOURCE: National Bureau of Statistics of China, 2017, Table 13-1.
NOTE: Amounts are in 2017 U.S. dollars.

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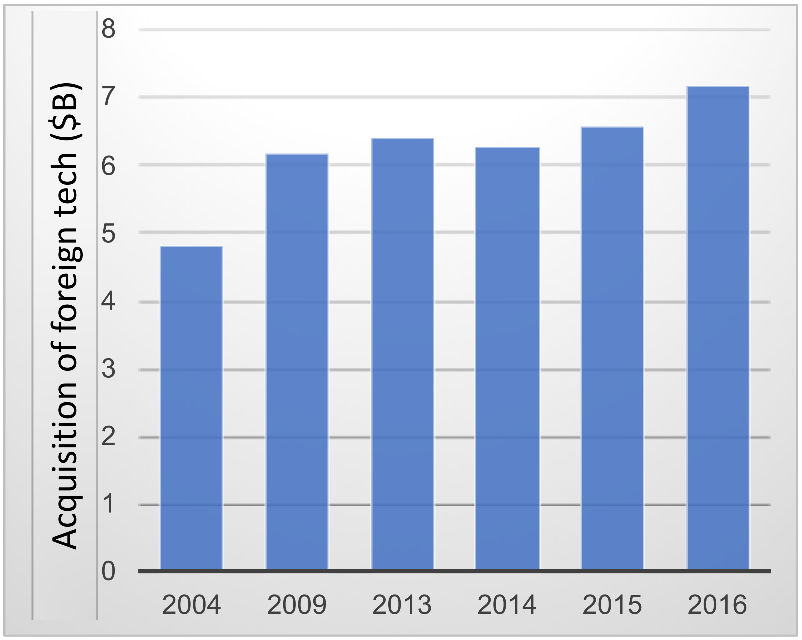
[77] Crane et al., 2014, p. 42.

[78] Crane et al., 2014, p. 39.

Figure 3.9. Chinese Acquisitions of Foreign Technology



SOURCE: National Bureau of Statistics of China, 2017, Table 20-4.
NOTE: Amounts are in 2017 U.S. dollars.

So, while China has had great success in applying a spin-on model for dual-use technologies, systems that do not have commercial analogues are significantly more difficult for it to produce. If Western countries continue to bar military cooperation with China, Russia may be the sole source of advanced single-use technologies. Therefore, Russia's decision to participate closely in joint-venture activities moving forward could be critical to China successfully acquiring the knowledge and expertise to produce these technologies in large quantities. Ironically, as China makes greater strides toward these goals, Russia may become more hesitant to engage in technology transfer, fearing that China's progress could pose a strategic threat and introduce a more formidable competitor in arms exports. Thus, Russia may instead choose to sell fully assembled versions of aircraft and other systems to China rather than share the underlying technology and processes.[79]

Even if Russia takes this approach, its exports to China are nonetheless an important feature in China's RDA system writ large. Buying foreign technology provides a check on Chinese SOEs by injecting additional competition into an otherwise monopolistic market. For example, China's recent purchase of 24 Russian Su-35 fighter aircraft may have applied some pressure on AVIC, the Chinese SOE developing the J-20, to improve its design. There were even suspicions

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[79] Saunders and Wiseman, 2011, pp. 48–49.

at one time that China might replace the J-20 engine with the high-performance engine from the Su-35.[80]

Overall, the PLA has overcome many technological barriers and is the clear pacing threat to the United States in defense acquisitions, but this progress has often been based on the assimilation of foreign processes and technology through intellectual property theft and, most recently, acquisitions and joint ventures. The PLA is still struggling to spur domestic innovation and close the gap on a few glaring technical deficiencies, such as high-end chips, silent submarines, and aircraft engines. Even as it strives to clear these technical hurdles, the PLA must address the institutional inefficiencies and barriers related to management and quality assurance that continue to frustrate its reform efforts.

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[80] Ethan Meick, *China-Russia Military-to-Military Relations: Moving Toward a Higher Level of Cooperation*, Washington, D.C.: U.S.-China Economic and Security Review Commission, March 20, 2017, p. 21.

4. Conclusion

On paper, the RDA processes in both Russia and China are comparable to those in the United States. Although terminology may differ slightly, there is common agreement among the three countries on certain essential steps. In practice, the outcomes of these broad RDA frameworks hinge on the people and institutions that are tasked with implementing the frameworks.

Neither Russia nor China has better acquisition processes. Russia maintains a large arms export market but struggles to produce its most sophisticated systems in strategically significant quantities. Its most recent SAP was successful insofar as it was adequately funded, managing to retrofit much of its legacy Soviet equipment to modern standards; however, the next SAP's goals will be harder to accomplish because it calls for the procurement of new and highly sophisticated systems in large quantities. Complete execution of the plan is unlikely without increases in manufacturing capability, funding, and political will.

China's reliance on intellectual property theft means its weapons are years behind, but the Chinese recognize that shortcoming and are investing in and growing their organic capabilities through joint ventures and acquisition of foreign technology. These business partnerships help China's large SOEs assimilate new processes and technologies and point to China being on a path to mitigating some of its historical shortcomings in RDA execution. In some areas, the PLA has already made substantial gains, but in others, such as aircraft, recent gains have been the result of decades of development. China's inability to manufacture highly sophisticated parts continues to limit its status as a first-rate developer and producer of state-of-the-art military materiel, but progress is apparent. Successfully developing an indigenous aircraft engine and producing it in large quantities will signal a turning point in the capabilities of the Chinese defense industry.

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