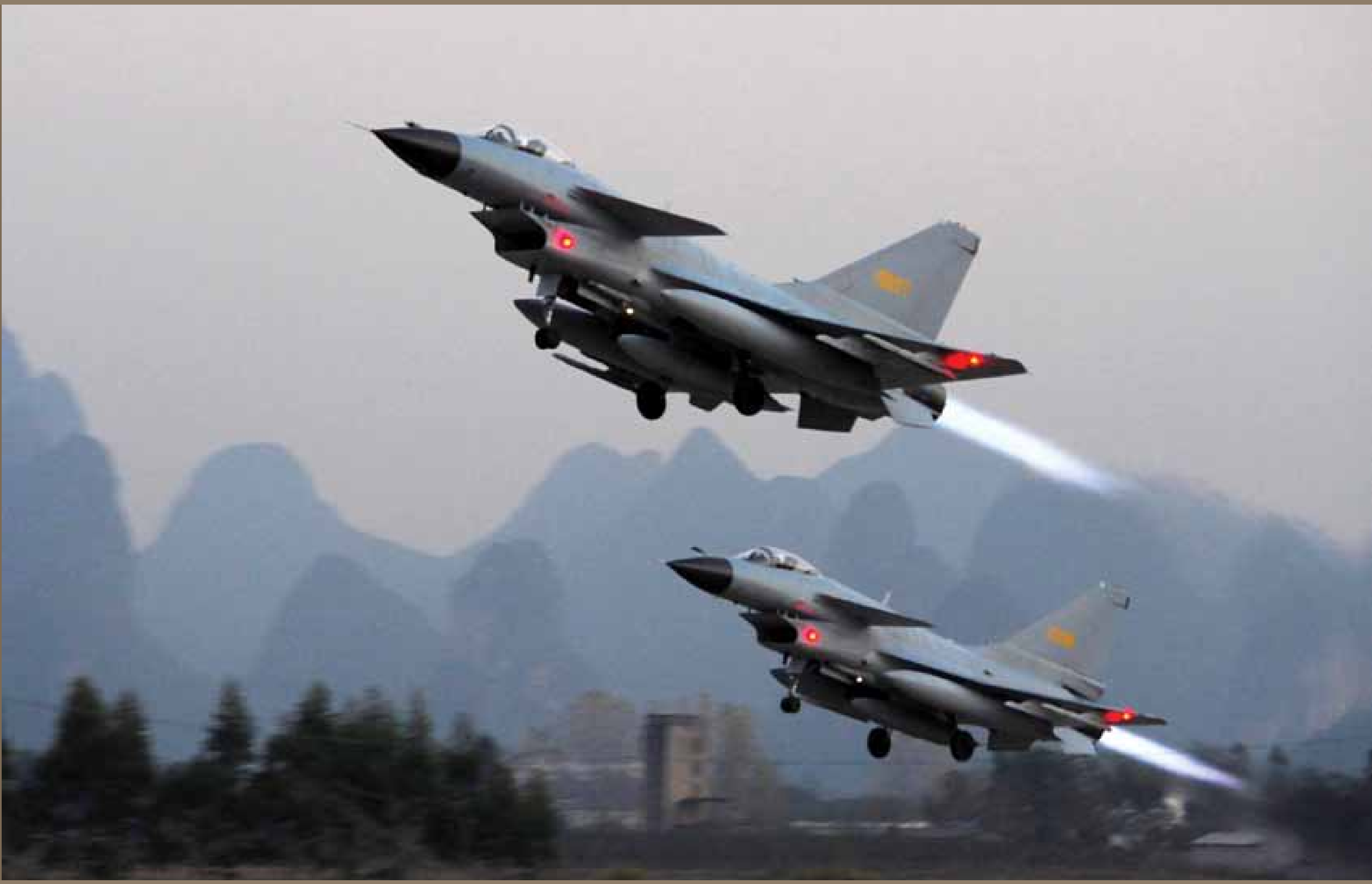
INSTITUTE FOR NATIONAL STRATEGIC STUDIES

CHINA STRATEGIC PERSPECTIVES 4

Buy, Build, or Steal: China's Quest for Advanced Military Aviation Technologies

by Phillip C. Saunders and Joshua K. Wiseman



Center for the Study of Chinese Military Affairs
Institute for National Strategic Studies
National Defense University

Institute for National Strategic Studies
National Defense University

The Institute for National Strategic Studies (INSS) is National Defense University's (NDU's) dedicated research arm. INSS includes the Center for Strategic Research, Center for Technology and National Security Policy, Center for Complex Operations, and Center for Strategic Conferencing. The military and civilian analysts and staff who comprise INSS and its subcomponents execute their mission by performing research and analysis, publication, conferences, policy support, and outreach.

The mission of INSS is to conduct strategic studies for the Secretary of Defense, Chairman of the Joint Chiefs of Staff, and the Unified Combatant Commands, to support the national strategic components of the academic programs at NDU, and to perform outreach to other U.S. Government agencies and to the broader national security community.

Cover: J-10 Fighters
Training in Guangzhou Military Region.

Photo courtesy of Shen Lin (Color China Photo, AP Images)

Buy, Build, or Steal: China's Quest for Advanced Military Aviation Technologies

Buy, Build, or Steal: China's Quest for Advanced Military Aviation Technologies

by Phillip C. Saunders and Joshua K. Wiseman

Institute for National Strategic Studies
China Strategic Perspectives, No. 4

Series Editor: Phillip C. Saunders

NDU Press

National Defense University Press
Washington, D.C.
December 2011

First printing, December 2011

For current publications of the Institute for National Strategic Studies, please go to the National Defense University Web site at: www.ndu.edu/inss.

Contents

Executive Summary

Although China continues to lag approximately two decades behind the world's most sophisticated air forces in terms of its ability to develop and produce fighter aircraft and other complex aerospace systems, it has moved over time from absolute reliance on other countries for military aviation technology to a position where a more diverse array of strategies can be pursued. Steps taken in the late 1990s to reform China's military aviation sector demonstrated an understanding of the problems inherent in high-technology acquisition, and an effort to move forward. However, a decade later it remains unclear how effective these reforms have been. Where are the People's Liberation Army Air Force (PLAAF) and China's military aviation industry headed? What obstacles must be overcome for China to join the exclusive ranks of those nations possessing sophisticated air forces and aviation industries capable of producing world-class aircraft?

This study identifies potential aviation technology development and procurement strategies, presents a general model of the options available to developing countries, and applies that model to explain Chinese procurement and aviation technology acquisition efforts over the last 60 years. The model articulates three main technology procurement avenues: purchase (buy), indigenous development (build), and espionage (steal), and three subavenues: reverse engineering (combining buy/steal and build), coproduction (combining buy and build), and codevelopment (combining buy and build, with an emphasis on build). It examines the costs, benefits, and tradeoffs inherent in each approach. Four variables influence decisions about the mix of strategies: (1) a country's overall level of economic development, in particular the state of its technical/industrial base; (2) the technological capacity of a country's military aviation sector; (3) the willingness of foreign countries to sell advanced military aircraft, key components, armaments, and related production technology; and (4) the country's bargaining power vis-à-vis potential suppliers.

In applying the model, we divide the evolution of China's military aviation industry into five periods based on China's changing access to foreign suppliers of military aircraft and aviation technology. Soviet assistance (1950–1960) provided the foundation for China's military aviation industry, which cut its teeth coproducing Soviet fighter, bomber, and transport aircraft. Given Western embargoes, Moscow offered the only viable path to advanced aviation technology and provided assistance on favorable terms to support its communist ally. The second period (1960–1977) is marked by the Sino-Soviet split, which eliminated Chinese access to cutting-edge aviation hardware. China continued to produce and make

modest refinements to 1950s vintage Soviet aircraft designs, using reverse engineering to fill in gaps where technical information was lacking. In the third period (1977–1989), China gained some access to Western aviation components and technologies and sought to apply them to a variant of the J–8 (a twin engine fighter based on a modified MiG–21 design) and the JH–7 (a fighter-bomber with a British engine). The fourth period (1989–2004) is marked by Western bans on arms sales to China in the wake of Tiananmen, Sino-Soviet rapprochement (leading to sales of advanced Russian fighters and coproduction arrangements), and a brief but important window of access to Israeli technologies. Covert access to advanced Western fighters and espionage (in both traditional forms and via computer network operations) also began to make more contributions.

In the fifth period (2004–present), China has enjoyed increased access to foreign commercial aviation technologies and has benefited from a "spin-off, spin-on" dynamic in gaining commercial access to dual-use technologies and applying them for military purposes. However, China's legitimate access to advanced military-specific technologies has been reduced as Western sources of supply remained closed and Russia has become more reluctant to provide advanced aviation technology due to China's reverse engineering of the Su-27, fear of future competition for export markets, and concerns about China's long-term strategic direction.

China has used coproduction, selected purchases of advanced aircraft, reverse engineering, and foreign design assistance to build a capable military aviation industry with a significant indigenous design and production capacity. The Chinese military aviation industry can now produce two fourth-generation fighters roughly equal to those in advanced air forces: the J–10 (indigenously developed with Israeli assistance) and the J–11B (based on coproduction and reverse engineering of the Su-27). Both aircraft still rely on imported Russian turbofan engines. Test flights of the new J–20 stealth fighter prototype demonstrate Chinese ambitions to build fifth-generation fighters, but the extent to which the J–20 will match the performance of state-of-the-art Russian and Western fighters is unclear. Significant technical hurdles in engine design, avionics, and systems integration are likely to delay operational deployment of the J–20 until about 2020. This would be about 15 years after the F–22 entered U.S. Air Force service, supporting an overall assessment that the Chinese military aviation industry remains 15–20 years behind.

Producing state-of-the-art fighters requires an aviation industry to master a range of highly advanced, military-specific technologies. The historical development of China's military aviation industry reflects an ongoing tension between the desire for self-reliance in defense and the need for access to advanced foreign technologies. China's legitimate access to cutting-edge

Western military technologies will likely remain curtailed and Russian reluctance to supply advanced military technologies will likely grow. These assumptions support two important conclusions. First, the Chinese military aviation industry will have to rely primarily on indigenous development of advanced "single-use" military aviation technologies in the future. The Chinese government is pursuing a range of "indigenous innovation" and technology development programs, but mastering advanced technologies becomes more difficult and expensive as a country moves closer to the technology frontier. This leads to a second, related conclusion: China will likely rely more heavily on espionage to acquire those critical military aviation technologies it cannot acquire legitimately from foreign suppliers or develop on its own.

Introduction

Although China continues to lag approximately two decades behind the world's most sophisticated air forces in terms of its ability to develop and produce fighter aircraft and other complex aerospace systems, it has moved over time from absolute reliance on other countries for military aviation technology procurement to a position where a more diverse array of strategies can be pursued. Steps taken in the late 1990s to reform China's military aviation sector demonstrated an understanding of the problems inherent in high-technology acquisition, and an effort to move forward.[1] However, a decade later it remains unclear how effective these reforms have been. Where are the People's Liberation Army Air Force (PLAAF) and China's military aviation industry headed? What obstacles must be overcome for China to join the exclusive ranks of those nations possessing sophisticated air forces and aviation industries capable of producing world-class aircraft? Answering these and related questions are at the heart of this study. Because advanced fighter aircraft exemplify the most sophisticated level of aerospace technology, are important for air force combat capabilities, and present unique design and fabrication challenges for a military aviation industry, the authors' analysis focuses primarily on China's efforts to acquire, produce, and develop fighter aircraft and related technology. It also includes some discussion of bombers, transports, and airborne early warning aircraft where relevant to Chinese technology development and acquisition efforts.

Approaches to Technology Development and Procurement

Few things differentiate the lethality of an air force more than the level of technology in its most advanced aircraft. Historically, advantages in aviation technology have often translated into significant advantages in combat environments, especially for fighter aircraft. In the current environment, the world's most advanced air forces have access to fifth-generation fighter aircraft technology.[2] Fifth-generation fighters are characterized by the incorporation of advanced technologies such as stealth, integrated avionics systems, thrust vectoring, and helmet-mounted sights.[3] The technological demands of designing and producing advanced fighters present considerable challenges for developing countries. They may want an air force that is on par qualitatively with the world's most advanced, but usually lack an aviation industry capable of producing cutting-edge fighter aircraft technology. A developing country may be able to produce some highly sophisticated components, but lack the knowledge or industrial capacity to design and build all necessary components or to integrate them into a finished product. Industrial capacity refers to the ability to fabricate each component part that goes into the final product and assemble it using indigenous labor. Knowledge encompasses the know-how to design and manufacture component parts, together with requisite competence in areas such as systems engineering, which is critical to integrating various complex systems into a working unit.[4]

Developing countries incapable of producing cutting-edge fighters on their own must seek to acquire complete aircraft or technologies from countries willing to sell them advanced aircraft or to export or codevelop the relevant technologies. However a number of factors might dissuade countries with an advanced aviation technology base from exporting aircraft or advanced aviation technologies to a particular developing country. The exporter country might view such transfers as potentially harmful to its security interests if it is unsure about the developing country's long-term intentions. It might seek to avoid entering into a technology transfer relationship out of deference to its relationship with allies or other customers. Allies might use leverage to dissuade potential exporters from making arms sales or technology transfers to developing countries about which they have security concerns. Nevertheless, access to foreign advanced fighters and aviation technology is critical for developing countries seeking to build a modern air force.

Buy, Build, or Steal

Countries whose overall level of economic development and relatively backward aviation industry limit their aircraft production capability have the three basic options of purchase (buy), indigenous development (build), or espionage (steal) in their efforts to develop a modern air force. For countries in this situation, all three options have significant limitations.

Buy

Buying imported aircraft allows a developing country to obtain more advanced fighters than its indigenous aviation industry can produce. Buying complete aircraft offers a developing country a relatively fast way to build its air force's combat capability (although in practice it may take 4 to 5 years from the time a deal is signed until a unit equipped with a new fighter reaches initial operational capability). Often a deal to purchase advanced fighters includes flight training, assistance with maintenance, and the acquisition of spare parts necessary to maintain operational readiness. This can not only speed the introduction of the aircraft into service, but also improve the acquiring air force's human capital and overall capabilities. Because purchasers usually have the opportunity to "fly before they buy," there is a clearer sense of what the capabilities of the aircraft will be and less risk of technological failure or inadequate performance.

The disadvantages of building a modern air force using imported aircraft include the relatively high cost, limited transfer of technology to the aviation sector, and continuing dependence on foreign suppliers. Buyers are also limited to the aircraft that supplying companies are willing to sell; advanced countries often restrict the type of aircraft or the sophistication of avionics and weapons systems that can be exported due to strategic concerns or to maintain a technological advantage for their own air force. A common approach is to export last generation systems or watered-down versions of the most advanced fighters. This enables the United States, Russia, and European powers to maintain a long-term competitive advantage in military aviation technology and a measure of air power dominance over their customers.

Purchases of complete aircraft do not produce jobs or technological spin-offs for the acquiring countries (though this may be partly overcome by the use of offsets in the contract that require the seller to accept payment in the form of goods produced by the buyer). Finally, the acquiring country will usually have a limited capacity to produce spare parts for an imported aircraft or to modernize its systems, resulting in long-term dependence on the seller in order to keep the aircraft flying or to update an older aircraft's systems. This can be problematic if the seller's economy goes through a major transition (note, for example, India's difficulty in acquiring spare parts for its Soviet aircraft following the breakup of the Soviet Union) or if changes in political relations make the supplier unwilling to continue to provide spare parts and maintenance (compare Iran's U.S.-built McDonnell-Douglas F–4, Northrop F–5, and Grumman F–14 aircraft following the Iranian revolution in 1979). Variations on the "buy" option such as coproduction are discussed later in this study.

Build

The pure "build" option requires planning, designing, and producing the desired fighter system utilizing only indigenous knowledge and production facilities. A developing country may invest significant resources in research and development (R&D) to build its domestic aviation technology production base. However, this requires a significant investment of both capital and human knowledge and presents large opportunity costs on both fronts. If a developing country seeks to push its aviation sector well beyond the technological development of its broader economy, this entails costly efforts with limited broader payoffs as scarce engineering talent and resources are focused on narrow military applications. If a developing country tries to push the overall technological capacity of the broader economy, this entails a much longer time period before improvements spill over and raise the technological level of the aviation industry.

The chief advantages of indigenous development are that a developing country can master the technologies required to design and build a fighter, limit its reliance on imported parts and technologies (and thus its potential vulnerability to a cutoff that might limit combat readiness), and diffuse some benefits of aircraft R&D and production into the broader economy (in the form of jobs and technology spin-offs). Over time, indigenous production can lay the foundation for a domestic aviation industry capable of designing, producing, and potentially exporting complete fighter aircraft.

The disadvantages are that a developing country's aviation industry may only be able to produce low-quality aircraft with limited combat capability, that large technological hurdles and a high learning curve must be overcome to establish an advanced aviation industry, and that the long period required to learn to develop and produce a modern fighter may yield aircraft that are obsolete before they are fielded. There is also no guarantee that investments in aviation R&D and production capacity will pay off. Few defense projects historically have been more costly, slower, or more prone to unforeseen difficulties than those undertaken to produce new fighter aircraft.[5] It is possible for a developing country pursuing the economic and technological spin-offs from indigenous design and production to spend much more than it would have cost to buy an advanced fighter from a foreign supplier, only to wind up with an inferior aircraft. Japan's F–2 fighter provides a good illustration.

Steal

A developing country can use surreptitious means to steal design and technology information on aircraft and aircraft components that it lacks the knowledge to design and produce domestically. This can be accomplished using covert procurement (often through third countries), traditional espionage methods, or computer network intrusion methods to exfiltrate the desired information. Individuals with access to information on classified weapons systems are prime targets of foreign intelligence organizations. Cyber espionage attacks against U.S. targets including military/government organizations and defense contractors have reportedly been successful in obtaining sensitive, though not classified, data.[6] The "steal" option can be used to gain blueprints or examples of weapons to use in reverse engineering a subsystem or to develop countermeasures that make a threat aircraft less effective in combat.

The principal advantage of the "steal" option is the potential to acquire advanced systems or technologies that other countries are unwilling to sell. In some cases, espionage can allow a country to acquire advanced technology without spending funds on its own research and development. The disadvantages include a developing country's limited ability to absorb or replicate stolen systems and technologies without technological support from the manufacturer, the haphazard and potentially incomplete access to systems and technologies through clandestine or surreptitious means, and the potential for espionage to send a country's aviation industry down a blind alley. In discussing the degree to which China has employed the "steal" option, we should differentiate its comprehensive efforts to collect and assimilate open source defense information (for example, through the China Defense Science and Technology Information Center) from its efforts to obtain restricted technologies covertly, by way of either traditional or cyber espionage. Exploiting the volumes of technical open source information produced in developed countries is an effective, legitimate, and predictable way to acquire knowledge.[7]

Of these three main avenues to technology procurement, the "build" option is the only one with the potential to stimulate innovation and create a broad-based domestic aviation industry from a low initial starting point. The United States and Russia produce the world's most complex fighter aircraft and, although they gained the ability in the midst of different economic and political circumstances, both were only able to reach this status through the ability to develop new technologies. Simply buying fighter aircraft from another country, with no plans to reverse engineer or coproduce, does not help a developing country move toward self-reliance. The steal option can have benefits if a developing country is able to obtain the information it needs without having to expend the necessary resources on R&D. However, simply possessing a blueprint does not guarantee success in reproducing the design, especially for a developing country with a limited aerospace production capacity.

Hybrid Approaches: Reverse Engineering, Coproduction, and Codevelopment

Hybrid approaches blend elements of buy, build, and steal in different combinations. This section considers reverse engineering, coproduction, and codevelopment as means of developing and acquiring aviation technology and building an advanced military aviation industry.

Reverse Engineering

Reverse engineering is the process of acquiring an aircraft, weapons system, or component and then taking it apart to understand how it works and potentially how to replicate or defeat it. The initial acquisition may be done through legitimate purchase (buy) or covert procurement (steal). Successful reverse engineering requires a certain level of technological sophistication in a country's aviation industry (for example, some degree of "build" experience and capacity).

Reverse engineering can serve several functions. Disassembling a mechanical or electronic device reveals its inner workings, yielding understanding of how it functions, the specific technologies and components involved, and identifying successful design paths that can be emulated. It may be possible to replicate the system or component by producing an exact clone of an aircraft component or weapons system. The knowledge gathered from reverse engineering may be incorporated into a newly designed subsystem that bears some resemblance to the original but is not an exact copy. As in the case of the "steal" option, a developing country might use reverse engineering to gain understanding of an aircraft's weapons systems or radars so that it can develop effective countermeasures. Developing countries often assume that reverse engineering can help accelerate development in certain sectors of the economy.[8] Examples of weapons reverse engineering do not validate this assumption in each case but rather suggest that success depends on a number of country-specific factors.

Developing countries sometimes attempt to purchase a small number of sophisticated fighters or advanced components from another country for the sole purpose of trying to reverse-engineer them in order to produce copies or gain knowledge about the component parts. (China was notorious for its efforts in the 1980s and early 1990s to purchase small quantities of advanced fighters and aviation components.) If a country is able to purchase small quantities and successfully reverse engineer them, the savings in development time (compared to completely independent development) and money (compared to a purchase of large quantities of aircraft or components) may be significant. However, this runs counter to the seller's best interests. Advanced arms suppliers such as the United States or Russia have no motivation to sell a small number of fighter aircraft to a country with the industrial capacity to copy them. A more usual variant can occur when a developing country procures a large quantity of an aircraft and then attempts to reverse engineer parts and components to reduce its dependence on the original seller for spare parts. (Both India and China have often pursued this approach.) This option is often explicitly banned by the sales contract, but the buyer may have a limited capacity to enforce these provisions once the sale is complete.

A developing country may also use covert procurement through a third party in order to acquire access to small quantities of an aircraft or component. An ally with legitimate access to advanced fighters or aviation technology may act as a "cut out" and either sell or turn over a working example of the aircraft for reverse engineering purposes. One widely cited example is the assumption that Pakistan, which purchased F–16 fighters from the United States, may have provided China with access to F–16 fighters and components. It is impossible to definitively determine the extent of access China may have had to Pakistani F–16s in the 1980s, but sources claim that Chinese technical personnel visiting Pakistan in the early 1980s were allowed to examine the U.S.-made fighter.[9] China may also have obtained some access to F–16 technology through its defense cooperation with Israel.[10]

In some cases, a country may be able to acquire an adversary's military hardware as a result of serendipitous circumstances, such as cases where a pilot loses his way in bad weather or defects with his aircraft.[11] For example, during the second Taiwan Strait crisis in fall 1958, the United States equipped Taiwan's F–86F Sabres with the AIM–9 Sidewinder infrared (IR)-guided air-to-air missile (AAM). On September 28, 1958, an F–86F fired and hit a PLAAF MiG–17 with a Sidewinder that lodged in the MiG's fuselage without exploding. The Soviet Union convinced China to turn over the unexploded missile and successfully reverse engineered it as the K–13. Soviet engineer Gennady Sokolovskiy described acquisition of the Sidewinder as, "a university offering a course in missile construction technology which has upgraded our engineering education and updated our approach to production of future missiles."[12]

The biggest benefit of reverse engineering is that a developing country can sidestep some of the R&D investment required to develop advanced weapons technologies. Unlike the pure "buy" option where a developing country merely operates the system it purchases, reverse engineering can lead to significant technical discoveries that propel a nation's defense industry forward. (The Soviet effort to reverse engineer the AIM–9 Sidewinder AAM is one such instance.) This is not always the case, however. Reverse engineering might allow for better understanding of a complex piece of military hardware, but there is no guarantee that a country can produce an exact clone or functional equivalent. Individual components may incorporate materials or be produced using advanced production processes that cannot be easily replicated by a developing country's aviation industry. (This was initially the case with composite materials and stealth aircraft designed using advanced computer systems, and remains the case for some materials used in high-performance jet engines.) Fighter aircraft present a particular reverse-engineering challenge because of the vast number of complex subsystems (for example, radars, avionics, and engines) that must be integrated into a functional whole. A developing country may obtain access to an advanced fighter, but lack the production capacity to reproduce it. A developing country may be able to reverse engineer and replicate key components, but lack the design skills to integrate them into an existing aircraft.

Coproduction and Codevelopment

The terms *coproduction* and *codevelopment* are sometimes used interchangeably. For the purposes of this paper, *coproduction* refers to a contract where the supplying country sells the purchaser the right to produce copies of a complete aircraft or key components. Coproduction deals can range from assembly of imported complete knock-down (CKD) kits with all necessary components to transfer of blueprints, machines, technical assistance, and relevant production technologies that give the purchaser an independent capability to build complete aircraft from scratch. *Codevelopment* refers to cooperation in the design stage of aircraft development where two or more countries work as partners.

Technology transfer and how expensive research and development costs are allocated are the principal issues in coproduction or codevelopment projects. The country with the more advanced industry has the motivation to withhold technical details from partners to protect its competitive advantage; the country with the less developed aviation industry typically has to agree to pay a premium price in order to gain access to relevant production (in the case of coproduction) or design/systems integration expertise (in the case of codevelopment).

Developing countries often seek coproduction arrangements as a means of starting an aviation industry or improving the technological capacity of their existing industry. The developing country typically seeks the maximum possible transfer of design information and production technology to allow fully independent production. Unless suppliers have a strategic reason for wanting to build up the recipient country's defense industry, they typically seek to retain control over key design information and production technology and prefer to supply components for assembly rather than give the purchasing country an independent production capability. The exact nature of the deal is often a function of the relative bargaining power of the parties involved. Coproduction usually involves a licensing agreement stipulating the number of systems the producer country can build at an agreed upon cost.

As a technology procurement strategy, coproduction is basically a combination of "buy" and "build." The developing country typically assembles aircraft from imported parts (often in the form of a complete knockdown kit) rather than producing them from scratch, at least initially. Contracts sometimes allow replacing imported components with indigenously produced components as the purchasing country's aviation industry gains the ability to successfully produce them. Developing countries sometimes evade contractual restrictions by using knowledge gained in the production process to design compatible subsystems or components that can either be integrated into an existing aircraft or that can be part of an improved variant of an existing aircraft. Because the supplier often provides knowledge about how to assemble the aircraft rather than complete design information, the buyer country still has a fair amount of work to do if the goal is to reverse engineer an exact clone or to develop an improved variant incorporating indigenous subsystems.

The nature of defense cooperation between countries is a good indicator of the overall political relationship. Coproduction agreements imply a basic level of political trust between partner countries. A supplier country will not enter into an agreement to sell a developing country the rights to build a fighter aircraft if there is a fundamental divergence of strategic interests or if the purchasing country poses a significant security threat. Coproduction is less of a risk than codevelopment to the supplier country from a technology procurement perspective because it does not usually grant the purchaser access to state-of-the-art aircraft or subsystems. As the next section will detail, China relied on coproduction with the Soviet Union in the 1950s to launch its military aviation industry and on coproduction deals with Russia in the 1990s to improve its capability to build advanced fighter aircraft.

Codevelopment in aircraft design implies that both partners possess a relatively well-developed aviation industry. The partners typically share the costs of R&D efforts; partners with less advanced aviation industries typically pay a premium price or commit to purchase significant quantities of the finished aircraft in order to gain access to advanced technologies, design processes, and systems integration expertise. In some cases, codevelopment will produce new technologies and intellectual property that will be shared by the partners.

A good recent example of codevelopment involves the joint venture between Russia's United Aircraft Corporation (UAC) and India's Hindustan Aeronautics Limited (HAL) to develop a fifth-generation fighter.[13] The work is split on a 75–25 percent basis, with Russia contributing the larger share.[14] "Codevelopment" is also sometimes used to describe projects where parties contribute to development costs without participating in the actual work. From a technology procurement standpoint, this is much closer to the "buy" avenue than to coproduction or codevelopment.

The F–35 Joint Strike Fighter program is an example of an unequal codevelopment partnership where a number of countries contributed financial support and committed to purchasing the aircraft without any involvement in development work.[15] The United States and Britain have carried out the vast majority of technical development work, with Italy making minor contributions.[16] The other six partners (Netherlands, Turkey, Australia, Canada, Denmark, and Norway) have bought into the project by contributing development funds and agreeing to purchase a specific number of F–35s. True codevelopment implies not just cost sharing, but shared ownership of the intellectual property generated by the project.

The decision to codevelop a fighter aircraft can be motivated by different circumstances but the logic in forming joint partnerships is the same: both countries benefit more through codevelopment than they would by working alone. Defense industries can share the substantial burden of R&D costs while bringing their technological comparative advantages to the fore. Perceived economic, political, and strategic benefits drive the decisionmaking process, with the relative importance of each depending on the relationship, political situation, and threat perceptions of the partner countries.

The UAC/HAL joint venture between Russia and India illustrates the complex economic and geopolitical pressures that drive defense technology decisionmaking. India was an end user and coproducer of Soviet military aircraft since a cooperative defense relationship was established in the early 1960s.[17] The relationship persisted throughout the Cold War, and after the Soviet Union dissolved, India helped Russia's defense industry stay afloat in the 1990s.[18] The plan to codevelop a fifth-generation fighter was hatched at a time (2000) when the dire Russian economic situation gave India a significant degree of bargaining power.[19] If not for economic necessity, Russia might never have proposed a codevelopment deal given the major step forward it provides the Indian aerospace industry.[20] Some Russian defense industry experts have been skeptical about the value India will bring to the project, citing Russia's half century of experience designing award-winning fighter aircraft.[21] Indian media reports have highlighted HAL's potential contributions in aircraft body design through its work on composites gained during the design of its indigenous Tejas Light Combat Aircraft (LCA).[22] Russia has designed mostly metal aircraft and thus lacks experience with composites. HAL will also design the mission computer, navigation, and countermeasure dispensing systems, and critical software.

PLAAF Technology Procurement Strategies: Past, Present, and Future

How have the pros and cons of the potential methods of building or acquiring military aircraft and aviation technology described above affected Chinese decisions about whether to "Buy, Build, or Steal"? This section briefly develops a concise model of a developing country's decision calculus, and then applies that model to explain Chinese choices over the period from 1949 to the present. We organize the analysis into five distinct periods defined by Chinese economic and technological capacity and the sources of foreign aircraft and aviation technology available to China at a given time.

The model we develop involves four factors. The first is the level of development of the overall Chinese economy, which defines China's general technological capability. The level of overall development constrains the indigenous technological capacity of China's aviation industry and defines the potential for China to "spin on" technologies from the civilian sector to the military sector. The second factor is the technological capacity of the aviation sector. The level of development of the overall economy constrains the indigenous capacity of the aviation sector, but it is possible to use foreign assistance and imported technology to build advanced capabilities in the aviation sector that surpass those in the broader civilian economy. To the extent that advanced fighter aircraft require technologies that do not have civilian applications ("single-use

Four Factors in Chinese Military Aviation Technology Procurement Calculus

Development level of overall Chinese economy	Technological capacity of Chinese aviation sector	Willingness of foreign suppliers to transfer technologies	China's relative bargaining power vis-à-vis foreign suppliers

technologies"), the military aviation sector must be ahead of the overall economy in some specific areas if indigenous production is to be an option.

The third factor is the willingness of foreign countries to sell advanced military aircraft, key components and armaments, and related production technology. Who is willing to sell to China and what aircraft and aviation technologies they are willing to sell define the available options in terms of purchasing ("buy"), coproduction, and codevelopment. The fourth and final factor is China's bargaining power vis-à-vis potential sellers of aircraft and aviation technology. This can be influenced by ideological and security factors (including the seller's calculus about whether China represents a potential ally or a potential threat), the health of the potential seller's overall economy and defense sector, and supply and demand within the broader military aviation market (for example, whether it is a "buyer's market" or a "seller's market"). Bargaining power influences whether potential sellers are willing to sell their most sophisticated fighters and whether they are willing to transfer production technology or consider coproduction or codevelopment deals. Sellers generally prefer to sell complete aircraft and spare parts (to maximize profits, maintain control of the supply chain, and limit potential competition) while buyers often want technology transfer and coproduction arrangements which provide employment opportunities and reduce their dependence on the seller.

We divide the time under examination into five periods. The first, from 1950 to 1960, is the period of Sino-Soviet defense cooperation. The Soviet Union's willingness to sell aircraft, designs, and production technology provided the foundation for China's modern defense aviation industry. At the same time, the United States and Western countries used a trade embargo and export controls to ban the sale of military aircraft and military technology. The second period is marked by the Sino-Soviet split and the withdrawal of Soviet advisors and technicians from China. With the Western embargo continuing, China was essentially cut off from legitimate access to military aircraft and related technology from 1960 to 1977. The third period, from 1977 to 1989, was marked by increasing Chinese access to Western commercial technology, including selected military systems, components, and technologies. Access to Eastern bloc technologies, which lagged behind Western systems but were more compatible with China's existing industrial base, remained very limited. China's cooperation with Israel on fighter aircraft began

Five Periods of Chinese Technological Development

1950–1960	1960–1977	1977–1989	1989–2004	2004–Present
Sino-Soviet defense cooperation	Chinese isolation	Window of access to Western technologies	West cuts access, Russia reopens; diversification of strategies	Russian reluctance; increased indigenous capacity

during this time.[23] The fourth period, from 1989 to 2004, is characterized by the U.S. and European ban on military sales to China following the Tiananmen incident in June 1989 and the gradual opening of the window for arms sales and technology transfers from the Soviet Union and its successor states. Western countries sought to limit the transfer of military and dual-use technologies to the Chinese defense industry, but the Chinese commercial sector gradually gained access to increasingly sophisticated civilian and dual-use technologies for commercial applications. Despite efforts to use end-use certificates and inspections to monitor where dual-use technologies were employed, many of these technologies could eventually be "spun on" to defense production.

The fifth period, from roughly 2004 to the present, is marked by Russia's growing reluctance to provide China access to its most advanced military fighters and production technology as Russian economic recovery increased Moscow's bargaining power and control over the Russian defense industry. Despite China's efforts to persuade the European Union to lift its arms embargo, access to Western military aircraft remained denied. However, some European countries did sell China components and technologies that could be employed in military aircraft.[24] At this time, Israel, under heavy U.S. pressure, cancelled a deal to upgrade unmanned aerial vehicles (UAVs) it had previously sold to China (having cancelled an earlier project to upgrade Chinese airborne early warning aircraft in 2000).[25] Although Chinese access to state-of- the-art military technology remains limited, the Chinese aviation industry made significant strides in absorbing foreign technology and demonstrated the ability to reverse engineer the Su-27 Flanker (as the J–11B) and to serially produce its own fourth-generation fighter (the J–10). It was also recently discovered that China is farther ahead in the development of its fifth-generation stealth fighter (the J–20) than many foreign sources anticipated.[26] Overall, China's level of economic development has advanced significantly, and its civilian industry has enjoyed significant access to state-of-the-art commercial (and sometimes dual-use) technology.

The Era of Sino-Soviet Defense Cooperation (1950–1960)

Buy	MiG–15*bis* (1951)	MiG–17 *Fresco-As* (early 1950s)	Il-28 bomber (early 1950s)	
Coproduce	4 Core Aviation Enterprises established with Soviet assistance (1952–1954)		Shenyang J–5: Chinese MiG–17F (1956)	J–6 rejected by PLAAF due to poor quality workmanship (1959–1960)
Build			JJ–1 trainer: 1st indigenously developed military aircraft (1958)	CJ–6 fighter trainer (1960)

In the aftermath of the Communist takeover and the establishment of the People's Republic of China (PRC) in 1949, the Chinese economy's level of development was relatively backward. Some pockets of industry employed modern technologies, but China was still predominantly a rural economy with limited industrial capacity. Given its limited technological base, China essentially had no ability to indigenously produce military aircraft. The first armed air contingent (and precursor to the PLAAF), the Nanyuan Flying Group, operated an assorted collection of around forty aircraft captured from the Nationalist air force.[27] There is no sourced record of the fighters operated by the short-lived Nanyuan Group, but they likely included U.S.-built Curtiss-Wright aircraft like the Hawk 75M, 75A–5, and CW–21, as well as the Soviet Polikarpov I–15bis and I–16, all operated by the Nationalist air force in the war against Japan. It is estimated that at the time the PLAAF was officially founded in late 1949, it had approximately 115 ex-Nationalist aircraft, though some sources place its strength approximately 40 percent higher.[28] Several dozen of these were not obtained until near the end of the Chinese civil war, when the Nationalist air force began to experience frequent uprisings and pilots defected to the Communist side along with their aircraft.[29] The Soviet Union soon augmented China's air force with an additional 434 aircraft and sent 878 experts to seven flight schools that had recently been approved by the Central Military Commission (CMC) of the People's Liberation Army.[30] Chinese involvement in the Korean War led to the rapid expansion of the PLAAF in terms of both equipment and capable personnel. By 1953, the last year of the war, there were 13 air force schools which had trained nearly 6,000 flight crew members and 24,000 maintenance personnel to service 28 PLAAF air divisions (around 3,000 aircraft).[31]

From the outset of Sino-Soviet defense cooperation, Moscow had considerable bargaining power vis-à-vis China, which had no alternative source for advanced military technology. Trade agreements that allowed for the transfer of technology boiled down to what Chinese Premier Zhou Enlai described as "selling agricultural products to buy machines."[32] In a conversation with Indonesian President Sukarno, Mao Zedong gave a candid assessment of the Chinese economy circa 1953 saying, "Frankly speaking, we haven't got a lot of things to export apart from some apples, peanuts, pig bristles, soy beans."[33] Despite this imbalance, the Soviet perception of China as a fellow Communist state and natural ally led Moscow to view a Chinese capacity to produce military aircraft as an asset in the Cold War against the West. As a result, the Soviet Union did not fully employ its potential leverage and provided the PLA Air Force with its first jet fighters and the Chinese aviation industry with its first capacity to produce modern jet fighters. So keen, in fact, were the Soviets to bring China online that some Chinese armament producing plants were turning out sophisticated weaponry before the Soviet defense industry itself could.[34] The decision to allow China to coproduce sophisticated fighter aircraft was part of the larger effort to transform it quickly into a capable, self-sufficient defense partner.

Archives maintained by the Communist Party of the Soviet Union Central Committee (CPSU CC) assert that ten thousand "specialists" were sent to China in the 1950s, but there is no corresponding record of who these specialists were, where they went, or how long they stayed.[35] It is clear that from the early 1950s the Soviet Union committed a massive amount of resources to build up Chinese industrial enterprises, with special attention given to the defense industry. The initial agreement pertaining to military aviation, signed by Stalin and Chinese Premier Zhou Enlai in October 1951, laid out the terms under which the Union of Soviet Socialist Republics (USSR) would render technical and repair assistance as well as construct new factories for the manufacture of aircraft.[36] This agreement was reached against the backdrop of the Korean War. In 1954, Moscow issued another memorandum to the People's Republic of China outlining cooperation on 15 new defense enterprises.[37] The Soviets agreed to perform design work, deliver equipment, and provide technical support for the fledgling enterprises. It is no exaggeration to say the Soviets helped China build a military aviation industry essentially from the ground up.

After a protracted civil war, which resumed after 7 years of Japanese occupation, China was left with almost no means to produce military aircraft indigenously. Several years after the founding of the PRC, China's nascent defense industry lacked the capability to produce advanced Western designs, or even to absorb Western technology into its Soviet-designed fighters, making the steal option impractical even if China could gain access to controlled Western designs and technologies. Initial purchases of Soviet fighters and aggressive pursuit of coproduction arrangements were logical responses to this set of constraints and opportunities, despite the implicit dependence on continuing access to Soviet designs, spare parts, and technical assistance. The massive infusion of Soviet personnel and equipment enabled China to design and produce several prototypes of its own fighter trainer (based largely on Soviet designs) by 1960, and to coproduce Soviet fighters, bombers, and transport aircraft throughout the 1950s.

China's leadership assessed the technical challenges implicit in licensed coproduction of Soviet aircraft and incorporated conclusions in the first five-year plan for the development of the aviation industry. The plan anticipated China's heavy reliance on the USSR to get the core enterprises that would form the backbone of military aviation up and running, but the end goal was for China to independently manufacture advanced Soviet aircraft within 3 to 5 years of facilities coming online. Four main production plants were established in the early to mid 1950s: the Nanchang Aircraft Factory, Shenyang Aircraft Factory, Zhuzhou Aero Engine Factory, and the Shenyang Aero Engine Factory.[38] Once these core enterprises were established, the emphasis shifted to manufacturing components. Construction of the Xian Aircraft Accessory Factory, Xinping Aviation Electronic and Wheel Brake Factory, and the Baoji Aviation Instrument Factory began in 1956. During the era of Sino-Soviet cooperation, these seven enterprises formed the core of China's military aviation industry. Though the degree of direct Soviet assistance varied by factory, the USSR was instrumental in the development of each.

Metallurgy in China prior to the 1950s was not suitably advanced for the production of advanced aero engine materials, which rely on the mastery of high temperature alloys including steel-titanium and aluminum-magnesium alloys. The PRC government made the development of high temperature alloys a priority for the Ministry of Metallurgical Industry.[39] Joint efforts of the aviation and metallurgical industries led to development of China's first high temperature alloy in 1956. A great deal of labor resources were devoted to this task, enabling the PRC to produce its first turbojet engine, the WP5.[40] Conversion from the WP5 to the next generation WP6 turbojet proved difficult, first due to technical differences—the WP6 had 2,521 parts, 46 percent more than its predecessor[41]—making it impossible to use the same production lines, and second, due to the chaotic work conditions resulting from the Great Leap Forward. Performance standards were not met when the WP6 underwent initial testing in 1958. It was not until 1963 that the engine was finally approved and paired with the J6.

China's first indigenously produced military aircraft, the CJ–5 trainer manufactured at the Nanchang Aircraft Factory, made its first successful test flight on July 11, 1954. The CJ–5, which was built around the M–11 powerplant produced by the Zhuzhou Aero Engine Factory, was a nearly exact copy of the Soviet Yakovlev Yak–18 fighter trainer. Based on ambitions laid out by China's military leadership to transition from repairing aircraft to manufacturing complete designs in 3 to 5 years, domestic production of the CJ–5 was ahead of schedule. The Shenyang Aircraft Factory was also able to produce its copy of the MiG–17 ahead of schedule. Originally slated for completion at the end of 1957, the J–5 fighter, powered by the domestically produced WP5 engine, made a successful test flight on July 19, 1956.[42] Coproduction of the J–5 went relatively smoothly, with the Soviet Union providing two MiG–17 pattern aircraft, manufacturing documentation, and 15 complete knock-down kits to the Shenyang Aircraft Factory. Over its 14-year production run from 1955 to 1969, the Chinese military aviation industry produced 767 J–5/J–5A fighters, first at the Shenyang Aircraft Factory (SAF) and later at Chengdu State Aircraft Factory No.132 (later Chengdu Aircraft Industry Group), which was established with the help of Soviet technicians in 1958. Around the time China successfully tested the J–5, preparations were underway for the first Chinese-designed and -produced fighter aircraft. This project culminated in the JJ–1 jet fighter trainer, which was test-flown in the summer of 1958. Although the JJ–1 met PLAAF inspection standards, it was not serially produced. Military planners opted for an alternate Chinese-designed fighter trainer, the CJ–6, which was tested successfully in 1960 and serially produced up until the mid 1980s.[43] Indigenous modifications made to the CJ–6 were meant to improve upon its predecessor, the CJ–5; itself a copy of the Yakovlev Yak–18 fighter trainer.

The J–6, based on the more sophisticated MiG–19P,[44] was the first Chinese-produced supersonic fighter.[45] Manufacturing rights for the MiG–19P were transferred in 1957, and in 1959 Moscow agreed to license coproduction of the MiG–19PM and S. As the Great Leap Forward began to affect China's industrial enterprises, the production quality of the J–6 rapidly declined. Rules and regulations adapted from the Soviet model were cast aside and "an unhealthy tendency of neglecting quality while pursuing quantity" appeared.[46] Soviet assistance was still available during initial production of the J–6 but China chose to manufacture the necessary tooling and assemble the aircraft without outside help. The end result was a large number of J–6 fighters produced in the period 1958–61 that were of such poor quality that they were not delivered to the PLAAF and PLA Navy Air Force. Performance appraisals of the J–6 that appear in the Chinese literature for this time period are unduly optimistic given SAF's inconsistent production record.[47] Although it had yet to master independent MiG–19 (J–6) production, China nevertheless sought access to more advanced Soviet fighters. In the last deal before the Sino-Soviet split ended all defense cooperation, Moscow licensed production of the MiG–21F–13 to China in 1961.[48] China received three pattern aircraft, as well as 20 kits, but did not take possession of all relevant technical information before defense cooperation ended in 1962. The MiG–21 served as the template for China's long running J–7 fighter program which began in the early 1960s.

Moscow also provided the PLAAF with a fleet of modern bomber aircraft. China took delivery of the Ilyushin Il-28 tactical bomber beginning in the early 1950s. A repair shop to service the Il-28 was set up in Harbin, but China did not receive licensing rights to coproduce the bomber before Soviet advisors were withdrawn in July 1960. China later reverse engineed the Il-28 and produced it as the It-5.[49] The Soviet Union licensed production of its state-of-the-art Tupolev Tu–16 Badger bomber in 1957, supplying China with two production aircraft, a semi knock-down kit, and a complete knock-down kit.[50] Soviet technicians and engineers were on hand to set up serial production of the aircraft the Chinese designated H–6 (or B–6) at factories in Harbin and Xian. The Xian factory was built specifically for production of the H–6 and was facilitated with help from over 1,500 skilled industry workers transferred from the Shenyang Aircraft Factory. H–5 repairs were already being made at the Harbin location, but serial production of the H–6 required a doubling of floor space and an expansion of the work force with experienced Shenyang workers.[51] Although Moscow granted China access to the latest fighter and bomber technologies—even allowing Beijing to produce copies of the MiG–17's Klimov VK–1F and Tumansky R–9BF–811 turbojet engines—the Soviets withheld the transfer of key technologies that would have allowed China to build a long- range strategic missile force.

While it had access to Soviet assistance China's military aviation industry made steady, quantifiable progress on almost every front. In addition to mastering production of several fighters and bombers, the PRC also began to form a research and development infrastructure meant to advance the end goal of self-reliance. In 1956, Mao Zedong called for a "march towards modern science," which was embodied in a 12-year development plan directed by Zhou Enlai, Chen Yi, Li Fuchun, and Nie Rongzhen.[52] Advancing military aviation technology, particularly fighter technology, was one of five objectives in the plan. To this end, Chinese technicians constructed a transonic wind tunnel for testing jet body designs based on the Soviet AT–1. The Shenyang Aircraft Factory began construction in September of 1958 and completed the tunnel in March 1960.[53] Design and research institutes were established to build China's knowledge base in aerodynamics, thermodynamics, and avionics development, with a total of 19 research and design departments employing approximately ten thousand employees operating at the end of 1960.[54] Overall, military aviation in the 1950s was technologically advanced compared to most of the Chinese economy. Of the handful of countries able to produce modern fighters and bombers, China was the poorest and most backward in terms of other scientific development. This situation was indicative of the importance Mao placed on strengthening China's defensive capabilities (at great cost to other areas of development) as well as Soviet willingness to transfer the necessary set of technologies and know-how.

Sino-Soviet Split to the Reform Era (1960–1977)

Buy		50 Spey fan-jet engines from Britain (1975)	SA–321 Super Frelon helicopter from France (1977)
Coproduce	Chengdu J–5A: Chinese MiG–17PF (1964)	Spey fan-jet engine coproduction (1975)	Harbin H–6: Chinese Tu-16 bomber (1968)
Reverse Engineer	Harbin H–5: Chinese Il-28 bomber (1966)	Shenyang J–7: from incomplete MiG–21 production documents (1966)	Shenyang J–8 : based on MiG–21 airframe (1969)
Build			Shenyang/Tianjin JJ–6 (1970)

At the time of the Sino-Soviet split, China possessed a military aviation industry with fully operational production facilities, almost a decade of experience manufacturing advanced fighter and bomber systems, and a reasonably well-equipped air force modeled along Soviet lines. However the withdrawal of Soviet advisors and technical assistance in July 1960 and the intensification of the Sino-Soviet split in the early 1960s had major consequences for the PLAAF and the Chinese aviation industry.[55] As relations between China and the Soviet Union deteriorated, the PLAAF lost the option of buying new and updated Soviet fighters and the Chinese aviation industry lost access to technical support from Soviet advisors to help improve aircraft production and master key technologies. The Chinese defense industry would spend much of this period struggling to absorb and extend the technology it had acquired from its coproduction deals with the Soviet Union or reverse engineered from its Soviet aircraft.

In the wake of the Sino-Soviet split, China lacked a relationship with another advanced country to acquire cutting-edge military hardware. Western export controls focused on preventing exports of militarily relevant technologies to the Eastern bloc foreclosed the "buy" option. Even after China's rapprochement with the United States in 1971, it took a number of years before the United States and European countries were prepared to ease export controls on military technology, pursue arms sales, or engage in defense industrial cooperation. The one noteworthy exception was a 1975 agreement (negotiations began in 1972) whereby Britain supplied China with 50 Spey fan-jet engines; the powerplant used in British versions of the multirole F–4 Phantom (the RN F–4K and RAF F–4M), as well as the Vought A–7 Corsair light attack aircraft.[56] China was given full production rights and began trial manufacturing the Spey RB–168–25R as the WS9 at its plant in Xi'an. Under the terms of the agreement, Rolls Royce provided both manufacturing facilities and technical expertise involved with testing the Chinese-produced Speys. To date, the Xian JH–7 fighter bomber is the only PLAAF aircraft powered by a variant of the original Rolls Royce Spey or the Chinese-manufactured WS9.[57] While the Spey arrangement was not a direct transfer of weaponry per se, it involves a single-use technology applicable only to combat aircraft and should thus be considered a transfer of military equipment.

Political restrictions on importing military hardware from the West were further aggravated by the fact that very few Chinese citizens were permitted to go abroad (even Chinese diplomatic missions were withdrawn from most countries during the Cultural Revolution), making it difficult to access the sorts of restricted technologies worth stealing. Obtaining access to information about improvements in Soviet weapons systems from other members of the Eastern bloc and developing country customers would have been a logical approach, but little information is available about the extent to which China pursued this direction and what success it might have had.

These challenges were compounded by the massive social upheavals and the cumulative impact of the Great Leap Forward and the Cultural Revolution, which stymied development of the Chinese economy for a decade, limiting the ability of the Chinese civilian economy to produce technologies that the military could incorporate into weapons systems. Industrial output not related to the defense sector was severely affected by the Cultural Revolution as capable individuals with managerial and planning roles in key enterprises were branded bourgeoisie reactionaries and removed from their positions. The damage done in this respect had long-term consequences for many sectors of the Chinese economy. Despite efforts to protect scientists and engineers working on high-priority defense projects, chaos in the wider economy inevitably had a negative impact on China's aviation industry.[58]

Although the Central Military Commission ordered the aviation ministry to commence R&D programs on some 27 new types of aircraft in 1971,[59] in reality China's aviation industry had its hands full mastering production and extending the designs of Soviet fighters and bombers designed in the late 1950s. For example, the design of the J–7, (China's MiG–21 variant) was not finalized until more than a decade after its initial flight test in 1966 and it was not approved for serial production until 1979.[60] China's aviation industry eventually proved capable of absorbing 1950s Soviet aviation technology and by the end of this period had developed some limited design innovations (for example on the J–7/F–7) via reverse engineering efforts that went a step beyond copying. However, by the time the Chinese industry reached this point, both Western and Soviet air forces had moved on to more advanced fourth-generation aircraft that made China's most advanced aircraft effectively obsolete as soon as they rolled off the production line.

Coproduction

As previously mentioned, the Shenyang Aircraft Factory refused Soviet assistance on the J–6A and set out to manufacture the required tooling domestically.[61] These efforts were not particularly successful; production was halted at various times as the result of poor quality manufacturing and the PLAAF refused to fly the J–6A until improvements were made.[62] Under the guidance of SAF vice general secretary Wang Qigong and vice chief technician Luo Shida, a document was drafted outlining 10 standards to follow in the second series of J–6 prototype production.[63] With better quality control procedures in place, SAF was able to finally produce a J–6 prototype which met state standards for mass production in 1963. Once mass production was approved, the Nanchang Aircraft Factory (NAF) began manufacturing the J–6. This required NAF to convert from a propeller aircraft factory to one that produced jet fighters.[64]

Improvements to J–6 production quickly eroded with the onset of the Cultural Revolution. Aircraft designers and engineers were among the group of "intellectuals" targeted in the mass movement, and their marginalization along with a number of other technical issues plagued China's defense industries.[65] By the early 1970s, hundreds of substandard J–6s had to be dismantled and rebuilt (to the tune of millions of yuan).[66] Though the J–6 and J–7 represent the height of Chinese advancement in terms of the serial production of military aircraft during this time period, efforts continued to improve upon previous J–5, J–5A, and JJ–5 designs. These improvements were for the most part cosmetic (the lengthening of a fuselage, relocation of components, etc.) and though Chinese writings are sanguine about the progress made, there was very little in the way of actual innovation.

Bomber production made some modest advances during this period, with a domestically manufactured Xian H–6 medium bomber taking to the air on December 24, 1968, and serial production beginning shortly thereafter.[67] Efforts to produce the H–6 were delayed significantly by the withdrawal of Soviet advisors, but Chinese engineers were eventually able to use the plans and tooling to successfully produce the bomber. Chinese serial production of the H–6 was a notable achievement for the military aviation industry, but the aircraft was based on the Tupolev Tu–16 Badger, which had been in service with the Soviet air force since 1954.[68] The H–6 has remained China's mainstay bomber over the decades with modified versions of the aircraft comprising the bulk of the PLAAF bomber fleet even today.

Reverse Engineering and Independent Production

China received licensing rights for the MiG–21F–13 and its Tumansky turbojet engine, but transfer of other MiG–21 technical information ended with the Sino-Soviet split.[69] Despite incomplete information, China managed to produce various models of the J–7/F–7, as well as the Tumansky engine, in the 1960s and 1970s. Some variants featured limited upgrades and improvements. SAF had taken possession of several completed models of the MiG–21, along with a number of assembly kits before the USSR withdrew assistance. This provided a decent base to start from, though SAF only succeeded in producing upgraded J–7/F–7 fighters through intense efforts at reverse engineering.[70] The original J–7 experienced numerous teething problems before making its maiden flight in 1966, but was reworked and ultimately entered service with the PLAAF, and was exported as the F–7A. Both the Tanzanian and Albanian air forces operated this aircraft.

SAF later came out with the upgraded J–7I that featured a variable air intake with translating shock cone, an indigenous add-on developed due to missing information in the Soviet manufacturing documents.[71] The PLAAF operated the J–7I interceptor along its southern borders during the Vietnam War, where it shot down six U.S. combat aircraft that entered Chinese airspace.[72] The J–7 program demonstrates that although China was unable to design and produce its own fighters, it had mastered coproduction and reverse engineering well enough to produce reasonably capable (though by no means state-of-the-art) fighters without Soviet assistance. This production capability allowed China to produce F–6 (MiG–19) and F–7 (MiG–21) variants to customers seeking low-cost fighters. The J–6 export variant (F–6C) was produced from complete Soviet blueprints and with initial Soviet assistance.

Although China had not received a license to coproduce the Il-28 bomber, it ultimately decided to try to reverse engineer and independently produce the bomber as the H–5 (or B–5). As a result, China did not possess the same level of design information and Soviet technical support as with its fighter aircraft or the H–6 bomber. When the project finally began in 1963, there were some significant design alterations in the Chinese version.[73] Chinese-produced H–5 bombers did not enter service with the PLAAF until 1967.[74]

The result of forced reliance on indigenous production and reverse engineering was a PLA Air Force equipped throughout the 1960s, 1970s, and 1980s with large quantities of obsolete aircraft based on 1950s vintage Soviet designs that were all the Chinese aviation industry could produce. Although PLAAF leaders (and to some extent Chinese civilian leaders including Deng

Xiaoping) were aware of the extent to which China was falling behind advances in Western and Soviet military aviation technology, they had few options available to rectify the situation. In addition to limited access to international aircraft and aviation technology potential, the loss of Soviet support highlighted the importance of self-reliance in military technology for Chinese political leaders and reinforced the interest of key civilian and military leaders in building a defense industry capable of independently designing and producing advanced systems. The result has been an enduring tension between PLA leaders focused on equipping the military with technologically advanced systems (acquired from abroad if necessary) and civilian and defense industry leaders focused on the Maoist goal of building an independent, indigenous defense industry (even if the weapons it produced fell well short of state-of-the-art Western systems).

New Windows of Opportunity (1977–1989)

Buy	British firm GEC Marconi sells China advanced avionics for J–7II/F–7 fighters (1979)	French Dauphin 2 attack helicopter (1980)	U.S. "Peace Pearl" transfer of advanced avionics for J–8 fighters (1984)
Coproduce		France gives China production rights for Dauphin 2 attack helicopter (1980)	
Reverse Engineer	Chengdu J–7II: Based on MiG–21; indigenous add-ons (1978)	Chengdu J–7C: Reverse engineered from Egyptian MiG–21MF (1984)	Shenyang J–8A: Based on MiG–21 airframe (mid 1980s)
Build		China develops 1st indigenous fire control radar—Type 204 (1984)	

Deng Xiaoping's emergence as China's top leader and the initiation of economic reforms and opening in 1978 offered new opportunities for the Chinese economy generally, and for the defense industry in particular. An initial focus of the reforms was the Four Modernizations campaign (Agriculture, Industry, Science and Technology, and National Defense). Although defense was the last of the Four Modernizations and given lower priority than the first three, the strategies used to modernize China's national defense were consistent with the broader economic development strategy's emphasis on opening and reform. Creating a self-sufficient

Chinese national defense infrastructure based on a modern technology base had been a goal since the first five-year plan.[75] The pursuit of air superiority and the role the Chinese military aviation industry played in this pursuit took on a new level of importance once Deng became Chairman of the CMC in 1977.[76] After consolidating all top positions within the Chinese Communist Party (CCP) and becoming "paramount leader," Deng continued to develop his case for air power, stating to the CMC in January 1979: "Without the air force and air domination, winning a future war is out of the question. . . . Stress investment in the development of the aviation industry and the air force to ensure air domination."[77]

China's ten-year plan for developing both the national economy and the science and technology base was published on February 26, 1978.[78] The plan outlined many of the key elements necessary to produce modern military equipment: more raw materials, better understanding of modern scientific techniques, and access to foreign technology and production practices. China would increase trade by opening its economy, allowing foreign direct investment, and purchasing capital goods and technology from the developed world. Investment from abroad would be obtained by expanding China's export-oriented light industries (i.e., textiles, clothing, and handicrafts), which required low amounts of capital, could be rapidly established, and had "high foreign exchange earnings potential."[79] Earnings originating from light industries could then be recapitalized to continue expanding that sector, applied to the import of advanced foreign technology, or both. China was also in a position to leverage its ample energy resources to finance technology acquisition from abroad. This was the basis of an 8-year, twenty billion dollar agreement signed with Japan in 1978.[80] Casting military modernization in a subordinate role to the other three modernizations inverted Mao's "superpower" strategy, which stressed building national defense as the first imperative in elevating China to great power status. The more pragmatic reform-era leadership understood that national defense capability improved as a function of overall economic progress. Moreover, it realized that to achieve self-reliance in the long term, China would have to pursue the transfer of advanced foreign military and dual-use technologies in the near term.

China continued to refine its industrial policy throughout the 1980s, with the goal of developing a modern, science and technology–driven economy in the first half of the 21st century. Evan Feigenbaum notes the contributions of scientists involved with China's nuclear program in the 1950s and 1960s in crafting and pushing forward the set of policies establishing a new national development trajectory.[81] Prominent nuclear scientists like Zhang Jingfu and Song Jian were among a small group of Chinese technical personnel involved in Mao-era programs requiring "'scientific' decision analysis."[82] This gave them valuable experience organizing research and development to meet specific scientific objectives, and applying lessons learned in the process to other related areas. Observing the state of global technological innovation in the late 1970s and early 1980s led the group of scientists advocating China's new industrial policies to the conclusion that novel state-of-the-art technologies (semiconductors, integrated circuits) would be increasingly dual-use in nature and thus result in a "spin-on" paradigm.[83] Because commercial and military technologies would be inextricably linked in the future, China would have to reengineer its entire state R&D system and not focus solely on developing military technologies. The Chinese government's efforts to bridge the technology gap with Western military powers rely on spurring innovation, stressing market competition, and emphasizing civil-military integration (*Junmin Yitihua*) to create greater efficiencies. These policies seek to construct an effective dual-use technology base that can support both the civilian economy and the needs of the military.[84]

China's opening and reform efforts built upon its rapprochement with the United States and the West in the early 1970s. The primary impetus for rapprochement was strategic, but improved relations also created a favorable climate for China's economic reforms and, eventually, for defense industrial cooperation with Western countries. Mirroring the Soviet logic of the 1950s, the United States and other Western military powers sought to improve China's defense capability as a means of tying down the vast Soviet military. There was obviously not the same strong ideological affinity between China and the West that there had been during the Sino-Soviet partnership. There was, however, a mutual understanding that certain common objectives—namely, undermining Soviet power and influence—could be advanced by assistance to China's defense industry. China did not view the West as an ally per se, nor did the West expect a close defense relationship to emerge from new circumstances.

The strategic rationale for cooperation was paired with the realization by Western defense industries that significant profits might be available by selling arms to China and assisting in the modernization of China's backward defense industries. Continuing export controls and legal restrictions on the export of arms and advanced technologies to China also meant that cooperation expanded at a gradual, modest pace with considerable oversight by Western governments. On China's side, the opportunity to take advantage of new access to Western military aviation technologies clashed with the desire to build an independent aviation industry and Maoist concerns about self-reliance. As Lewis and Xue write, "The ensuing compromise restricted the definition of self-reliance to the outright purchase of aircraft, while extending the meaning of Deng Xiaoping's Open Door policy to permit the acquisition of foreign air-launched weapons and avionics."[85]

Buying, Coproduction, and Integration

China chose to pursue acquisition of armaments and avionics rather than outright purchases of Western combat aircraft (which Western governments would have been reluctant to allow). Helicopters were an exception to this general rule. In 1977, the French delivered the SA–321 Super Frelon helicopter to China, and allowed China to coproduce it as the Z–8 beginning in 1981.[86] France also agreed to let China coproduce its Dauphin 2 attack helicopter as the Z–9 beginning in 1980.[87] The earliest fighter technology transfers came in 1979, in the form of a license agreement between China and the British defense firm GEC-Marconi (now BAE avionics) to supply the J–7II tactical fighter, as well as F–7 export variants, with a complete avionics suite. This upgrade, which included the Type 226 Skyranger radar, weapons-aiming computer, and state-of-the-art display systems, represented a huge boost for China's military aviation industry. Chinese-produced F–7s with Western avionics sold well on the export market with the air forces of Sri Lanka, Iran, Myanmar, Bangladesh, and Pakistan all signing purchase agreements in the 1980s. The F–7s were not actually delivered until the late 1980s and early 1990s and many remain in service today. J–7/F–7 aircraft produced in the 1970s and 1980s with advanced avionics were an improvement over the J–6/F–6 series, but still lagged far behind Western and Soviet fourth-generation fighters that were entering service in the same time period.[88]

The Shenyang J–8A (a twin-engine MiG–21 derivative) was the most sophisticated fighter China operated in the late 1980s. Shenyang Aircraft Corporation (SAC)[89] proved that it could go beyond simply reproducing Soviet designs by modifying the MiG–21 airframe to accommodate the J–8A's two Wopen–7A turbojet engines. However, the derivative body design limited top speed to a "modest" Mach 2.2, making the J–8A slower than third-generation Soviet fighters like the MiG–23.[90] China sought to use its newfound access to Western avionics to improve the J–8A's combat capability. By the mid-1980s, China had developed its first indigenous fire control radar (Type 204), but this system lacked some state-of-the-art features embedded in Western and Soviet radar systems, most notably beyond-visual-range capacity. One of the four programs under the U.S./China "Peace Pearl" initiative launched in the mid 1980s involved the U.S. firm Westinghouse equipping 50 J–8 fighters with advanced, beyond-visual-range capable radar systems. Sanctions banning sale of U.S. arms to China were imposed in the wake of the 1989 Tiananmen massacre, but in 1992 President George H.W. Bush issued a waiver stating that it was "in the national interest" to fulfill the terms of four suspended weapons sales programs on the grounds that none of them "significantly" boosted Chinese military capabilities.[91] The waiver also stated that fulfilling these programs would "improve the prospects for gaining further cooperation from China on nonproliferation issues."[92] The PLAAF ultimately received two modified J–8 fuselages and four avionics kits to close out the "Peace Pearl" effort.

China also reportedly developed a variant of the J–8, the ACT control variant, which featured analogue fly-by-wire (FBW) controls. A working test bed was flown in 1988. The ability to produce an aircraft incorporating this technology is noteworthy given the fact that China had no legal access to it through Western or Soviet channels (FBW controls had been incorporated into new Western and Soviet fighters by the mid-1970s). Chinese military aviation had not mastered less challenging aspects of avionics development at the time the J–8ACT program was underway, and it is unlikely that the knowledge to produce FBW controls came about via indigenous R&D. There is no way to draw definitive conclusions about where China acquired the knowledge to produce this technology, but its defense relationship with Israel provides one possible answer. Development work on the FBW-capable Israeli Lavi fighter began in 1982 and by the time Sino-Israeli defense cooperation was established in 1984, the Lavi project was in full swing. A range of open source information suggests that Israel transferred advanced military aviation technologies to China long before formal diplomatic relations were established in 1992.[93]

Advances in Chinese military aviation from the late 1970s to the late 1980s came primarily as a result of exposure to more sophisticated Western aviation technologies and their integration into PLAAF aircraft. Access to the GEC Marconi radar and to FBW technology required Chinese technical personnel to perform design modifications necessary to accommodate these new systems. It also provided a starting point for reverse engineering efforts, though due to China's inexperience with Western production practices there was no guarantee of success. Despite newfound access to some state-of-the-art military hardware and innovations in airframe design, China's defense sector remained incapable of producing modern weapons systems.[94] Numerous deficiencies prevented China from turning out cutting-edge equipment. The issues it faced were specific to its system of economic and political organization, not merely the byproducts of central planning. (The Soviet case proves that an economy based on central planning can produce some of the world's most advanced military hardware.)

During the 1980s and 1990s, state-owned Chinese defense enterprises received cost plus 5 percent for all equipment produced, providing no incentive to cut costs or maximize production efficiency.[95] There was no competition to determine which enterprise would build which system. Enterprises were (and still are to some degree) assigned projects based on ministerial bargaining, nullifying a great deal of the incentive to turn out a better end product.[96] The story of this time period for the aviation industry is mixed: from an organizational perspective, the objectives articulated in the Four Modernizations campaign and attention to air power at the highest levels of leadership set a course for progress. On the other hand, the industry made almost no tangible progress in closing the technology gap with Soviet or Western air forces in the 1980s.

Three significant developments would come to shape the trajectory of Chinese military aviation in the next time period we analyze. First, there was the decision to emphasize the development and diversification of the overall Chinese economy via deeper market reforms. The initial impact on the defense industry was negative, as funding for the military was reduced and the defense industry was encouraged to convert to civilian production. Over the longer run, however, development of the broader economy produced both financial resources and access to technologies that would support a more advanced defense technology base. The second important event was the Sino-Soviet rapprochement. Soviet Premier Mikhail Gorbachev's visit to Beijing in May 1989 marked the official return of normal relations between the two sides and was eventually followed in the early 1990s by new arms sales agreements, including the sale of the Sukhoi Su-27 Flanker.[97] These deals were largely negotiated on Chinese terms, offering China the opportunity to pursue new procurement strategies. Finally, the Tiananmen massacre in June 1989 led to an immediate end of Chinese legitimate access to most Western arms and military aviation technologies.

New Partners, New Strategies (1989–2004)

The immediate Chinese leadership response to Tiananmen was a political clampdown and economic retrenchment, but by early 1991 economic growth had resumed and the stage was set for further economic reforms that would lay the foundation for sustained Chinese growth. Openness to trade and foreign investment helped the Chinese economy grow rapidly and develop a deeper civilian technology base. Although the United States and Western European countries sought to limit Chinese access to Western arms and military technology through export controls and sanctions, the lure of access to China's market ultimately gave China's defense industries access to considerable dual-use technology that could be "spun on" to military applications. Moreover, the rapid advancement of computer, communications, and material technologies in a globalized economy meant that technologies once used primarily in military industries became ubiquitous (and free from export controls).

The Chinese defense industry's access to advanced computers in the mid-1990s supported efforts to develop more sophisticated design capabilities. Supercomputers obtained from the United States after export laws were loosened in 1996 and 1998 were later used to simulate the detonation of nuclear warheads without actual underground testing.[98] China's shipbuilding

Buy	12x Su-27 *Flanker* (1992)	24x Su-27 *Flanker* (1995–1996)	80x Su-30MKK (2000–2001)	Ukraine sells China single Su-33 (2000)
Coproduce		Sino-Russian agreement for SAC to manufacture 200 Su-27s as J–11 (1996)	SAC masters coproduction of J–11 (2002)	
Reverse Engineer	Shenyang J–8D (1990)	Shenyang J–8F (2000)		
Steal		China begins reverse engineering Su-27 subsystems for use in indigenized J–11B (2002–2003)	Chinese cyber espionage efforts target information on foreign military aviation technologies (mid 2000s)	
Codevelop	Espionage emerges as technology acquisition strategy with increased Chinese presence abroad (mid 1990s)			
Build	China begins to develop indigenous 4th gen fighter (J–10); significant technical assistance from Israel (mid 1990s)	China develops JH–7 fighter/bomber with assistance of imported U.S. supercomputers (mid 1990s)		China violates terms of Su-27 contract with Russia; develops indigenized J–11B (2003–2004)

industry also made new advances enabled by computer-assisted design (CAD) technology to improve both the quantity and quality of maritime vessels.[99] The Xian FBC–1 fighter-bomber (also known as the JH–7) presents the most compelling example of U.S. supercomputer technology being used to expand Chinese military aviation capabilities. Designed to replace outdated light bombers like the Nanchang Q–5 and Harbin H–5, the development program for the JH–7 began in the 1980s. Six prototypes were developed in the early 1990s and delivered to the PLAAF and PLANAF for evaluation. An upgraded variant, the JH–7A, came out around 2000 and was the first Chinese aircraft based solely on CAD design. Chinese engineers reportedly bragged that the fighter-bomber was designed using supercomputers imported from the United States. The fact that Xian Jiaotong University houses a supercomputer and has ties to the Xian Aircraft Industry Corporation (XAC) and the 603[d] Aircraft Design Institute, the principal contractors on the JH–7A, may explain why CAD technologies were applied to the JH–7A rather than the more advanced J–10 fighter. In the wake of discoveries during the 1990s that China had diverted some supercomputers acquired from the United States for military purposes, Congress passed a law in 1998 tightening restrictions on the technology. China's indigenous efforts to develop its own supercomputers since the late 1990s have made the law (at least as it applies to China) somewhat irrelevant.[100] A 2003 report cites the twin seat J–10BS variant as the first Chinese fighter produced with CAD, noting that the software decreased the time it took to render design drawings from 10 to 6 months.[101] The fact this achievement was reported publicly does not contradict the conclusion that the JH–7 was China's first CAD-assisted fighter, but instead hints at the fact that the J–10BS was the first example of a military aircraft designed using domestically produced CAD technology. All subsequent Chinese military aviation development projects almost certainly utilize CAD.

Although China lost legitimate access to most Western defense technologies after Tiananmen, it continued existing defense technology ties with Israel and reestablished them with Russia. Ukraine also emerged as an important source of air-to-air (AAM) and air-to-surface missiles (ASM) for the PLAAF.[102] Unlike the previous Sino-Soviet defense arrangement where Beijing was dependent on Moscow and negotiated from a weaker bargaining position, the economically tumultuous post-Soviet Russian state was much more dependent on China as a buyer. This allowed China to gain access to both advanced fighters and aviation technologies that a more solvent Russian government likely would have preferred not to sell.

In response to these new opportunities, China pursued multiple options to advance military modernization. The PLA purchased limited quantities of advanced Russian aircraft, ships, and submarines in order to gain experience operating modern weapons systems. For the PLAAF, this included acquisition of the Su-27 fighter and the S–300 surface-to-air missile. The deal eventually evolved into a coproduction arrangement intended to produce 200 aircraft and then into efforts to reverse engineer key components to create an independent production capability. Chinese defense industries continued efforts to develop their own new systems, seeking to integrate advanced imported technologies and components into the design where Chinese equivalents were not available. The J–10 fighter, which uses Russian engines, is one such example. Chinese defense industries also sought to adapt imported and indigenous avionics and armaments to improve the capabilities of older platforms.

At the strategic level, in keeping with Deng's earlier pronouncements regarding the centrality of air power in winning modern wars, the Chinese began investing more time in related research. Academics and military strategists examined U.S. and Soviet theories on how to achieve maximum effect through the use of air power.[103] Beijing was realistic about the relative weakness of the PLAAF when measured against its U.S. and Soviet counterparts. While it assimilated air power strategy as conceived by the superpowers, China was equally interested in understanding how countries with qualitatively less advanced air forces could employ air power against more powerful opponents. Several works cite surprise attacks by the Argentine air force against British naval forces during the Falklands War as an illustrative example.[104] It was also during this time period that Chinese defense analysts and military planners began to translate the emphasis on expanded air power into concrete technology acquisition and procurement goals. In the early 1990s, the PLA was still operating under significant budget constraints; since the outset of opening and reform resources had been shifted to nondefense areas of the economy. Despite this situation, PLAAF planners mapped out a development trajectory for the air force which has been more or less followed: (1) phase out equipment based on antiquated technology; (2) place emphasis on aircraft quality over quantity; (3) graft, when possible, new technology (radar, avionics, missiles) onto older airframes to increase combat effectiveness and extend service life; and (4) focus on long-term self-reliance, while filling existing technology gaps in military aviation via procurement of foreign equipment/knowledge.[105]

In 1998, China undertook a massive restructuring of its defense industry with the aim of ensuring that the PLA was adequately involved in procurement decisions. Prior to creation of the General Armaments Department (GAD), the intermediary between the end user of weaponry (PLA) and the supplier (the defense industry) was the Commission of Science, Technology, and Industry for National Defense (COSTIND). This system resulted in a fundamental misalignment of interests as COSTIND failed to properly represent the needs of the Chinese military, instead allowing the weapons producers to advance their own institutional interests at the expense of the PLA.[106] The defense reforms of the late 1990s allowed the PLA, through the GAD, to take the lead in dictating procurement requirements based on actual need.[107] While the reforms did not specifically address resource competition among the service branches, they did provide a mechanism for the PLAAF to align procurement with its strategic development objectives. Leadership support for increased air power capability also helped the PLAAF advance its procurement agenda.

Buying, Coproduction, and Reverse Engineering

After Gorbachev's 1989 visit to Beijing, Sino-Soviet rapprochement was solidified by various arms sales agreements including the 1991 deal for China to purchase a dozen Sukhoi Su-27 fighters.[108] At the time, the Soviet Union had just collapsed and the new Russian economy was in a shambles. Strapped for cash, Moscow was ready to leverage the defense industry—one of the few performing sectors of the economy—in order to profit. China was quick to take advantage of the deteriorating situation in the early 1990s, getting Moscow to accept poor quality "barter goods" in exchange for weaponry.[109] Russia had little choice but to put longer-term strategic security concerns on the back burner and do what it could to keep its arms industry operational. To provide some idea of how important Chinese arms sales became to the Russian defense industry, a U.S. Department of Defense report estimated the value of weaponry delivered to China (not simply agreed upon) from 1990 to 2002 at between $7 and $10 billion.[110]

China took delivery of its initial order of 12 Su-27s in 1992, and an additional batch of 18 Su-27SKs and 6 Su–UBKs in 1995–1996. Altogether China purchased 48 Su-27 Flankers before deciding to build the aircraft domestically as the Shenyang J–11.

The J–11 story began in 1996, when Russian arms export organization Rosoboronexport signed a $2.7 billion licensing agreement with Shenyang Aircraft Corporation allowing coproduction of 200 Su-27s.[111] The agreement came with two provisos: that China would not export the J–11 and that the fighters would be fitted with Russian engines, radar, and avionics which would not be licensed for coproduction.[112] This important agreement, which moved China's military aviation industry from third-generation to fourth-generation production capacity, came about through the actions of the General Director of the Sukhoi Design Bureau, Michael Simonov, who negotiated the deal without Moscow's approval and later presented it to the Yeltsin government as a *fait accompli*.[113] Simonov (acting more in the interests of Sukhoi than the new Russian state) knew that forming a strategic partnership with China was the cornerstone of Yeltsin's Asia policy and that a reversal of the Flanker deal on Moscow's part might sabotage these efforts. The terms of the arrangement were finalized and SAC received manufacturing documents for the Su-27 in 1997 along with complete knock-down kits from which it assembled its first two J–11s. Although both fighters were test flown, they proved to be of such poor workmanship that Russian technicians were called in to rebuild them.[114]

During the first 3 years of production, SAC assembled just five J–11s. Over the next 3 years it quadrupled this number, turning out 20 aircraft by 2003. As SAC began to successfully produce its own replacement parts, the Russian supplier (KnAPPO) began to reduce the contents of the knock-down kits it provided. By 2002 China was not just coproducing the J–11, but doing it at a high level of quality—a remarkable development given that just 4 years earlier SAC could not even put the fighter together correctly without Russian technical assistance.[115] By late 2004, SAC had taken possession of all 105 CKD kits delivered from Russia and had managed to assemble and deliver 95 of those to the PLAAF. After mastering coproduction China quickly moved on to developing its own version of the J–11. Russia cancelled plans to fulfill the remainder of the order after discovering that China had an indigenous J–11 in the pipeline.[116] The 1996 agreement stipulated that China would equip its J–11s solely with Russian made engines, radar, and avionics, which left China dependent on KnAPPO. Russia had no objection to China producing replacement parts not related to engine, radar, or avionics; the violation occurred when it began to develop these three systems indigenously. By doing so, China ensured that it would not be reliant on Moscow for any component part of its J–11s. This presented the Russian aviation industry with a loss of future revenue and also presented the possibility that China would attempt to sell its J–11 on the international arms market. To date China has made no effort to export any J–11 variant, nor has it expressed any interest in doing so. Chinese officials justified the decision to violate the contract by claiming that the 95 Su-27s on order were no longer adequate to serve the needs of the PLAAF—an interesting claim given the large number of third generation J–8s still in service. China's decision to abrogate the terms of the Su-27/J–11 contract has had lasting consequences. Since 2006, Russia has refused to enter into any substantive military aviation transfer agreement. We discuss some of the repercussions for China in the next section.

It took 4 years to produce three prototypes of the J–11B multirole fighter, and another 2 years to build the twin-seat J–11BS variant. Sources in the Chinese defense industry report that the J–11B is based on roughly 90 percent Chinese-designed parts and subsystems, including the Type 1474 serial radar system, 3-axis data system, power supply system, emergency power unit, brake system, hydraulic system, fuel system, environment control system, and molecular sieve oxygen generation systems.[117] The J–11B/BS is also fitted with indigenous PL–12 air-to-air missiles. There have been several cases since 2008 of Russian authorities in the Transbaikal region arresting Chinese citizens for attempting to smuggle spare Su-27 parts into China.[118] This might suggest that China is not able to design 90 percent of the original fighter's parts and subsystems (the 10 percent gap in design capability alluded to presumably refers to engines, avionics, and radar which were not among the smuggled items). The engine is the only major subsystem China has openly acknowledged it has yet to master, relying on the imported Russian AL–31F turbofan for both the J–11 and J–10 fighters.[119] Shenyang Liming Motor Corporation has produced a turbofan engine in the WS–10A Taihang (likely the product of substantial reverse engineering) that approaches the performance of the AL–31F, but takes twice as long to "spool up," or obtain the same thrust output, as its Russian counterpart.[120] This lag time could have life or death consequences for a pilot needing to restart his engine.

Chinese military aviation worked hard to incorporate indigenous systems into the J–11B. The upgraded systems were developed as improvements to the original Su-27SK, which was dated technology by the mid 1990s (the Soviet Air force began operating the Flanker in 1985). China's subsequent decision to lobby Sukhoi to sell it an upgraded version of the Flanker was precipitated by a handful of factors. China was looking for a faster way to obtain increased fighter capability than was presented by developing indigenous upgrades. The 1995–1996 Taiwan Strait crisis highlighted the real possibility of an armed conflict, which in turn reinforced previous conclusions about the centrality of Chinese air power in prevailing in a Taiwan scenario. Displays of overwhelming U.S. air power in the 1991 Gulf War were undoubtedly still fresh in the minds of Chinese military planners during the Strait crisis. In addition, the Russian government's inability to regulate military transfers and the tenuous state of the national economy ensured that China could gain access to fighter technology that was closer to state of the art than Russia might have been willing to sell in better circumstances.[121]

The Su–30MK (*modernizeerovannyy kommercheskiy*—upgraded export variant) was already available on the international arms market at the time China was seeking an upgraded Flanker. Russia agreed to sell China a version of this aircraft, appending "K" to the name to denote the customer (*kitayskiy*—Chinese), in 1998. While the two-seat Su–30MKK was not the best fighter Russia was able to produce, it represented a significant jump forward for the PLAAF, particularly in terms of subsystems. The avionics suite incorporated cutting-edge digital processors that linked the primary avionics subsystems together via multiplex databuses.[122] This made it possible for China to integrate new avionics components, either indigenously produced or purchased from a third party, as they became available. The first batch of 10 Su–30MKK aircraft entered service at Wuhu airbase in December 2000.[123] Another 70 were delivered to China in 2001. China and Russia signed a contract in 2003 for the sale of a Su–30 variant with maritime strike capability (MK2), with the PLANAF taking possession of 24 of the aircraft in early 2004.

The Su–30MKK is the most sophisticated fighter the PLAAF operates to this day—a mantle it is likely to wear until China's fifth-generation fighter comes into service.

Buying, Building, and Stealing

In addition to acquisition and coproduction of the Su-27, China also continued to pursue indigenous development efforts in parallel through the J–10 fighter program, which drew significantly on Israeli-rooted technology and design assistance.[124] Defense collaboration between the two countries was in full swing as early as 1984 with arms sales reaching an estimated $3.5 billion in that year alone.[125] A great deal of speculation remains regarding the amount and type of technical assistance Israel provided in the development of the J–10, but open source materials clearly indicate that Israel used some expertise gained from developing the U.S.-financed Lavi fourth-generation fighter to assist in the development of the J–10.[126] It is difficult to determine whether the design assistance provided by the Israelis on the J–10 rises to the level of codevelopment as articulated in the model. It is likewise difficult to determine from open source materials what, aside from money, China offered Israel in exchange for design assistance on the J–10. One logical possibility is that Beijing shared technical information on the missiles it sold to countries hostile to Israel—Iran being a prime example. Arguments have also circulated that China had access to a Pakistani F–16, parts of which it may have reverse engineered and integrated into the J–10. The J–10 is clearly not a Lavi clone, however. It has significant design differences from the Lavi including its larger size, canard positioning, wing platform, and two-dimensional air intake.[127] It was originally designed to use the Israeli Elta EL/M–2035 radar, which can simultaneously track six air targets and lock onto the four most-threatening, but is also able to incorporate Russian and Chinese avionics. Both the original J–10 and the J–10B/AS/AB upgrade variants that came into PLAAF service in 2006 sport specially designed Russian Lyul'ka Saturn AL–31N turbofan engines.[128]

Israel was China's second largest source of military aviation technology transfer in the 1990s.[129] While this data point is undeniable, some clarification should be added. Russian arms sales to China during the 1990s topped those of all other countries combined; Israel's stake in the market was trivial by comparison. Nevertheless, it assisted Chinese military aviation in several other areas. In the mid-1990s Israel agreed to sell China its Phalcon Airborne Early Warning and Control (AEW&C) platform and the Harpy unmanned aerial vehicle. At the time, some defense experts rated the Phalcon as the most advanced AEW&C system in the world. This might explain why China approached Israel rather than Russia for access to the technology. With Western arms embargoes still in full force, there was a very short list of states willing and able to sell China advanced military aviation hardware. Israeli Aircraft Industries (IAI) received an initial $319 million deposit from China to secure the Phalcon. News of the deal provoked a strong reaction in Washington, where there was growing concern over Chinese military modernization, particularly as it applied to a potential Taiwan scenario. Chinese military planners understood that in order to prevail in a Taiwan scenario (with U.S. military intervention likely), it was essential to control the airspace over the strait. The first Gulf War confirmed to Beijing the extent of the gap between the PLAAF and its potential U.S. rival. AEW&C was one of a set of capabilities that China needed to develop in order to stand a chance of contesting the U.S. Air Force over the Taiwan Strait. From Israel's perspective, a supplier-client relationship with a rising power like China was a golden opportunity for its small yet capable indigenous defense industries.

Israel ultimately decided that its relationship with the United States was too important to jeopardize, and in July 2000 it canceled the Phalcon sale and refunded China's deposit. Beijing was furious when Israel announced it was backing out of the deal. Prime Minister Ehud Barak had promised that China would receive Phalcon technology, leading President Jiang Zemin to make public statements to that effect.[130] Jiang lost face over what turned out to be empty promises and a substantial diplomatic rift between the two sides ensued.[131]

Since the Phalcon deal fell through in 2000, China has pursued its own domestic AEW&C development program, encountering numerous difficulties along the way. In 2006 a prototype aircraft undergoing flight testing crashed in Anhui province, killing 40 people, among them 35 technicians who were intimately involved with the project.[132] China has since succeeded in producing several types of AEW&C aircraft: the KJ–200, based on the Soviet Yak–8 transport, and the KJ–2000, based on the Russian A–50 MAINSTAY airframe.[133] The PLAAF has taken possession of, and is presumably operating, at least four KJ–2000s.[134] Little is known about the exact capabilities of these aircraft, though there is speculation that they are similar in design, though technically inferior, to the Phalcon.[135] The degree to which China's AEW&C aircraft were developed domestically remains an open question. Despite the fact that Israel cancelled its sale of the Phalcon, it is not implausible that it might have provided China design and technical assistance after the fact.

Israel's reversal on the Phalcon damaged its military aviation technology transfer relationship with China (and also affected overall bilateral relations), but the Harpy fiasco in 2004 was the knock-out punch. Designed to "detect, attack, and destroy radar emitters with a very high hit accuracy," the Harpy is an unmanned aerial vehicle (UAV) with all-weather capability.[136] Its range, the fact that it is launched from a ground vehicle outside the immediate battlespace, and its ability to neutralize SAM and radar sites for long periods of time made the Harpy a sought-after item for Chinese military planners looking out over the Taiwan Strait. The Harpy deal was negotiated in the mid-1990s, with China having taken possession of around one hundred of the UAVs by 1999.[137] The deal was reported to the United States at the time it was negotiated and although there were objections, Washington did not pressure Israel to cancel it. Because the Harpy was a system wholly designed and produced by Israel there was no basis to block the sale on the grounds of illicit technology transfer. It was only when China sent its Harpy inventory back to Israel for service and repair in 2004 that the United States objected. The Bush administration claimed that the true purpose was to upgrade the systems with new sensors that could detect radar emitters even when they are not actively transmitting a signal.[138] Taiwan was reportedly already in possession of the new, upgraded Harpy.[139]

Concerned about the threat the Harpy posed in the case of a Taiwan scenario, the United States demanded that Israel not return the drones that China had already purchased and thus legally owned. What finally happened to China's Harpy aircraft remains unclear (at least in open source material).[140] Israel did refund China a considerable sum of money related to the UAV upgrade indicating that some part of the work was not completed, though whether this included technical upgrades (as Washington claimed) or routine maintenance is still unknown.[141] There is also the possibility that Israel confiscated Harpy components and paid China off in order to mitigate political fall-out over the incident. Whatever the case, the Harpy episode marked the last significant military aviation transfer between Beijing and Jerusalem. It also had negative repercussions for U.S.-Israeli relations: Amos Yaron, Director General of Israel's Ministry of Defense, resigned after the incident.

Ukraine also emerged as a source of advanced military aviation technology during this period. It has not played as prominent a role in equipping the PLAAF as has Russia, but Ukraine has served as an important conduit for Russian military hardware that China has been unable to procure directly. In 2000–2001, the Ukrainian firm Progress reportedly supplied both Iran and China with Soviet Kh–55 cruise missiles, which have an active range of 3,000 kilometers and can be armed with both nuclear and conventional warheads.[142] The highly accurate guidance system used in the Kh–55 was more advanced than anything China was producing indigenously at the time, and expanded the capability of its aged bomber fleet (the Kh–55 is an air-to-surface missile fired solely from bomber platforms). Around this time China also gained access to a single Su–33 (air frame T–10K–7) prototype from Ukraine.[143] China has used this aircraft as a template for its J–15 naval fighter, which is reported to have made a successful test flight in August 2009.[144]

From 1989 to 2004, China actively pursued acquisition of advanced aircraft and aviation technology from Russia, Ukraine, and Israel; used a combination of coproduction and reverse engineering to make advances in subsystem design and manufacturing; and came up with innovations in its own capacity to build fighter aircraft at least partially based on indigenous design. China also appears to have greatly expanded its efforts to steal restricted technologies by way of industrial espionage using both traditional and computer network intrusion techniques. While there are few documented examples citing fighter aircraft technology, there are a number of cases where China obtained, or attempted to obtain, restricted dual-use technologies from the United States using surreptitious means. By 1993 approximately 50 percent of the 900 technology transfer cases handled by U.S. federal law enforcement agencies involved the Chinese.[145] Cases of cyber espionage that track back to China provide more detail about the types of military aviation–related technical data attackers are after. It should be noted that the relative anonymity afforded cyber attackers often leads to problems of attribution. Forensic investigators can trace the origin of a certain exploit back to a computer server in China, for example, but the attacker might be using Chinese commercial networks, which are notoriously porous, as an intermediary point. We therefore only cite examples where evidence exists linking the source of espionage attempts to China, and suggests the involvement of the military or intelligence organizations.

Although the intrusions did not target fighter technology, the 2004 attacks on a number of computer networks belonging to the U.S. military and defense contractors that came to be known as Titan Rain were definitively traced back to a location in Guangdong Province by a computer specialist working at Sandia National Laboratories in New Mexico. The specialist, a former U.S. military intelligence officer, surreptitiously monitored the activities of the attackers after the Sandia networks he was responsible for safeguarding were attacked. He discovered an operation that involved 20 or more individuals connecting through three separate end nodes in Guangdong. While this is not hard proof of a Chinese military or intelligence operation, the sort of data being targeted suggests a military end user. The attackers reportedly breached the systems of the Redstone Arsenal, home of Army Aviation and Missile command, and stole technical data for the mission planning system used by U.S. Army helicopters, as well the Falconview 3.2 flight planning software used by both the U.S. Army and Air Force.[146]

Chinese cyber espionage operations aimed at extracting sensitive technical data began in the period under consideration (1989–2004), and expanded rapidly in terms of both volume and sophistication since. In a 2009 case, computer networks belonging to at least one defense contractor working on the F–35 Joint Strike Fighter program were reportedly compromised, giving intruders access to Pentagon computer systems that contained sensitive, though not classified, data on the J–35's design, performance, and electronics systems. There is not as much evidence linking this exploit to Chinese attackers, but U.S. officials interviewed about the breach reported that it had been traced to China and bore the hallmark of a state-sponsored operation.[147] In this particular case, the stolen information could not be used to reverse engineer F–35 systems, but could have been helpful in learning how to better defend against them.

This paper has examined the evolution of China's military aviation industry over the decades and discussed the various procurement strategies it has used at different points in time. The approach has been based on four main variables: (1) the state of China's domestic economy, in particular the state of its technological and industrial base; (2) the technological capacity of China's military aviation sector; (3) the willingness of foreign countries to sell China advanced military aircraft, key components, armaments, and related production technology; and (4) China's bargaining power vis-à-vis potential sellers of military aircraft and aviation technology. Between 1989 and 2004 China was able to diversify avenues of aviation technology procurement. Expansion occurred as a result of favorable developments across each of the four main variables. China's civilian technology base grew as a result of trade and foreign investment, generating access to dual-use technologies which the military aviation sector leveraged to improve design and production capacity. Rapprochement with Russia once again gave China access to advanced military hardware that was blocked by Western embargoes post-Tiananmen. Moreover, China's newfound economic clout afforded it a much stronger negotiating position with a Russian state that faced myriad economic difficulties after the Soviet collapse. Defense cooperation with Israel, though ultimately problematic, provided China a window of access to technical knowledge and design expertise which moved its aviation industry forward. Engagement with the outside world resulted in an increased Chinese presence abroad, providing avenues to restricted military technologies via espionage. Finally, cyber espionage emerged in the later part of this time period as a new vector for the extraction of data related to restricted military aviation technologies.

Looking Forward: Chinese Military Aviation Technology Procurement (2004–Present)

Reverse Engineer		J–15: Chinese Su-33 (2009)	
Steal		China successfully exfiltrates terabytes of data on U.S. Joint Strike fighter electronics systems (2007–2008)	
Build	J–10 enters PLAAF service (2006)	J–11B enters PLAAF service (2008)	J–20 flight test (2011)

Building

China's overall economic development continues to progress rapidly, both in terms of growth and technological sophistication. Investment by developed countries, imports of sophisticated production technology, and indigenous production have created an advanced-Chinese economy that approaches world-class standards in many areas. Chinese companies do not necessarily have full knowledge of all the advanced technologies embodied in equipment operated on Chinese territory, but the situation has changed fundamentally. The government's focus on developing indigenous innovation with Chinese characteristics (*zizhu chuangxin*) emphasizes the importance of foreign technology and knowledge in moving China's overall level of industrial and scientific development forward. The most recent iteration of the Medium- and Long-Term Science and Technology Development Plan (MLP), released in 2006, outlines a path to "promote original innovations by reassembling existing technologies in different ways to produce new breakthroughs and absorb and upgrade foreign technologies."[148] The idea at the core of this approach is to assimilate and absorb preexisting foreign technologies and in the process of merging them with domestic technologies, realize new breakthroughs and improvements.[149] The decision of many advanced Western companies to locate technology R&D labs in China has led to an improvement of China's technology knowledge base which has in turn enabled overall economic progress.

This economic progress has benefited the Chinese defense industry in general and the military aviation industry in particular. Globalization has increased China's access to technologies originally developed by the West for military applications, and then applied widely for civilian purposes. This allows China to benefit from a "spin-off, spin-on" dynamic to apply these technologies to its defense industries. Advances in information technology (IT) and communications technology are providing new design tools and the basis for improved avionics systems that can be applied to Chinese fighters. Key companies in this sector such as Huawei and Julong were founded by ex-PLA officers and are closely tied to the Chinese defense industry.[150] China has been involved in commercial joint ventures with Western aviation companies since the 1980s, producing subassemblies and parts for civilian aircraft and has continued to expand its role in the global aviation supply and production chain. However, unlike the IT sector, there have been relatively few opportunities for Chinese civil/military aviation integration and technology sharing.[151] This is partly due to the limited applicability of civilian aviation technologies for military use. Compartmentalization also prevents useful transfers of personnel, knowledge of production practices, and materials. Commercial and military aviation projects are conducted by different enterprises on different production lines with apparently little or no interaction on areas that might be of common interest.[152] There are a few isolated cases where technologies and process improvements derived from civilian production may spill over to the military side, but this is not an institutional feature of the Chinese aviation industry.[153] Despite these inefficiencies and continuing problems, the Chinese military aviation industry's ability to "build" a more sophisticated PLAAF has advanced significantly.

China's potential to continue to "build" its way to a more sophisticated air force in the future depends on the degree to which it will be able to meet its indigenous innovation objectives, which continue to depend on access to advanced foreign technologies. Examples of true indigenous innovation are still few and far between. Even with the benefit of "follower's advantage," Chinese military aviation is still unable to copy some subsystems at a level equivalent to those of the original. Continuing limitations are most apparent in the industry's inability to design a turbofan engine that meets the requirements of its fleet of indigenously produced advanced fighters. In April 2009, the head of Aviation Industries of China (AVIC), Mr. Lin Zuoming, admitted that the WS–10A (China's most advanced turbofan at the time) was still "unsatisfactory in its quality" and that engine production for military aircraft has been a "chronic illness" in China's defense industry.[154] AVIC is investing $1.5 billion into jet engine research and development to try to overcome persistent problems with quality control and reliability.[155]

Flight tests of the new J–20 stealth fighter may reveal whether China has overcome this hurdle. Chinese news sources reported after the initial test flight that two J–20 prototypes had been produced, one with a Russian engine and the other with an indigenously produced engine.

It is not clear which engine is coupled with which prototype. Photographic analysis reveals that the exhaust nozzles of one prototype are "jointed in a way that implies thrust vectoring capability."[156] China has been using the thrust-vectored Russian AL–31FN–M1 in its two-seat J–10 AS/BS fighters since 2006.[157] This is most likely the engine in one of the J–20 prototypes, although there is speculation that the production model will be powered by thrust-vectored WS–10G turbofans, manufactured by the Shenyang Liming Aircraft Engine Company.[158] If Chinese media reports are accurate and one prototype sports a non–thrust vector capable indigenous engine (probably, based on past instances where Russian and Chinese engines were simultaneously tested in the same model aircraft), this engine is likely some version of the WS–10.[159]

The unveiling of the J–20 is the most significant recent event for Chinese military aviation. The J–20 prototype's maiden flight coincided with U.S. Defense Secretary Robert Gates' January 2011 visit to China. Learning of the successful test flight, Gates commented, "They may be somewhat further ahead in the development of that aircraft than our intelligence had earlier predicted." The J–20 reportedly made a second round of successful test flights on April 17, 2011, to commemorate the sixtieth anniversary of the PLAAF.[160] Most recently, Chinese military bloggers posted photos of the J–20 making what appears to be a third and fourth set of test flights.[161] The fighter is expected to enter into service with the PLAAF between 2018 and 2020. While the development of J–20 prototypes is a significant achievement for Chinese military aviation, the flight tests provide no insight into whether the industry is any closer to overcoming its engine impediment or whether it has mastered critical challenges in avionics and radar. J–20 test pilot Xu Yongling made statements to the Chinese media touting technological breakthroughs embodied in the fighter, including supersonic cruise capability.[162] Publicly available data on the test flights does not provide enough evidence to support Xu's assertion. About the only thing that can be determined from them is that China can produce a few prototypes of an aircraft that appears to incorporate some stealth technology and that one of these prototypes can be flown for a short period of time without crashing. Interpreting the appearance of the J–20 as proof that China is right on the heels of U.S. military aviation capability is a misinterpretation of the known facts. Russian and Western military aviation experts maintain that the PLAAF is still 15 to 20 years behind the most advanced air forces in terms of equipment.[163]

Buying

Given continuing limitations in China's domestic military aviation industry, the PLAAF's ability to compete on an equal footing with the most advanced air forces will rest on China's ability to purchase, acquire, or codevelop advanced military aviation technology from foreign sources or partners. This access may be problematic. The United States is likely to continue to ban arms exports to China and to restrict the transfer of advanced military technologies. U.S. pressure on the European Union to maintain its ban on arms sales and on European countries and Israel to restrict the transfer of advanced military technologies will likely continue to restrict Chinese access from these countries. Ukraine has served as an important secondary point of access for Russian military aviation technology in the past, but its military aviation design and production capability lie primarily in the area of transport aircraft, limiting its ability to provide state-of-the-art fighter technologies. Ukrainian aerospace cooperation with China in recent years has focused primarily on civilian projects and military transports. The Ukrainian aviation firm Antonov signed an agreement with AVIC II in 1997 to help China develop a large transport aircraft and to assist in the design of light- and medium-sized transport platforms. Antonov has also agreed to improve the PLAAF's existing fleet of Y–8 turboprop aircraft.[164]

This leaves Russia as the only plausible source of advanced fighter aircraft and aviation technologies. Military aviation technology transfer is a key component of Sino-Russian relations. As this study has documented, the relative bargaining power of the two countries has shifted over time as a function of economic status, threat perceptions, and shifts in the broader geostrategic landscape. The terms of transfer have been based on a calculus of dependence and risk.

China's decision to violate the Su-27/J–11 coproduction contract in 2004 was an important factor influencing Russian decisionmaking on military aviation transfers to China. The official Chinese explanation, proffered only after Russia discovered that China was developing an indigenized J–11, was that the Su-27 no longer met the needs of the PLAAF. China was clearly aware that its decision to violate the contract with Russia would create strains in the relationship and might threaten Russia's willingness to sell additional fighter aircraft or components, yet it went ahead anyway. This decision may have reflected China's confidence that its domestic aviation industry could meet current and future aircraft needs of the PLAAF through indigenous development without Russian assistance. Alternatively, it may have reflected the belief based on experience that the Russian reaction would be minimal and would not impede future technology cooperation.

China may have miscalculated the scope of Moscow's reaction to the aborted Flanker deal, possibly due to the belief that Russia was more reliant on China as a buyer than China was on Russia as a seller. There is obviously a much larger dimension to Sino-Russian relations than one failed weapons system deal, but the Russian side has cited repeatedly China's 2004 contract breach as a reason it is reluctant to enter into another aircraft coproduction agreement with Beijing. It was likely a contributing factor in the stalled deal for China to purchase additional Il-76/

CANDID heavy transports and Il-78/MIDAS tankers to extend the range of its Russian fighters. China's primary indigenous in-flight refueling platform, the H–6U tanker, has significant limitations in that it holds only 37,000 pounds of transferable fuel (PLAAF analysis calls for a platform capable of holding 80,000–100,000 pounds), and cannot be used to refuel China's Su–30 fighters.[165] On the other hand, Russia has continued to sell China S–300 surface-to-air missile systems and large quantities of advanced turbojet engines. Moscow also announced in November 2010 its willingness to sell China the Su–35 fighter, which it bills as "fourth generation plus": a fourth-generation fighter that incorporates some fifth-generation technologies.[166] According to Sukhoi, the Su–35 will see a 10-year production run (through 2020) and be available for foreign purchase in 2011. Russia has not expressed interest in a coproduction agreement with China on the aircraft, nor is it likely to. In order to maintain control of its most advanced aviation technologies, Russia will likely offer a watered-down export version of the Su–35, possibly choosing to sell clients like India a more capable variant than China.[167]

A relationship of mutual advantage still exists, at least for now; each side's perception of its interests and relative bargaining power will influence how much cooperation occurs and on what terms. A stronger Russian state under Putin has managed to rein in much of the economic chaos that plagued Russia during the Yeltsin years and re-exert centralized control over many issues, including arms sales and technology transfers. The ability of Russian leaders to maintain economic growth and political stability in the face of fluctuating energy prices, systemic corruption, and limited economic reforms will affect Russia's long-term bargaining power vis-à-vis China.[168]

Conclusion

The Chinese military aviation industry is now capable of producing two fourth-generation fighters roughly equal to those operated by the most advanced air forces: the J–10 (indigenously developed with Israeli assistance) and the J–11B (based on coproduction and reverse engineering of the Su-27). The J–15 naval fighter (based on reverse engineering of the Su–33), which was successfully test flown in 2009 and is likely to enter serial production in the next 3 to 5 years, will give China a capable fourth-generation fighter that can be operated from aboard aircraft carriers. China also now operates functional AEW&C systems in the KJ–200 and KJ–2000, though the technical sophistication of these systems falls well short of systems fielded by the world's most advanced air forces. Test flights of the new J–20 stealth fighter prototype demonstrate Chinese ambitions to build fifth-generation fighters, though the extent to which the J–20 will match the performance of state-of-the-art Russian and Western fighters is unclear. Significant hurdles in engine design, avionics, and systems integration are likely to delay operational deployment of the J–20 until around 2020. This would be 15 years after the F–22 entered service with the U.S. Air Force, supporting the overall assessment that the Chinese military aviation industry remains 15–20 years behind.

Over the last 20 years, China has benefited significantly from "follower's advantage." Its military aviation industry has accessed the innovations of others via coproduction, espionage, and reverse engineering while making limited developments in genuinely new technology. In order to bridge the technology gap, China's military aviation industry will have to develop the capacity to master dual-use and especially militarily unique technologies that go into state-of-the-art fighter aircraft components. It will also have to develop the competence in systems integration to make the complex components work together. Developed countries with more advanced techno-industrial bases than China, like Japan and Taiwan, have struggled to achieve the systems integration know-how necessary to produce cutting-edge fighter aircraft. The ability to reach the technology frontier across a range of related civilian and dual-use modalities (for example, Japan's space program) is not necessarily transferable to the military aviation realm. Even if the technical knowledge and industrial capacity exist, opportunity costs involved with developing single-use military technologies might prove too great. Further Chinese integration into the global economy will increase its capacity to develop and apply dual-use technologies, but legitimate access to "single-use" military specific technologies will remain problematic.

Restrictions on advanced Western military technologies are likely to remain in place, leaving Russia as the only viable source. China remains dependent in the near term on access to Russian engines to power its indigenous fourth-generation fighters,[169] Russian spare parts for its inventory of Su-27 and Su–30 fighters, and Russian advanced surface-to-air missiles. The overall state of the Sino-Russian relationship will shape what systems and technologies Russia is willing to transfer to China, and the bargaining power between Russia and China will influence whether transfers take place in the form of sales of aircraft and complete components, coproduction of aircraft and components, or codevelopment of new aircraft and technologies. Russia's significant concerns about China as a potential strategic competitor and rival in the fighter export market suggest that Russia will seek to maintain a degree of control and leverage by supplying complete aircraft and components rather than transferring advanced technologies, which is China's preference. Paradoxically, the development of China's aviation industry to the point where it can participate in aviation technology and fighter aircraft codevelopment efforts on a more equal footing will likely make Russia less willing to engage in such cooperation. Russia's improved bargaining position as the sole source potentially willing to provide China with advanced aviation technology will likely allow Russia to exert more control over the aircraft and technologies it decides to sell.

Advanced technology is a key factor in the performance of state-of-the-art military fighters. Many relevant technologies have equivalent applications in the civilian sector and can be acquired legitimately in the global technology marketplace. But advanced fighters (especially fifth-generation aircraft) also incorporate a number of unique single-use technologies developed solely for their military applications that are not readily available on the commercial market. The likelihood that China will have no foreign source of advanced military aviation technology supports two important conclusions. First, the Chinese military aviation industry will have to rely primarily on indigenous development of advanced "single-use" military aviation technologies in the future. The Chinese government is pursuing a range of "indigenous innovation" and technology development programs, but mastering advanced technologies becomes more difficult and expensive as a country moves closer to the technology frontier. This leads to a second, related conclusion: China will likely rely more heavily on espionage to acquire those critical military aviation technologies it cannot acquire legitimately from foreign suppliers or develop on its own.

Notes

[1] Evan S. Medeiros et al., *A New Direction for China's Defense Industry*, RAND Document MG-334 (Santa Monica: RAND Corporation, 2005), 27–48.

[2] "Fifth generation" reflects the Western generational classification for American aircraft such as the F–22 and F–35, Russia's Sukhoi T–50, and China's own Chengdu J–20. The Chinese use a different classification scheme that refers to F–16s and Su-27s as "third generation" fighters, and the F–22 and F–35 as "fourth generation" fighters. Because this paper draws on international examples, we employ the Western terminology, which classifies the F–15/F–16 (and MiG–29 and Su-27) as fourth generation, and their stealthy successors as fifth generation.

[3] Joe Yoon, "Fighter Generations," June 27, 2004, at www.aerospaceweb.org. Accessed August 1, 2011, at <http://www.aerospaceweb.org/question/history/q0182.shtml>.

[4] "The systems engineering method recognizes each system is an integrated whole even though composed of diverse, specialized structures and subfunctions. It further recognizes that any system has a number of objectives and that the balance between them may differ widely from system to system. The methods seek to optimize the overall system functions according to the weighted objectives and to achieve maximum compatibility of its parts." From Harold Chesnut, *Systems Engineering Tools* (Somerset, NJ: J.W. Wiley and Sons, 1965).

[5] The U.S. F–22 Raptor, arguably the world's most sophisticated aircraft, took 20 years to develop. See "Chronology of the F–22 Program," accessed October 15, 2010, at <http://www.f22-raptor.com/about/chronology.html>.

[6] Brian Grow, Keith Epstein, and Chi-Chu Tschang, "The New E-spionage Threat," *Business Weekly* Web edition. (April 10, 2008). Accessed August 4, 2010, at <http://www.businessweek.com/magazine/content/08_16/b4080032218430.htm>.

[7] For the purposes of this paper, we assume that China's military aviation industry is always trying to fully exploit available open source information (although its ability to do so varies depending on its technological capacity).

[8] Carol Evans, "Re-appraising Third World Arms Production," *Survival* 28, no. 2 (March 1986), 98–117.

[9] Wei Chen Lee, "The Birth of a Salesman: China as an Arms Supplier," *East Asia International Quarterly* 6, no. 4 (Summer 1987), 32–46.

[10] David Isenberg, "Israel's role in China's new warplane," *Asia Times Online* (December 4, 2002), at <http://www.atimes.com/atimes/China/DL04Ad01.html>.

[11] Legally speaking, an aircraft is sovereign property of the state and should be returned, although this does not always happen in practice.

[12] Federation of American Scientists Military Analysis Network, "AA 2 Atoll," accessed September 3, 2010, at <http://www.fas.org/man/dod-101/sys/missile/row/aa-2.htm>.

[13] The aircraft, based on the Sukhoi T–50 prototype, is referred to by Russia as "*Perspektivny aviatsionny kompleks frontovoy aviatsii*" (PAK FA, or "Future Airborne Complex—Frontline Aviation"), and by India as "Fifth Generation Fighter Aircraft" (FGFA). The variants operated by the Russian and Indian air forces will differ in many respects, though both parties will share in funding costs and will benefit equally in terms

of engineering and intellectual property generated from the project. The Indian air force plans to purchase 200 two-seat models of the FGFA and only 50 single-seat models. Russian procurement plans call for the opposite balance, with the air force buying 200 single-seat PAK FA models and 50 two-seat models.

[14] Ajai Shukla, "India to Develop 25% of Fifth Generation Fighter," *Business Standard* (January 6, 2010), accessed September 7, 2010, at <http://www.business-standard.com/india/news/india-to-develop-25fifth-generation-fighter/381786/>.

[15] Katherine V. Schnasi, "Joint Strike Fighter Acquisition: Observations on the Supplier Base," GAO-04-554, accessed September 3, 2010, at <http://www.gao.gov/new.items/d04554.pdf>.

[16] "F–35 Joint Strike Fighter (JSF) Lightning II: International Partners," *Global Security*, accessed September 5, 2010, at <http://www.globalsecurity.org/military/systems/aircraft/f-35-int.htm>.

[17] The Soviets sided with India in the Sino-Indian border war of 1962, which represented essentially the last straw in deteriorating Sino-Soviet relations.

[18] Sudha Ramachandran, "India, Russia Still Brothers in Arms," *Asia Times* (October 27, 2007), accessed September 9, 2010, at <http://www.atimes.com/atimes/South_Asia/IJ27Df01.html>.

[19] Ajai Shukla, "India, Russia Close to Pact on Fifth Generation Fighter," *Business Standard* (January 5, 2010).

[20] Shukla, "India to Develop 25% of Fifth Generation Fighter."

[21] Ramachandran.

[22] Shukla, "India to Develop 25% of Fifth Generation Fighter."

[23] David Isenberg, "Israel's role in China's new Warplane," *Asia Times Online* (December 4, 2002), accessed July 31, 2011, at <http://www.atimes.com/atimes/China/DL04Ad01.html>.

[24] Kristin Archick, Robert Grimmett, and Shirley Kan, *European Union's Arms Embargo on China: Implications and Options for U.S. Policy*, CRS Report for Congress RL32870 (Washington, DC: Library of Congress Congressional Research Service, May 27, 2005), accessed July 31, 2011, at <http://www.fas.org/sgp/crs/row/RL32870.pdf>; and Government Accountability Office (GAO), *China: Military Imports from the United States and the European Union Since the 1989 Embargoes*, Report NSIAD-98-176 (Washington, DC: GAO, June 1998), accessed August 20, 2010, at <http://www.gao.gov/archive/1998/ns98176.pdf>..

[25] Luke G.S. Colton, "A Chinese AEW&C Threat? The Phalcon Case Reconsidered," *Chinese Military Update* 1, no. 7 (January 2004), 9–12.

[26] Austin Ramzy, "China Flexes Its Muscles with Stealth Fighter Test," *Time* (January 11, 2011), accessed August 5, 2011, at <http://www.time.com/time/world/article/0,8599,2041755,00.html>..

[27] Yefim Gordon and Dmitriy Komissarov, *Chinese Air Power: Current Organisation and Aircraft of All Chinese Air Forces* (Surrey: Ian Allan Publishing Ltd., 2010), 3.

[28] National Air and Space Intelligence Center (NASIC), *People's Liberation Air Force 2010* (Wright-Patterson AFB, OH: NASIC, August 1, 2010), 11–12, accessed April 19, 2011, at <http://www.au.af.mil/au/awc/awcgate/nasic/pla_af_2010.pdf>; Chinese aviation historians Liang-yen Wen and Lennart Andersson conclude that at the beginning of December 1949, the PLAAF's strength was 159 aircraft of 21 different types, ranging from three B–24s to P–47s, P–51s, and even two British-built Mosquitoes; see Lennart Andersson, *A History of Chinese Aviation: Encyclopedia of Aircraft and Aviation in China until 1949* (Taipei: Ko-lo Color Printing Company—Chu-men Company), 2008), 176–177.

[29] Wu Chun Guang, *Zhongguo Kongjun Shi Lu* [Record of the Chinese Air Force] (Beijing: Chun Feng Wenyi Chubanshe, 1997).

[30] Ibid., 39.

[31] Zhang Xiaoming, *Red Wings over the Yalu: China, the Soviet Union, and the Air War in Korea* (College Station: Texas A & M Consortium Press, 2002), 45–51.

[32] Jung Chang and Jon Halliday, *Mao: The Unknown Story* (New York: Anchor Books, 2005), 374.

[33] Ibid., 375.

[34] Sergei Goncharenko, "Sino-Soviet Military Cooperation," in Arne Westad, ed., *Brothers in Arms: The Rise and Fall of the Sino-Soviet Alliance* (Washington DC: Woodrow Wilson Center Press, 1998), chapter 4.

[35] Deborah A. Kaple, "Soviet Advisors in China in the 1950s," in Westad, ed., *Brothers in Arms*, chapter 3, 120.

[36] Duan Zijun, ed., *China Today: Aviation Industry* (Beijing: China Aviation Press, 1989), 18.

[37] Sergei Goncharenko, "Sino-Soviet Military Cooperation," in Westad, ed., *Brothers in Arms*, chapter 4, 147.

[38] Duan, ed., *China Today: Aviation Industry*.

[39] Ibid., 352.

[40] Duan, ed., *China Today: Aviation Industry*: In addition to challenges posed by creating high temperature alloys, production of the WP5 was also compounded by the "high precision of nozzles, the complexity of blade profiles, and many thin wall welding parts in the combustion afterburner systems. Therefore, apart from precision machining and advanced heat and surface treatment technologies, it was also necessary to set up precision casting and forging production lines which can make parts with little or no machine allowances, as well as various welding production lines such as seam welding, butter welding, DC electrode welding, hydrogen atom welding, high frequency brazing, manual and automatic argon arc welding, etc."

[41] Duan, ed., *China Today: Aviation Industry*, 203.

[42] The Chinese military aircraft naming convention is to designate models for domestic use as 'J' and those for export as 'F.' The F–5 is, for example, the export version of the J–5. As the Chinese military aviation industry improved its productive capacity, it was able to turn out export models designed to suit the particular needs of purchasing countries.

[43] Ibid.

[44] In a PBS NOVA interview, former U.S. Air Force Historian Richard Hallion argues that the Soviets were likely able to close the fighter gap with the United States as a result of technology transfer gained via espionage. The MiG–19 and the U.S. F–100 were the first two supersonic fighters produced. When both came out in 1953, the MiG–19 outperformed its American counterpart. Hallion traces the technology transfer that enabled the Soviet breakthrough to an individual who was part of the infamous atomic espionage ring established by Julius Rosenberg. While the Rosenberg spy ring is known primarily for its role in atomic espionage which enabled the USSR to develop its first nuclear weapon, it also actively targeted the U.S. aeronautical and electronics industries. William Perl, a government aeronautical scientist who held posts at the National Advisory Committee for Aeronautics' ([NACA, the predecessor to NASA) Langley and Lewis research centers, was a key player in the Rosenberg spy ring, providing the USSR with

the results of highly secret tests and design experiments for American military aviation technology; see <http://www.pbs.org/wgbh/nova/barrier/history.html>. Perl was unmasked by the Venona intelligence collection program, arrested, and, after interrogation, was charged, tried, and convicted of perjury (after denying he knew the Rosenbergs). More serious charges were not placed for fear of compromising the ongoing Venona effort. For a further discussion of Perl's espionage activities, see Richard Hallion, "Sweep and Swing: Reshaping the Wing for the Jet and Rocket Age," in Richard P. Hallion, ed., *NASA Contributions to Aeronautics*, 1, NASA SP-2010-570-Vol-1 (Washington, DC: NASA, 2010), 17, n. 30; Katherine A.S. Sibley, *Red Spies in America: Stolen Secrets and the Dawn of the Cold War* (Lawrence, KS: University Press of Kansas, 2004), 10, 115, 196–198, 315, n. 126; John Earl Haynes and Harvey Klehr, *Early Cold War Spies: The Espionage Trials that Shaped American Politics* (Cambridge: Cambridge University Press, 2006), 161–163, 167, 172, 175, 188, 236; and Robert L. Benson, *The Venona Story* (Fort Meade, MD: Center for Cryptologic History of the National Security Agency, 2001), 8, 24–25.

[45] Gordon and Komissarov, *Chinese Air Power*, chapter 2.

[46] Duan, ed., *China Today: Aviation Industry*, 115.

[47] See Wu Chun Guang, *Zhongguo Kongjun Shi Lu* [Record of the Chinese Air Force], 128.

[48] Gordon and Komissarov, *Chinese Air Power.*

[49] Ibid., chapter 3.

[50] Ibid.

[51] Ibid.

[52] Duan, ed., China Today: Aviation Industry, 35.

[53] Ibid.

[54] Ibid., 36.

[55] For early accounts, see Donald S. Zagoria, *The Sino-Soviet Conflict, 1956–1961* (Princeton, NJ: Princeton University Press, 1962); and Roderick MacFarquhar, *The Origins of the Cultural Revolution*, 2: *The Great Leap Forward 1958–1960* (New York: Columbia University Press, 1983), 255–292. For a later account that incorporates Russian and Chinese archival materials, see Lorenz M. Luthi, *The Sino-Soviet Split: Cold War in the Communist World* (Princeton, NJ: Princeton University Press, 2008).

[56] Jonathan Pollack, "The Modernization of National Defense," in Richard Baum, ed., *China's Four Modernizations: The New Technological Revolution* (Boulder, CO: Westview Press, 1980), 249.

[57] The JH–7 was not delivered to the PLANAF for evaluation until the mid-1990s, giving some sense of the time it took for Chinese military aviation to absorb the Spey. Coproduction of the WS–9 succeeded in bringing the engine industry to a higher technical level due to the precision tooling required and introduction of new equipment to meet these requirements, yet its integration into just one combat aircraft (only operational 20 years after the original import agreement) must have been disappointing. The Spey case is a prime example of an aviation industry ill-prepared to absorb more advanced technologies in a timely and meaningful way.

[58] For an illustration, see Marc J. Blecher and Gordon White, *Micropolitics in Contemporary China: A Technical Unit during and after the Cultural Revolution* (White Plains, NY: M.E. Sharpe, 1979).

[59] Duan, ed., *China Today: Aviation Industry*.

[60] Gordon and Komissarov, *Chinese Air Power*, chapter 3.

[61] Ibid.

[62] Ibid.

[63] Duan, ed., C*hina Today: Aviation Industry*, 115.

[64] Ibid.

[65] John Wilson Lewis and Xue Litai, "China's Search for a Modern Air Force, *International Security* 24, no. 1 (Summer 1999), 64 –94.

[66] Ibid.

[67] Ibid.

[68] Hans Heymann, Jr., *China's Approach to Technology Acquisition: Part I—The Aircraft Industry*, RAND Document R-1573-ARPA (Santa Monica, CA: RAND Corporation, February 1975), 18, 23–24.

[69] For Jian–7 Interceptor Fighter, see *Sinodefence.com*, accessed September 19, 2010, at <http://www.sinodefence.com/airforce/fighter/j7.asp>.

[70] Chinese writings seldom mention reverse engineering and instead use either *fangzhi* "manufactured imitation"—or *zixing yanzhi* "self-researched and manufactured."

[71] Ibid.

[72] Walter J. Boyne, *Air Warfare: An International Encyclopedia* (Santa Barbara, CA: ABC-Clio, 2002).

[73] Gordon and Komissarov, *Chinese Air Power*, chapter 3.

[74] See <http://www.sinodefence.com/airforce/groundattack/h5.asp>.

[75] "Imbued with revolutionary fervor, but confronting backwardness on nearly every front, China's Communist leaders committed themselves from the earliest days of the People's Republic to a broad-based modernization of their country. Inevitably, the military's powerful claim on a limited pool of resources, and its policy and technological priorities, became a subject of intense political controversy. To sustain these priorities, key leaders of the PLA argued for more than simply new and better weapons; they fashioned a powerful set of ideas about the relationship between state, technology, and national power in China." From Evan Feigenbaum, *China's Techno-Warriors: National Security and Strategic Competition from the Nuclear Age to the Information Age* (Stanford: Stanford University Press, 2003), 2.

[76] Lewis and Xue, "China's Search for a Modern Air Force," 70.

[77] Shao Zhenting, Zhang Zhengping, and Hu Jianping, "Theoretical Thinking on Deng Xiaoping's Views on the Buildup of the Air Force and the Reform of Operational Arts," *Zhongguo Junshi Kexue* [China Military Science], no. 4 (1996), quoted in Lewis and Xue, "China's Search for a Modern Air Force."

[78] Hua Guofeng, "Report on the Work of Government to the 1st Session, 5th National People's Congress," Peking Review (February 26, 1978).

[79] Baum, ed., *China's Four Modernizations*, 5.

[80] Ibid.

[81] Evan Feigenbaum, "Who's Behind China's High-Technology 'Revolution?'" *International Security* 24, no. 1 (Summer 1999), 95–126.

[82] Ibid.

[83] Ibid., 100.

[84] Tai Ming Cheung, *Fortifying China: The Struggle to Build a Modern Defense Economy* (Ithaca, NY: Cornell University Press, 2009), 246.

[85] Lewis and Xue, "China's Search for a Modern Air Force," 74.

[86] Government Accountability Office, *China: Military Imports from the United States and the European Union*, 8.

[87] Ibid.

[88] Phillip C. Saunders and Eric Quam, "Future Force Structure of the Chinese Air Force," in Roy Kamphausen and Andrew Scobell, eds., *Right Sizing the People's Liberation Army: Exploring the Contours of China's Military* (Carlisle Barracks, PA: U.S. Army War College, Strategic Studies Institute, 2007), chapter 8.

[89] Shenyang Aircraft Corporation (SAC) began as a single enterprise, the Shenyang Aircraft Factory (SAF), which was established with Soviet assistance during the Korean War to coproduce MiG fighter aircraft. SAC went on to encompass a number of enterprises and in 1994 became the "core enterprise of the newly formed Shenyang Aircraft Industries Group." See Yefim Gordon and Dmitriy Komissarov, *Chinese Aircraft: China's Aviation Industry since 1951* (Manchester: Hikoki Publications, 2008), 15–16.

[90] Duan, ed., *China Today: Aviation Industry*, 192.

[91] Government Accountability Office, *China: Military Imports from the United States and the European Union*, 6.

[92] Ibid.

[93] See for example, Yitzhak Shichor, "Israel's Military Transfers to China and Taiwan," *Survival* 40, no. 1 (Spring 1998), 68–91.

[94] Medeiros, et al., *A New Direction for China's Defense Industry*, 51–52.

[95] Keith Crane, Roger Cliff, Evan Medeiros, James Mulvenon, and William Overholt, *Modernizing China's Military: Opportunities and Constraints*, RAND Document MG-260 (Santa Monica, CA: RAND Corporation, 2005), 144.

[96] Ibid.

[97] Jennifer Anderson, *The Limits of Sino-Soviet Strategic Partnership*, Adelphi Paper 315 of the International Institute for Strategic Studies (Oxford: Oxford University Press, 1997).

[98] Bill Gertz, "China Uses Supercomputers Illegally; Nuclear Facility Simulates Blasts," *The Washington Times*, June 27, 2000.

[99] Richard Bitzinger, "Civil-Military Integration and Chinese Military Modernization," *Asia Pacific Center for Security Studies* 3, no. 9 (December 2004).

[100] As of November 2010, China was home to the world's second most powerful supercomputer, the Tianhe-1A, which has a peak computing rate of 2.507 petaFLOPS per second, that is 2.5 quadrillion calculations per second. (FLOP = Floating Point Operations per Second; a petaFLOP is 1015 FLOPS.) The fastest computer as of this editing is the K Computer in Kobe, Japan, which computes at the rate of 8.162 petaFLOPS (8.2 quadrillion calculations per second).

[101] Huang Tung, "'Xiaolong,' New Model of Chinese-Built Foreign Trade-Oriented Fighter Plane," *Kuang Chiao Ching* [Wide Angle], October 23, 2003, 72–73, in Foreign Broadcast Information Service CPP20031023000106.

[102] Richard D. Fisher, Jr., "The Impact of Foreign Weapons and Technology on the Modernization of China's People's Liberation Army," *Report for the U.S.-China Economic and Security Review Commission* (Washington, DC: U.S.-China Economic and Security Review Commission, January 2004).

[103] Teng Lianfu and Meifu Sheng, *Kongjun Zuozhan Yanjiu* [Air Force Operational Research] (Beijing: Guofang Daxue Chubanshe, 1990), 78–94.

104 Ibid., 278–279.

105 Wu Chun Guang, *Zhongguo Kongjun Shi Lu* [Record of the Chinese Air Force] (Beijing: Chun Feng Wenyi Chubanshe, 1997).

106 Tai Ming Cheung, "The Chinese Defense Economy's Long March from Imitation to Innovation," *Journal of Strategic Studies* 34, no.3 (June 2011), 325–354.

107 Ibid.

108 Robert Benjamin, "As Pace of Rapprochement Quickens, China Offers Soviets 'Commodity Loans,'" *The Baltimore Sun*, March 1, 1991.

109 Fisher, "The Impact of Foreign Weapons and Technology."

110 U. S. Department of Defense, *Report to Congress Pursuant to the FY2000 National Defense Authorization Act: Annual Report on the Military Power of the People's Republic of China* (Washington, D.C.: DOD, July 28, 2003).

111 "Jian 11 Multi-role Fighter Aircraft," at Web site *Sinodefence.com* (February 20, 2009).

112 Rick Kamer, "Flankers of the People's Liberation Army," *Chinese Military Update* 1, no. 7 (January 2004), 5–8.

113 Stephen J. Blank, "The Dynamics of Russian Weapon Sales to China," *Army War College Strategic Studies Monograph* (Carlisle Barracks, PA: U.S. Army War College, March 4, 1997), 5.

114 Gordon and Komissarov, *Chinese Air Power*, 105.

115 Fisher, "The Impact of Foreign Weapons and Technology."

116 Wendell Minnick, "Russia Admits China Illegally Copied Its Fighter," *Defense News* (Feb. 13, 2010), accessed May 2, 2011, at <http://www.defensenews.com/story.php?i=3947599andc=ASIands=AIR>.

117 Andrei Chang, "China Imitates Russian Su-27SK Fighter," UPI Asia (February 25, 2008), accessed September 28, 2010, at <http://www.upiasia.com/Security/2008/02/25/china_imitates_russian_su-27sk_fighter/1740/>,.

118 "Russia charges man with smuggling military equipment," *RIA Novosti* (July 8, 2011), accessed July 14, 2011, at <http://en.rian.ru/russia/20110708/165082151.html>.

119 Phillip C. Saunders and Eric Quam, "Future Force Structure of the Chinese Air Force," in Kamphausen and Scobell, eds., *Right Sizing the People's Liberation Army*, 19.

120 Jane McCartney, "Chinese J–10 fighter in televised drama," *The Sunday Times Online* (March 24, 2009).

121 Russia sold India a more sophisticated version, the Su–30MKI, which features the thrust-vectoring version of the Al–31F turbofan engine.

122 Gordon and Komissarov, *Chinese Air Power*, 80.

123 Ibid.

124 Richard D. Fisher, "How America's Friends are Building China's Military Power," *Heritage Foundation Backgrounder* (November 5, 1997).

125 Ken Allen and Eric A. McVadon, *China's Foreign Military Relations*, Report no. 32 (Washington, DC: Henry L. Stimson Center, October 1999), 25.

126 Aron Shai, *Sino-Israeli Relations: Current Reality and Future Prospects*, Memorandum 100 (Tel Aviv: The Institute for National Security Studies, September 2009).

127 Gordon and Komissarov, *Chinese Air Power*, 96.

[128] Ibid.

[129] Shai, *Sino-Israeli Relations*, 26.

[130] Ibid., 27.

[131] Ibid.

[132] Joseph Kahn, "Crash of Chinese Surveillance Plane Hurts Efforts on Warning System," *The New York Times*, June 7, 2006.

[133] NASIC, *People's Liberation Air Force* 2010.

[134] Photos of these four KJ–2000s can be seen at <http://www.china-defense-mashup.com/?p=3266>.

[135] Michael Sheridan, "China's Hi-Tech Military Disaster: Bid to Copy Israeli Electronics Kills Experts," *London Sunday Times*, June 11, 2006.

[136] Yitzhak Schichor, "The U.S. Factor in Israel's Military Relations with China," *China Brief* 5, no. 12 (June 2005).

[137] Ibid.

[138] Shai, *Sino-Israeli Relations*.

[139] Schichor, "The U.S. Factor in Israel's Military Relations with China."

[140] Shai, *Sino-Israeli Relations*, 28.

[141] Ibid.

[142] "Russia says Ukraine sold banned missiles to Iran, China," *RIA Novosti* (June 30, 2006), accessed July 6, 2011, at <http://en.rian.ru/russia/20060630/50710729.html>.

[143] Guillaume Steuer, "Chinese J–15 Soon in Air," *Air and Cosmos* [Paris], May 6, 2011, 16–17.

[144] Ibid.

[145] Nick Eftimiades, *Chinese Intelligence Operations* (Annapolis, MD: Naval Institute Press, 1994)

[146] Nathan Thornburgh, "The Invasion of the Chinese Cyber Spies," *Time* (August 29, 2005).

[147] Siobhan Gorman, August Cole, and Yochi Dreazen, "Computer Spies Breach Jet Fighter Program," *The Wall Street Journal*, April 21, 2009.

[148] Tai Ming Cheung, "The Chinese Defense Economy's Long March," 325–354.

[149] Ibid.

[150] Bitzinger, "Civil-Military Integration,"

[151] The push to develop an indigenous engine for China's C919 commercial airliner has "spin-on" potential for a future large military transport aircraft, but official Chinese sources have not confirmed whether this is the intent. See Samm Tyroler-Cooper and Alison Peet, "The Chinese Aviation Industry: Techno-Hybrid Patterns of Development in the C919 Program," *Journal of Strategic Studies* 34, no.3 (June 2011), 325–354.

[152] Roger Cliff, Chad J.R. Ohlandt, and David Yang, *Ready for Takeoff: China's Advancing Aerospace Industry*, RAND Document MG-1100 (Santa Monica, CA: RAND Corporation, 2011).

[153] One author claims that Chengdu Aircraft Corporation (CAC) subcontracting facilities have reported gains in production efficiency as a result of military and commercial production lines being located close together. See Fisher, "The Impact of Foreign Weapons and Technology."

[154] Jonathan Weng, "China AVIC Top Head Admits Poor Quality of Jet Engine," *China Defense Mashup* (April 2, 2009), accessed August 1, 2011, at <http://www.china-defense-mashup.com/?p=3179>.

[155] Gabe Collins and Andrew Erickson, "Jet Engine Development in China: Indigenous High-performance Turbofans Are a Final Step toward Fully Independent Fighter Production," *China SignPost,* no. 39 (June 26, 2011), accessed August 1, 2011, at <http://www.chinasignpost.com/wp-content/uploads/2011/06/China-SignPost_39_-China-Tactical-Aircraft-Jet-Engine-Deep-Dive_20110626.pdf>.

[156] Gabe Collins and Andrew Erickson, "China's New Project 718/J-20 Fighter: Development Outlook and Strategic Implications," China SignPost, no. 18 (January 17, 2011).

[157] Gordon and Komissarov, *Chinese Air Power*, 101.

[158] "Chengdu J–20 Multirole Stealth Fighter Aircraft," *Airforce-technology.com*, accessed June 8, 2011, at <http://www.airforce-technology.com/projects/chengdu-j20/>.

[159] "China's stealth fighter takes to air," *People's Daily Online* (January 12, 2011), accessed June 1, 2011, at <http://english.peopledaily.com.cn/90001/90776/7257512.html>.

[160] "Global Times: J20 'appears' to have made second flight," *People's Daily Online* (April 19, 2011), accessed April 21, 2011, at <http://english.peopledaily.com.cn/90001/90776/90786/7354617.html>.

[161] See, for example, <http://bbs.tiexue.net/default.htm?ListUrl=http://bbs.tiexue.net/index.htm>; and http://bbs.huanqiu.com/thread-697950-1-3.html>.

[162] Song Shengxia, "J–20 Stealth Fighter Jet; Innovative, Not Stolen from U.S.," *Global Times*, January 25, 2011.

[163] See, for example, Ilya Kramnik, "The Future of China's Fifth-generation Stealth Fighter," *RIA Novosti* (December 29, 2010), accessed July 1, 2011, at <http://en.rian.ru/analysis/20101229/161986565.html>; Nathan Hodge, "China's J–20 Fighter: Stealthy or Just Stealthy Looking?" *The Wall Street Journal Online* (January 19, 2011), accessed July 1, 2011, at <http://blogs.wsj.com/washwire/2011/01/19/chinas-j-20-fighter-stealthy-or-just-stealthy-looking/>.

[164] "AVIC II, Antonov to design aircraft," *China Economic Net* (September 20, 2007), accessed August 1, 2011, at <http://en.ce.cn/Industries/Aerospare/200709/20/t20070920_12975829.shtml>.

[165] Gabriel Collins, Michael McGauvran, and Timothy White, "Trends in Chinese Aerial Refueling Capacity for Maritime Purposes," in Andrew Erickson and Lyle Goldstein, eds., *Chinese Aerospace Power: Evolving Maritime Roles* (Annapolis: Naval Institute Press, 2011), 198–200.

[166] "Russia ready to sell Su–35 fighter jets to China," *RIA Novosti* (November 16, 2010), 11; accessed June 22, 2011, at <http://en.rian.ru/mlitary_news/20101116/1 61359301.html>.

[167] The Su–30MKI sold to India featured upgrades not included in the Su–30MKK sold to China.

[168] John W. Parker, *Russia's Revival: Ambitions, Limitations, and Opportunities for the United States*, Institute for National Strategic Studies (INSS) Strategic Perspectives, no. 3 (Washington, DC: INSS, January 2011).

[169] Reports indicate that the WS–10 Taihang is being used in some J–11Bs, and that it might possibly replace the Russian Al–31 series engines in the J–10 and be used in the J–15; see Collins and Erickson, "Jet Engine Development in China."

Acknowledgments

The authors would like to thank Ken Allen, Roger Cliff, Andrew Erickson, Richard Hallion, Michael Hughes, and Christopher Yung for their helpful comments and contributions in improving this paper. They also thank Jenny Lin for her diligent translation efforts, and Scott Devary for his assistance gathering research material. Richard Hallion did initial editing and provided an improved introduction. At NDU Press, we would like to thank George Maerz and Tara Parakh.

About the Authors

Phillip C. Saunders is a Distinguished Research Fellow and Director of Studies in the Center for Strategic Research (CSR), Institute for National Strategic Studies (INSS), at the National Defense University. He also serves as Director of the Center for the Study of Chinese Military Affairs. Dr. Saunders previously worked at the Monterey Institute of International Studies, where he was Director of the East Asia Nonproliferation Program from 1999 to 2003, and served as an officer in the U.S. Air Force from 1989 to 1994. Dr. Saunders is co-editor of *The Chinese Navy: Expanding Capabilities, Evolving Roles* (NDU Press, 2011) and co-author with David C. Gompert of *The Paradox of Power: Sino-American Strategic Restraint in an Age of Vulnerability* (NDU Press, 2011). He has published numerous articles and book chapters on China and Asian security issues. Dr. Saunders attended Harvard College and received his M.P.A. and Ph.D. in International Relations from the Woodrow Wilson School at Princeton University.

Joshua K. Wiseman is a Research Analyst in CSR. Prior to joining INSS as a Contract Researcher in 2010, he worked as a Chinese language translator for the Department of Commerce. His research focuses on Chinese security issues; specifically the Chinese defense industrial sector, Sino-Russian strategic relations, and China's expanding aerospace power. Mr. Wiseman attended The George Washington University, where he completed an MA in Security Policy Studies with a China regional focus. He has extensive experience working, traveling, and studying in China.

Center for Strategic Research Senior Fellows

COL MICHAEL H. BELDING, USMC
Senior Military Fellow

MS. M. ELAINE BUNN
Distinguished Research Fellow

MR. JOHN A. COPE
Senior Research Fellow

COL MARK FIELDS, USA
Senior Military Fellow

DR. T.X. HAMMES
Distinguished Research Fellow

MS. SANDRA HODGKINSON
Distinguished Visiting Research Fellow

COL MICHAEL P. HUGHES, USAF
Senior Military Fellow

MR. TETSUYA ITO
Visiting Research Fellow

DR. CHRISTOPHER J. LAMB
Distinguished Research Fellow

DR. ANDRE LE SAGE
Senior Research Fellow

DR. THOMAS F. LYNCH III
Distinguished Research Fellow

MR. LEO G. MICHEL
Distinguished Research Fellow

DR. JOHN PARKER
Visiting Research Fellow

DR. JAMES J. PRZYSTUP
Senior Research Fellow

LTC JOEL D. RAYBURN, USA
Senior Military Fellow

CAPT MARK E. REDDEN, USN
Senior Military Fellow

DR. NICHOLAS ROSTOW
Senior Director

DR. PHILLIP C. SAUNDERS
Director of Studies

DR. JUDITH S. YAPHE
Distinguished Research Fellow

DR. CHRISTOPHER YUNG
Senior Research Fellow

For a complete list of INSS researchers and staff, please visit www.ndu.edu/inss/index.cfm.

NDU Press