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The Chinese Defense Economy's Long March from Imitation to Innovation

Tai Ming Cheung [a]

[a] University of California Institute on Global Conflict and Cooperation/University of California San Diego , USA

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The Chinese Defense Economy's Long March from Imitation to Innovation

TAI MING CHEUNG

University of California Institute on Global Conflict and Cooperation/University of California San Diego, USA

ABSTRACT China's defense economy has been vigorously developing a comprehensive set of innovation capabilities that will eventually allow it to join the world's top tier of military technological powers. China's target is to catch up by 2020. Although this maybe possible in a few select areas, the defense economy as a whole will likely require another decade or more to successfully master the ability to produce major innovations of a radical nature. This paper analyzes the key areas in the Chinese defense economy's gradual but accelerating shift from imitation to indigenous innovation.

KEY WORDS: Defense, Innovation, Technology

In its quest for defense technological excellence and self-sufficiency over the past 60 years, China has sought to pursue a two-pronged development strategy of indigenous innovation and imitation. But the country's technological backwardness, economic underdevelopment, and international isolation during much of this period meant that innovation took a back seat. A few sectors of critical strategic importance did successfully nurture home-grown technological capabilities, most notably the nuclear weapon and ballistic missile programs, but the overwhelming proportion of the conventional defense economy has relied on the copying, adaptation, and incremental improvement of foreign technologies.[1]

With growing prosperity and global integration in the twenty-first century, China's leaders have called for the building of a world-class indigenous national innovation system that would allow the country and

[1]For a review of this development period, see Tai Ming Cheung, *Fortifying China: The Struggle to Build a Modern Defense Economy* (Ithaca, NY: Cornell UP 2009).

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the defense economy to meet all its technological needs within the next couple of decades. Under intense leadership scrutiny, China's weapons designers and builders are busy forging an autonomous innovation capacity. Considerable progress has been made as a result of ample access to financial, human, and research resources, strong political support, inflows of foreign technologies and know-how, and the introduction of advanced modes of governance, market competition, and management.

This paper examines the progress made by the Chinese defense economy in shifting from imitation to indigenous innovation. It will begin by identifying key capabilities that a state requires in advancing along the innovation path and the different stages and development routes from imitation to innovation. This will be followed by a detailed review of the evolution in innovation capabilities of the Chinese defense economy over the past decade.

Defining Indigenous Innovation with Chinese Characteristics

Zizhu Chuangxin (自主创新), or innovation with Chinese characteristics, has become a core aspiration for China's leaders, scientific community and defense economy since the early years of the twenty-first century. References to *Zizhu Chuangxin* have soared since the phrase was adopted as a central principle in the country's latest Medium- and Long-Term Science and Technology Development Plan (MLP) in 2006.[2] Different translations of *Zizhu Chuangxin* abound, with the most popular being indigenous innovation, independent innovation, autonomous innovation, self-reliant innovation, endogenous innovation, or sovereign innovation. The term is defined in the MLP as a way to promote original innovations by reassembling existing technologies in different ways to produce new breakthroughs and absorb and upgrade imported technologies.[3] One of the key concepts highlighted here is the combination of existing technologies in novel ways.

The Chinese approach to *Zizhu Chuangxin*, which will be defined as indigenous innovation in this paper, appears to be a practical, gradualist, and hybrid strategy that focuses primarily on the assimilation of

[2]A keyword search of *Zizhu Chuangxin* in the journals section of China Knowledge Resource Integrated Database (CNKI) found that the term first appeared in 1994 with two references. The term became widely used from 2005 and peaked in 2007 when there were more than 11,500 article references to the phrase. This intensity subsequently declined to 6,600 references in 2009. I am indebted to Lu Hanlu for this information.

[3]The actual definition of *Zizhu Chuangxin* is 'original innovation, integrated innovation, importation, absorption, assimilation, and re-innovation'. 'People's Republic of China State Council, Guidelines for the Medium- and Long-Term National Science and Technology Development Program (2006–2020)', (Beijing 2006), Ch. 2, Sec. 1.

domestic and foreign knowledge and technologies that are improved upon so that they become original. The MLP also stresses the importance of 'improving indigenous innovative capabilities, mastering a number of core technologies, and ownership of a number of proprietary intellectual property rights,' although this should be achieved through the 'absorption, assimilation, and re-innovation' of existing and external technologies.

Assessing a State's Innovation Potential: Hard and Soft Capabilities

A useful starting point in examining the Chinese defense economy's journey from imitation to indigenous innovation is to understand how states learn and pursue innovation during different stages of their economic development.[4] The pace, sophistication, and effectiveness of technological progress depends on the capabilities available to conduct innovation activities, which can be sorted into two broad categories. The first group consists of 'hard' innovation capabilities, input factors intended to advance technological and product development. This includes research and development facilities such as laboratories, research institutes and universities, human capital, contribution of enterprises, manufacturing capabilities, access to foreign technology and knowledge, and availability of funding sources.

The second category is made up of 'soft' innovation capabilities. The sources of innovation in this group are far broader than hard factors and cover political, institutional, relational, social, and other factors that shape non-technological and process-related innovative activity. This is what innovation scholars such as Moses Abramovitz define as 'social capability.'[5] These soft capabilities include organizational, marketing, and entrepreneurial skills as well as governance factors such as the existence and effectiveness of legal and regulatory regimes, the role of political leadership, promotion of standards, and corporate governance mechanisms.

The Different Stages and Paths from Imitation to Innovation

For states in their formative periods of industrialization, the principal means of technological development is through the absorption of already existing foreign-derived technology. This is because they lack both hard and soft innovation capabilities. In a study of the successful

[4]See Linsu Kim, *Imitation to Innovation: The Dynamics of Korea's Technological Learning* (Boston: Harvard Business School Press 1997).

[5]Moses Abramovitz, 'Catching Up, Forging Ahead, and Falling Behind,' *Journal of Economic History* 46/2 (1986), 385–406.

development of newly industrializing economies in Asia, Linsu Kim and Richard Nelson observed that absorption stemmed largely from the reverse engineering of available foreign technologies.[6] They noted that there are two distinct forms of imitation that correspond with different stages of development. The initial phase is 'duplicative imitation', in which products are closely copied with little or no technological improvements. This requires low levels of hard and soft innovation capabilities. This is a passive 'black box' form of absorptive learning in which technological capabilities for production are provided but not the underlying blueprints or source technologies. The Chinese defense economy went through this duplicative imitation phrase during the 1950s and 1960s.

Creative imitation is a second and more sophisticated form of imitation that aims at 'generating imitative products but with new performance features'.[7] This imitation can come in several forms of which the most basic approach is design copying that mimics the style or design of the market leader but the copier has their own brand name and engineering specifications. A classic example of this is the Chengdu J-7 fighter aircraft, which is a copy of the 1960s generation Soviet MiG-21 fighter.

The next level up is creative adaptation, in which products are inspired by existing foreign-derived technologies but differ from them significantly. These more advanced imitation methods require increasing levels of hard and soft innovation capabilities, especially the ability to conduct research and development (R&D) and strategic marketing activities. For the Chinese defense economy, this creative imitation phase has spanned from the 1970s to the present day. Design copying was the primary form of imitation between the 1970s and 1980s, but creative adaptation became more prevalent in the 1990s with the development of innovation capabilities.

China's aviation industry has led the way in creative adaptation through its extensive access to the technological capabilities of the Russian aviation industry, especially in the reverse engineering of the Russian Su-27 'Flanker' fighter-aircraft. After absorbing and mastering the technology and knowledge transfers that the Russians provided for the aircraft, the Chinese undertook the illicit reverse engineering of the Su-27, which they referred to as the J-11B. The J-11B is reportedly a generational improvement over the Su-27 with the addition of new capabilities such as a reduced radar cross-section, improved fire-control radar, wide use of composite materials, a new flight control system,

[6]Linsu Kim and Richard R. Nelson (eds), *Technology, Learning, and Innovation* (Cambridge UP 2000), 3–5.
[7]Kim and Nelson, *Technology, Learning and Innovation*, 5.

a digital glass cockpit, and a Chinese-developed engine.[8] As the Chinese were engaged in this imitation, they terminated negotiations with Russia to build more Su-27s. Moscow was incensed after it discovered what was going on and this led to a sharp, but temporary, chill in Chinese–Russian defense technological cooperation.

Overlapping and complementing these imitation approaches is incremental innovation, which is also extensively practiced by the Chinese defense economy. Incremental innovation and creative adaptation are key elements in the Chinese government's *Zizhu Chuangxin* strategy. The main difference between creative imitation and incremental innovation is that the former involves the adaptation of foreign acquired technologies while incremental innovation is the limited updating of existing indigenously developed systems and processes. This innovation is often the result of organizational and management inputs aimed at producing different versions of products tailored to different markets and users, rather than significant

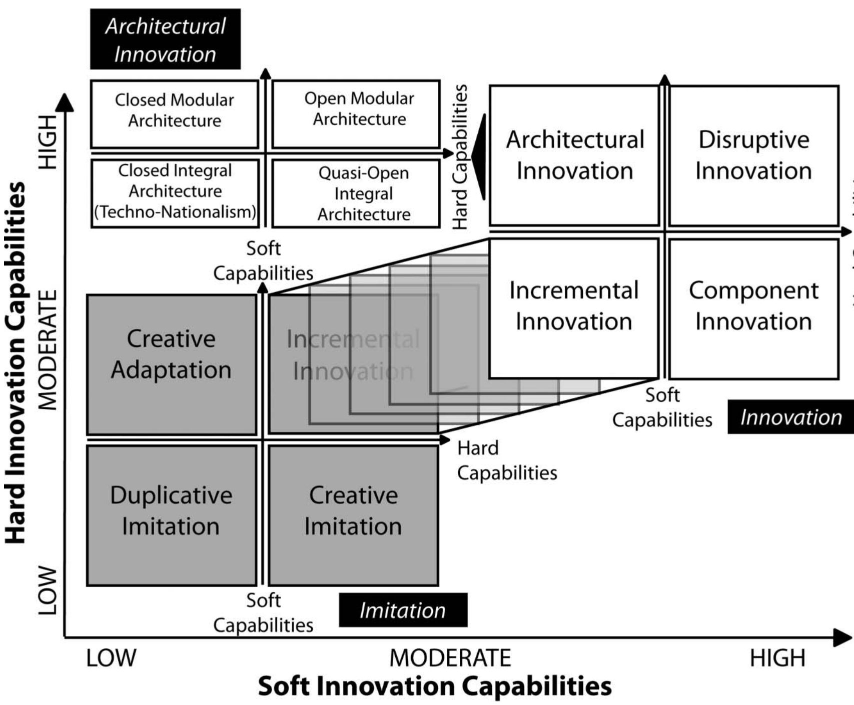

Figure 1. Types of Innovation.

[8]Andrei Chang and Yuri Baskov, 'China's Imitation of Su27SK and Its Impact', *Kanwa Asian Defense Review* (May 2008), 14–15.

technological improvements through original R&D. Incremental innovation is one of the primary pathways of innovation for the Chinese defense economy for the near-to-medium term because it is the most suited to its technological capabilities. Several defense sub-sectors, including the aviation, shipbuilding, ordnance, and electronics industries, have come out with new generations of weapons systems over the past decade that are subsequently updated on a regular basis.

As innovation capabilities become more sophisticated, the next stage of progress is architectural innovation. This refers to 'innovations that change the way in which the components of a product are linked together, while leaving the core design concepts (and thus the basic knowledge underlying the components) untouched.'[9] The primary enablers are improvements in organizational, marketing, management, systems integration, and doctrinal processes and knowledge that are coupled with a deep understanding of market requirements and close-knit relationships between producers, suppliers, and users.[10]

As these are also the same factors responsible for driving incremental innovation, distinguishing between these different types of innovation poses a major analytical challenge. While many of these soft capabilities enabling architectural innovation may appear to be modest and unremarkable, they have the potential to cause significant, even discontinuous consequences through the reconfiguration of existing technologies in far more efficient and competitive ways that challenge or overturn the dominance of established leaders. Andrew Ross points to the all-volunteer force, maneuver warfare, and German Blitzkrieg doctrine as examples of architectural innovations and architectural breakthroughs that were caused by the development of new operational doctrines or the establishment of new organizations.[11] China's efforts to develop asymmetrical warfare doctrine and capabilities are also another example of architectural innovation, especially the employment of ballistic missiles as an anti-access weapon against the United States.[12]

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[9]Rebecca Henderson and Kim Clark, 'Architectural Innovation: The Reconfiguration of Existing Product Technologies and the Failure of Established Firms', *Administrative Science Quarterly* 35/1 (March 1990), 10.

[10]Dieter Ernst, *A New Geography of Knowledge in the Electronics Industry? Asia's Role in Global Innovation Networks*, East-West Center, Policy Studies No. 54 (2009), 10.

[11]Andrew L. Ross, 'On Military Innovation: Toward an Analytical Framework', paper presented at the Conference on China's Defense and Dual-Use Science, Technology, and Industrial Base, University of California, San Diego, 1–2 July 2010, 14.

[12]See Thomas G. Mahnken, 'China's Anti-Access Strategy in Historical and Theoretical Perspective', *Journal of Strategic Studies* 34/3 (June 2011), 299–323; and Andrew Erickson and David Yang, 'Using the Land to Control the Sea? Chinese Analysts Consider the Anti-Ship Ballistic Missile', *Naval War College Review* 62/4 (Autumn 2009), 53–86.

For China, low-end architectural innovation is beginning to take root in several industrial and high technology sectors, most notably in the automobile, telecommunications, and information technology industries. One type of low-end Chinese architectural innovation that has become popular since the mid-2000s is *Shanzhai* (山寨) or 'guerrilla' innovation in which small-scale Chinese firms, often working closely together in vertically integrated alliances, produce low-cost copycat models of foreign products such as mobile phones and automobiles, but with improved features.[13] Some of these *Shanzhai* companies have emerged to become major players in the Chinese mobile telephone and automobile industries.

In the defense economy, the aviation and shipbuilding sectors are spearheading the embrace of architectural innovation. The fledging commercial aviation industry stands out for designing its long-term development model around this approach. In its development of the ARJ-21 trunk liner and C-919 single-aisle passenger aircraft, the aviation industry is concentrating its efforts on airframe design and sourcing most of its components from foreign suppliers. Local content will only account for 10 percent of the ARJ-21 and this will increase to 30 percent for the C-919, with all the critical technologies being imported.[14] A critical element in this foreign dependence of Commercial Aviation Corporation of China is its willingness to allow these suppliers to assume a prominent role in systems design and integration, including at the concept definition phase.[15]

Component innovation is the next step up the innovation ladder and involves the development of new component technology that can be installed into existing system architecture. While imitation, incremental, and architectural innovation depend more on organizational and marketing innovation skills, component innovation emphasizes hard innovation capabilities such as advanced research and development facilities, a cadre of experienced scientists and engineers, and large-scale investment outlays. Component innovation is an area of major weakness for much of the Chinese defense economy, especially the more high-technology-oriented sectors such as the aviation and naval sectors. Chinese avionics, radars, fire-control systems, and engines lag at least one to two generations behind leading international competitors

[13]Sheng Zhu and Yongjiang Shi, 'Shanzhai Manufacturing: An Alternative Innovation Phenomenon in China', *Journal of Science and Technology in China* 1/1 (2010), 29–49.
[14]Gao Lu, 'Chinese Jetliner Development is on Track,' *Guoji Xianqu Daobao*, 9 June 2009.
[15]Michael Mecham, 'Yankee Support', *Aviation Week and Space Technology*, 19 July 2010, 59–60.

and the near-term prospects of narrowing this gap are poor because of the under-development of the country's R&D capabilities.

At the top of the innovation chain is radical innovation. Radical innovation requires major breakthroughs in both new component technology and architecture and only countries with broad-based, world-class R&D capabilities and personnel along with deep financial resources and a willingness to take risks can engage in this activity. This type of innovation is required for the development of 5th-generation stealth aircraft. Radical innovation is currently beyond the ability of the Chinese defense economy, but the country has shown with its strategic weapons programs in the 1960s that it can engage in such high-quality work despite the lack of world-class R&D capabilities and isolation from the outside world.[16]

There is considerable debate as to whether China's stealth-like J-20 fighter aircraft represents a radical innovation.[17] While Internet images of the J-20 provide external details of its design profile, there are critical knowledge gaps that make it difficult to determine whether the aircraft represents an incremental or breakthrough technological innovation or more likely an architectural innovation. One big question concerns how stealthy the aircraft is. This refers to its ability to minimize its radar-cross section through its architectural design and radar-absorbent composite materials. Another issue concerns the sophistication and integration of avionics capabilities. The latest generations of state-of-the-art Western fighter aircraft are now being equipped with Active Electronically Scanned Array radar and advanced sensors; there are few indications that the Chinese defense industry has been able to master this technology. Additionally, stealth aircraft are supposed to be exceptionally maneuverable and able to cruise at high speeds because of high-performance vectoring engines.

If the J-20 were able to meet all or even some of these requirements, it would be a remarkable breakthrough technological accomplishment. While the Chinese aviation industry has made some important progress in the fields of composite materials, avionics and sensors, design processes, and propulsion technology over the past decade, these technological capabilities and standards remain considerably short of world-class standards. For example, the Chinese aero-engine sector has yet to begin serial production of its own high-performance turbofan engines such as the WS-10 even though it claims to have mastered development a few years ago.

[16]See Cheung, *Fortifying China*, Ch. 2.

[17]See Tai Ming Cheung, 'What the J-20 Says About China's Defense Sector', *Wall Street Journal Blog*, 13 Jan. 2011.

The Development of Hard Innovation Capabilities in the Chinese Defense Economy

The Chinese defense economy is undertaking a broad and concerted effort to improve its hard innovation capabilities in order to sustain its rapid climb up the innovation ladder and into the top tiers of the world's advanced military technological powers. The most important of these hard innovation capabilities include the research and development apparatus, the talent pool of scientists and engineers, access to capital markets and investment funds, the role of defense conglomerates, linkages with foreign flows of technology and global innovation networks, and benefits that come from civil–military integration activities.

Building an Advanced Research and Development Apparatus

The Chinese defense R&D apparatus has been undergoing a far-reaching overhaul and expansion since the late 1990s to overcome serious organizational, management, and operational problems that crippled its ability to conduct high-quality work. The key goals of these reforms have been to enhance basic research capabilities, diversify management oversight and funding sources from the state to the corporate sector, tear down the barriers that have kept the defense R&D system separate from the rest of the national innovation system, and forge close linkages with universities and civilian research institutes.

A major push has been taking place since the second half of the 2000s to speed up the establishment of a high-end basic research capability in both the national and defense arenas. This was highlighted by Premier Wen Jiabao in his central work report in 2008 when he said that an important priority in the building of China's national innovation system was the 'construction of an array of state laboratories, national engineering centers, and enterprise-oriented platforms for innovation support and enterprise technology centers.'[18]

The development of a robust defense R&D system was also highlighted in the 'Defense Industry 2006–2020 Medium- and Long-Term Science and Technology Development Plan' (Defense MLP) that was issued by the Commission for Science, Technology, and Industry for National Defense (COSTIND) in 2007.[19] The 15-year plan emphasized six key R&D priorities:

[18]Wen Jiabao, 'Report of the Work of the Government', (State Council of the People's Republic of China, 5 March 2008), <www.chinadaily.com.cn/china/2008npc/2008-03/19/content_6549177.htm>.

[19]'Summary of the Medium- and Long-Term Science and Technology Development Plan for the Defense Industry' (Commission of Science, Technology and Industry for

- Promote the corporatization of R&D institutes and speed up the transformation of public research institutes into shareholding entities.
- Develop a strong defense laboratory system along with advanced technology application centers. A chief laboratory scientist responsibility system should be established to run these laboratories, which is similar to the chief designer system that manages weapons R&D projects.
- Establishment of a defense science and technology (S&T) basic research innovation fund and a requirement that defense firms and research institutes invest 3 percent of their annual sales into R&D.

China has been building up a network of national-level science and engineering laboratories since the mid-1980s to spearhead its technological modernization. But while more than 220 of these key state laboratories had been established by 2008, insufficient funding stunted their research performance. Between 1984 and 2004, total investment in these laboratories totalled a paltry Renminbi (RMB) 1.9 billion, much of which was spent on maintenance and salaries. In 2008, the Chinese government decided to increase significantly funding to these laboratories and undertake an overhaul to weed out the weakest.[20]

COSTIND and the People's Liberation Army (PLA) launched their own initiative during the 10th and 11th Five-Year Plans (2000–2010) to expand and upgrade the defense R&D laboratory system, which today numbers around 90 laboratories.[21] A centerpiece of this effort was the establishment of a select number of new defense-oriented laboratories in leading research universities as well as COSTIND-affiliated universities. COSTIND and its successor SASTIND have established more than 50 of these units.[22]

Another important initiative has been a concerted effort to corporatize key segments of the defense R&D process to lessen the financial dependence on the state. This involves locating the country's ten big conglomerates at the heart of the defense innovation system by having them set up their own research and technology development

National Defense, 20 June 2007), <www.costind.gov.cn/n435777/n1146913/n1440180/n1440183/105777.html>.

[20]'China Sets Up Funds for Key Labs', *Xinhua News Agency*, 3 March 2008.

[21]Hou Guangming, *The Organization and Policy Research of Military–Civilian Technology Transfers* (Beijing: Science Press 2009), 5.

[22]Yang Yue, 'Raise Innovative Ability to Promote Sustainable Development', *Zhongguo Guofang Keji Gongye* [China Defense Science, Technology, and Industry], Aug. 2009, 16–19.

centers as well as take over public research institutes. The primary goals of this reform are (1) to reduce the complete dependence of the R&D apparatus on the state for research funding; (2) increase the amount of investment that firms devote to R&D, especially in applied and commercial development; (3) allow state funds to be concentrated in basic research; (4) promote interaction with universities and research institutes; (5) concentrate more resources on developing high-technology and dual-use products; and (6) speed up the exploitation and commercialization of proprietary R&D output. In the civilian arena, corporate R&D now accounts for 65 percent of total R&D funding, which is almost entirely targeted at commercial development. The remaining 35 percent of funds comes from the state and is intended for basic R&D activities.

COSTIND's stipulation in its Defense MLP that defense enterprises and research institutes invest at least 3 percent of their annual revenues in R&D during the plan is a highly ambitious target as Chinese large- and medium-sized enterprises spend less than three quarters of one percent of their annual revenues on R&D.[23] Nonetheless, two of the ten defense conglomerates pledged to meet or exceed this ratio. China Electronics Technology Group said that it would spend no less than 5 percent of its annual revenues for R&D while China Ordnance Industrial Group Corporation said that it would require its subsidiaries to plough back at least 2.5 percent of their sales into R&D.[24]

With many laboratories and technology centers only established in the last decade, the defense industry's institutional capacity for innovation has significantly expanded. However, the actual ability of these units to conduct high-quality innovative research is questionable because of their lack of operational experience and qualified personnel. The establishment of entities able to engage in R&D that would lead to radical technological breakthroughs requires extensive periods of nurturing and access to a world-class talent pool. But as Qian Xuesen, one of China's most distinguished defense scientists, explained to Wen Jiabao in 2005, one of the major issues holding back China's science and technology was that the country's universities were unable to produce innovative scientific and technical personnel.[25] Within the

[23]Organization for Economic Cooperation and Development, *OECD Review of Innovation Policy: China* (Paris: OECD 2008), 154.

[24]'Major Initiatives of 11 Military Industrial Enterprise Groups on Promoting Indigenous Innovation,' (Commission of Science Technology, and Industry for National Defense, 4 July 2007), <www.costind.gov.cn/n435777/n1146913/n1440180/n1440190/108392.html>.

[25]Denis Fred Simon and Cong Cao, *China's Emerging Technological Edge: Assessing the Role of High-End Talent* (Cambridge UP 2009), 164.

entire defense S&T laboratory system, only one scientist had been elected as an academician in the Chinese Academy of Sciences by 2009.[26]

Cultivating Scientific and Engineering Talent

The Chinese defense economy has strong and growing demand for new generations of well-trained scientists, engineers, managers, and skilled factory workers to replace the greying ranks of its two-million-strong workforce and fill new positions created by the rise of new high-technology sectors. While the country's higher educational establishment is able to produce large quantities of science and engineering graduates to satisfy demand from both the civilian and defense economies, the quality of this talent pool is far from adequate.

The number of natural science and engineering (NSE) graduates from Chinese higher education institutions has surged since the late 1990s. In 1998, there were around 250,000 NSE first degree graduates, but this more than tripled to 800,000 by 2006. By comparison, the US produced 250,000 NSE graduates in 2006.[27] Upwards of 70 percent of the Chinese graduates are engineering majors.

Perhaps a better gauge of advanced educational quality that contributes to innovative capacity is the number of awards for postgraduate degrees. Around 10–12 percent of all NSE degrees issued annually in China are at the masters or doctorate level, which in 2005 numbered around 120,000. For doctorates, China has made significant strides. The country issued 1,900 doctorates in 1993, but this climbed to 21,000 in 2006.[28] The United States awarded 22,500 doctorates in 2006, although 24 percent of them were given to Chinese nationals.[29] Although these figures are impressive, they barely tap into the full potential of the Chinese human resources talent pool.[30]

The Chinese defense S&T educational establishment has also undertaken a major expansion in its training capabilities over the past decade, although on a more modest scale compared with the civilian sector. The seven universities affiliated with the State Administration

[26]Yang, 'Raise Innovative Ability to Promote Sustainable Development',18.
[27]*Science and Engineering Indicators 2010*, National Science Board (Arlington, VA: National Science Foundation), O-7. The OECD has different estimates of Chinese NSE graduates. It reports that there were 0.5 million NSE graduates in 1995 and 1.5 million in 2005. While these numbers include postgraduates, the discrepancy with the NSF figures is significant. *OECD Review of Innovation Policy: China*, 316.
[28]*Science and Engineering Indicators*, National Science Board, O-8.
[29]*Science and Engineering Indicators*, National Science Board, 2-27.
[30]*OECD Review of Innovation Policy: China,* 316.

for Science, Technology and Industry for National Defense (SASTIND), the successor to COSTIND, registered an 86 percent increase in its total student populations between 1999 and 2005. The total number of students in these universities numbered 230,000 in 2005. The quality of these students was also higher, with the number of postgraduate students accounting for a greater proportion of total numbers. The ratio of postgraduate to undergraduate students rose from 1:4.3 in 1999 to 1:2.2 in 2005.[31]

These SASTIND universities are a major, although not exclusive, pipeline of human talent to the defense economy. Of the 284,000 students who graduated from these universities between 1999 and 2005, 18 percent or 52,000 went to work in the defense economy. More significantly, 35 percent of those going into the defense economy, or 18,000 people, were postgraduates, which indicates that the quality of human talent being recruited by the defense S&T establishment is of a higher quality than the rest of the national innovation system.

This influx of younger talent is transforming the demographic make-up of the defense economy. The aging of the defense S&T workforce had been a deep concern during the 1980s and 1990s as many of the senior and rank-and-file pre-Cultural Revolution-era employees were reaching retirement age. But an analysis of the age structure of the technical workforce at Aviation Industry Corporation of China (AVIC) 1 in 2003 provides a window into the demographics of the general defense economy: 42 percent of the employees are under 35 years old and only 9 percent are 55 years or older.[32] Moreover, between 2000 and 2003, when AVIC 1 cut its technical workforce by 16 percent from 100,648 employees to 86,818 employees, the biggest demographic change was in the increase of workers in the 36–45 age range from 28 percent to 32 percent of the workforce and a decrease of employees in the 46–54 age range from 21 percent to 17 percent of the technical staff. Although these statistics show a corporation with a relatively young workforce, it also suggests that there may be a shortage of senior, experienced employees.

This passing of leadership from older to significantly younger generations does appear to have taken place at the senior levels of the defense economy over the past decade. Fourth- and fifth-generation post-Cultural Revolution-educated scientists, engineers, and technocrats in

[31]Jin Lixia, 'Study of the Ability of COSTIND-Affiliated Universities to Contribute to the Indigenous Innovation Capabilities of the Defense Science and Technology Base', master's thesis, Harbin Institute of Technology, China, June 2006, 19.

[32]Shanghai Univ. of Economics and Finance 500 Strongest Enterprises Research Center, '500 Strongest Enterprises Report: China's 100 Strongest in 2006' (Shanghai: Shanghai Univ. of Economics and Finance Press 2007), 460.

their mid-40s to mid-50s are assuming top corporate, bureaucratic, and project management posts and replacing their second- and third-generation elders. Many of these new leaders have science and engineering degrees from defense industry–affiliated universities.

Opening Up to Capital Markets

One of the most significant initiatives in the modernization of the defense economy since the mid-2000s has been its opening up to the capital markets and non-state economy to allow defense industrial firms to raise new sources of financing. This reform was detailed in the 2006–10 11th Five-Year Program, which called for the deepening of 'reform of the investment structure of defense industry' and diversification of major investors in the defense sector.[33] A key goal is to expand the sources of funding available for defense firms to reduce their heavy reliance on the state. Chinese officials have said that the limited access to investment funds has been a major factor holding back the defense economy's growth and technological modernization.[34]

The authorities are especially eager to attract domestic state-owned, private and even foreign firms to acquire equity stakes in defense companies as well as allow them to list on the country's two stock markets in Shenzhen and Shanghai and also in Hong Kong. COSTIND issued a series of policy guidelines and regulations in 2007 to define the framework of this market liberalization.

Defense industrial firms have been allowed to list on the stock markets since the early 1990s, but under tight restrictions that precluded entities involved in military-related work. The more permissive regulatory regime now would allow firms with military programs to make stock market or private listings to outside investors as long as they satisfied secrecy regulations and their defense projects were not deemed to be too sensitive.

This financial opening up of the defense economy was slowed down by the 2008–09 global financial crisis, as stock and capital markets in China and around the world sharply cut back on their willingness to provide funding to companies. With access to these markets temporarily curtailed, defense companies appeared to slow down their pace of reforms, especially restructuring themselves into shareholding entities that would allow them to issue shares to outside investors.

[33]National Development and Reform Commission (NDRC) of the People's Republic of China, 'Outline of the 11th Five-Year Program', Ch. 45.

[34]See Wang Xiaobin, 'Analysis and Evaluation of the Capabilities of the Defense Science, Technology and Industrial Base,' Master's thesis, Harbin Institute of Technology, China, 2007, 43.

Defense regulatory authorities had hoped that all state-owned defense firms would be reorganized into shareholding outfits by 2013, but only 22.5 percent of these firms had completed this shareholding restructuring by the end of 2007, compared with 65 percent in the national economy.

The number of defense industrial firms listed on the Chinese and Hong Kong stock markets in 2010 numbered in the mid-60s, and only a handful were able to conduct initial public offerings in 2008 and 2009. Many defense enterprises decided instead to borrow from state-owned banks to take advantage of the government's generous stimulus program. This suggests that instead of looking to the stock markets as their principal source of fund raising, defense firms may rely far more on other modes of capital acquisition, especially the corporate bond market, bank lending, and non-stock market private placements.

The Growing Innovation Potential of the Defense Conglomerates

China's ten sprawling defense conglomerates have emerged over the past decade to become the most important cogs in the defense innovation system. This is a far cry from the central planning era when they functioned as quasi-state bureaucracies rather than independent commercial corporations. Painful downsizing initiatives, debt restructuring, and access to new sources of capital combined with a strong uptick in defense and civilian orders have led to an impressive turnaround in the business operations of the defense conglomerates since the early 2000s. In 2008, total profits for the defense industry are estimated to have been around RMB 45 billion, which was the highest in its history.[35]

The central authorities are keen to build upon these successes by pushing the defense conglomerates to accelerate their reform efforts, but with major adjustments in the direction and focus of this restructuring strategy. One significant departure took place in 2008 when AVIC I and II were consolidated into a single entity, only nine years after they were separated.[36] This signalled a major step back for the defense economy's de-monopolization strategy. A key reason

[35]No official figures for defense industry profits have been released since 2007 when the figure was RMB 43 billion, but defense industry officials announced a 6 percent increase in profits in 2008 over the previous year, which would have been an RMB 2.5 billion rise. See Chen Qiufa, 'Unremitting Efforts Made in the Construction of an Advanced Defense Industry', *Zhongguo Guofang Keji Gongye*, Jan. 2009, 11; and Lu Zhou, 'Profits of Military Industrial Enterprises Last Year was RMB 43 Billion, Double the Profit of Three Years Ago', *Zhongguo Zhengquan Bao*, 8 Jan. 2008.

[36]'China Discusses Feasibility of Large Aircraft Program,' *Xinhua News Service*, 3 July 2008.

behind this move was that the 1999 separation of the aviation manufacturing sector was poorly conceived and had weakened the Chinese aviation industry's competitiveness because of widespread duplication of activities.[37]

Additionally, the two companies were squeezed out of the international marketplace by far larger Western firms. The annual sales revenues of Boeing, for example, is four times the combined total for AVIC I and AVIC II. The remerged AVIC has around 200 subsidiaries and assets of US$32 billion. If the new AVIC performs successfully, it could pave the way for the re-integration of the other defense conglomerates in the nuclear, shipbuilding, ordnance, and space sectors.

There are at least four reasons why these revamped defense enterprise groups are so important to the strengthening of the defense economy's innovation capabilities. First, they now own and manage a growing segment of the R&D apparatus. Second, their growing financial might allows these firms to invest heavily in innovation activities. Third, their collaboration with foreign companies and engagement in foreign markets makes them important conduits of external knowledge and technology. Fourth, it is in the core interest of these firms to support the development of key institutional mechanisms that will safeguard the results of their innovation activities, especially the strengthening of intellectual property rights protections.

One of the biggest obstacles though to these efforts to transform the defense conglomerates into innovation powerhouses is their continuing monopolistic dominance of the defense industry.[38] Monopolies stifle competition, a core dynamic for enabling innovation, and the return to single-firm monopolies of major sectors is a troubling sign.

Access to External Technology Flows and Linkages with Global Innovation Networks

China is a semi-pariah in the international defense industry. While its civilian economy is closely integrated into the global economy, the United States and its Western allies have shunned the Chinese defense sector since the end of the 1980s. Beijing has been able to sidestep this embargo by forging a close relationship with Russia, which has been a principal source of military technology, equipment, and knowledge since the beginning of the 1990s. This has been a fruitful marriage of convenience for both countries. China acquired upwards of $30 billion of weapons and defense technologies from Russia from 1992 to 2009,

[37]Charlotte So, 'AVIC Firms Reuniting To Form Aircraft Manufacturing Giant', *South China Morning Post*, 18 June 2008.
[38]Interviews with Chinese defense industry experts, China, Feb. 2011.

and this has played a vital role in enhancing the qualitative modernization of both the PLA and defense economy.[39] The Chinese sales have also been crucial in keeping the struggling Russian defense industry financially afloat.

Although self-sufficiency is an often-expressed goal in China's defense technological and industrialization modernization goals, this is a long-term strategic aspiration. The operational focus over the next one to two decades is to pursue a dual-track development strategy of acquiring and absorbing foreign technology that both complements and supports indigenous weapons R&D. The defense economy has employed various approaches in the pursuit of Russian and other foreign technological products and processes since the 1990s, ranging from off-the-shelf purchases to license production that allowed the transfer of technological products and manufacturing processes that were at least a generational leap ahead of existing Chinese technological levels.

The approach that offers the greatest opportunities for technology transfers and the nurturing of domestic industrial capabilities is joint design and development. At the beginning of the twenty-first century, the Chinese government asked Russia to undertake the joint development of new generations of weapons and supporting systems. Moscow has been lukewarm to these proposals because of concerns that this would allow the Chinese defense economy the means to fast track and rapidly catch up with Russian defense technological levels. Nonetheless, Russia has been willing to pursue some joint projects with China because of the strategic desire to retain close defense technological ties with one of its premier customers.[40]

These Russian suspicions and worries have been confirmed since the mid-2000s when the Chinese defense economy was discovered to have been furtively engaged in creatively adapting Russian weapons systems and indigenizing them through a combination of unauthorized reverse engineering and the widespread substitution of Chinese components for Russian parts. Platforms such as the Su-27 fighter and advanced defense electronic systems such as the radar and data link systems for the *Sovremenny* II 956E destroyer and the *Frigate* M2EM 3D and

[39]Russian sales totalled US$27 billion between 1992 and 2006 and has averaged $2 billion annually between 2001 and 2008. See Sergey Luzyanin, 'Analysis of Russian–Chinese Military–Technical Cooperation', *Moskovskiye Novosti*, 17 Aug. 2007; and 'Total of VTS Between Russia and China Has Amounted to $16 Billion in the Last 8 Years', *RIA-Novosti*, 10 April 2009.

[40]'Russian Official Notes Shift from Direct Arms Sales to Joint Projects with China', *Interfax-AVN,* 8 Oct. 2009.

Mineral-ME radar systems have all been successfully copied by China, much to the consternation of Russian suppliers.[41]

The Chinese defense economy appears to have made this reverse engineering-driven creative adaptation strategy a central tenet of its near-term development approach and this has caused a major slowdown in Russian arms sales to China in the past few years. Besides illicit reverse engineering, Chinese military, defense, industrial, and civilian intelligence agencies have aggressively sought access to non-public and classified technologies and knowledge from foreign countries using a wide assortment of legal and clandestine means.

Despite concerted efforts to break out of its international predicaments, the Chinese defense economy's prospects of changing the situation has had limited success. The US–led arms embargo remains strong, despite wavering by some Western European countries, such as France and Germany, in the early 2000s. China's defense technological cooperation with Russia appears to be on the mend after nearly breaking down during the second half of the 2000s because of Beijing's flagrant record of reverse engineering Russian weapons. Moscow began to signal in 2010 that it was once again willing to engage in joint weapons research and development with Chinese partners in areas such as air defense, naval equipment, and aviation projects.[42] Of particular interest was the sale of Su-35 fighter to equip China's impending aircraft carrier capability. This possible resumption in flows of Russian foreign technology and knowledge to China may remove the threat of a serious brake on the defense economy's urgent push to improve upon its innovation capabilities.

If the Chinese defense economy's links to foreign sources appear increasingly strained, the only useful alternative is through indirect access and collaboration in the civilian arena, especially in areas such as high technology, electronics, and information technology. Since the late 1990s, a growing trend has been the formation of global innovation networks that 'integrate dispersed engineering, product development, and research activities across geographic borders'.[43] Recent research on the global electronics industry, which often is a harbinger of change for the rest of the high-technology economy, indicates that the rise of global innovation networks has been rapid and will lead to far-reaching structural changes to the geography of innovation and production in

[41]Wu Xingchen and Andrei Chang, 'Business Cultures and Russia–China Military Cooperation', *Kanwa Asian Defense Review,* 15 Aug. 2007, 29–30, and Reuben Johnson, 'Sino-Russian Union Falters', *Janes Defense Weekly*, 7 Nov. 2007.

[42]'Russian Federation–China Military–Technical Coop Shows Positive Trend', ITAR-TASS, 9 Nov. 2010.

[43]Ernst, *A New Geography of Knowledge in the Electronics Industry?*, 1.

the high-technology sector within the next decade.[44] While these global innovation networks first originated in the United States, Europe, and Japan, they have now expanded into less developed regions, with China becoming one of the leading hubs of this reconfigured twenty-first century geography of offshore innovation.

Civil–Military Integration and Spin-On

Chinese civilian and military leaders have placed plenty of hope since the early 2000s on the ability of civil–military integration (CMI) to enhance the defense economy's innovation capabilities.[45] CMI encompasses a diverse range of activities based on the notion of harnessing the technological and industrial capabilities of the civilian economy to advance defense capabilities. Instead of relying on its own resources, the defense economy seeks to make use of commercially available technologies and manufacturing processes as a suitable substitute. CMI advocates argue that most of the technological needs of the military can be met through commercially available channels, although the actual experience from countries such as the United States is debatable.[46]

With this high-level political and bureaucratic support for CMI, modest functional and geographical pockets of CMI activity have appeared since the early to mid-2000s. The electronics, information technology, high-technology, and automotive sectors have been in the vanguard through the efforts of China Electronics Technology Group and non-state owned firms such as Huawei Technologies Ltd., Zhongxing Telecommunications Equipment Company Ltd., and Datang Telecom Technology Company Ltd.[47] Geographically, cities such as Mianyang in Sichuan Province have been designated as military-to-civilian S&T zones because of their concentration of industries with significant civil–military potential, including in areas such as optical technology, composite materials, and space and aviation-related technology.[48] But in overall terms, CMI has so far barely scratched the surface of the

[44]Ibid., 1–6.
[45]Cheung, *Fortifying China*, Ch.5.
[46]Mark Lorell, Julia Lowell, Michael Kennedy and Hugh Levaux, *Cheaper, Faster, Better? Commercial Approaches to Weapons Acquisition* (Santa Monica, CA: RAND 2000).
[47]Cheung, *Fortifying China*, 215–27.
[48]Tai Ming Cheung, 'Mianyang-Science at the Epicenter: The Shaken Foundations of Mianyang's Quest to be a Dual-Use and Hi-Tech Hub,' National Center for Technology and Law, George Mason Univ., VA (Aug. 2008), <http://www.law.gmu.edu/nctl/stpp/mianyang.html>.

Chinese economy. Less than 1 percent of the country's civilian high-technology enterprises are estimated to participate in defense-related activities.[49]

The ability of the Chinese defense economy to adopt successfully CMI practices will require major structural and operational reforms. It will need to be more transparent, adaptable, and market-oriented, but this clashes with its insular and secretive nature. This means that the introduction of CMI practices needs to take place alongside other key 'soft' reforms.

Development of Soft Innovation Capabilities

One of the most intractable challenges for the Chinese defense economy is to foster a creative and entrepreneurial innovation culture in a system renowned for its secrecy, conservatism, egalitarianism, and rigid adherence to bureaucracy and discipline. Changing long-held social, organizational, and cultural patterns of interaction and norms of behavior are likely to be far more difficult than increasing investment, recruiting new talent, and utilizing other 'hard' inputs. This section examines some of the most important 'soft' innovation factors, such as support from the top leadership, adopting a new state regulatory model, cultivating new institutional culture and governance norms, constructing a modern regulatory and standards-based regime, improving technology diffusion and promoting intellectual property rights protection, and enhancing the role and influence of the PLA, through the General Armament Department (GAD), in guiding technological development within the defense economy.

The Importance and Role of National Leadership Support

Active and credible support and guidance from the highest levels of the policy-making leadership is a crucial enabling factor in the Chinese defense economy's ability to carry out innovation activities. Leadership backing is essential in tackling key structural barriers that include entrenched bureaucratic inertia, risk-adverse decision making, institutional compartmentalization, and chronic project management problems that cause prolonged delays and cost overruns. Without outside leadership intervention and oversight, there is a high probability that many of the key achievements of the defense economy would not have happened. This would include the development of the

[49] Jiang Luming, Luo Yongguang and Liu Qun, 'Military-Civilian Integrated Development of Weapons and Equipment in China: Problems and Solutions', *Junshi Jingji Yanjiu* [Military Economic Research] (July 2010), 31–3.

nuclear and strategic missile programs in the 1960s, the turnaround in the fortunes of the defense economy since the end of the 1990s, and the launching of the country's manned space program in the mid-2000s.

Credible commitment from the political leadership to the defense economy can be demonstrated and measured in at least four ways. First, the most obvious form of signalling is through high-level speeches, visits to defense industrial facilities, and attendance at defense economy-related events by senior leaders.

Second, there is strategic guidance through policy reviews and longer-term development plans and projects. The enactment of the Defense MLP in 2006 is an indicator of the leadership's interest in the long-term vision and development trajectory of the defense economy. Another noteworthy signal of the leadership's support is the continuing importance and expansion of the 863 Project, which is the country's premier strategic high-technology development program.

Third, there is the leadership's direct and continuing engagement and oversight in the operations of the defense economy and of critical projects. This is often done through the establishment of leadership small groups and special committees. In defense S&T matters, one of the key mechanisms is the Central Special Committee, a high-powered ad hoc committee that is formally affiliated with the Central Military Commission, the country's top politico-military policy-making body. However, the Central Special Committee apparently lacks the administrative and decision-making capabilities to properly handle the supervision of major weapons projects, and there are calls to beef up its role and turn the committee into a permanent administrative organization.[50]

A fourth key measure of credible commitment by the leadership is the defense economy's access to funds and resources. This can come through regular budget allocations as well as through the leadership's willingness to mobilize state resources on special occasions for key strategic projects. The defense economy's improving economic performance since the early 2000s suggests that the leadership has been generous with its fiscal largesse.

In the aftermath of the 2008–09 global economic crisis, the Chinese leadership has made it clear that the goal of building a strong indigenous innovation capability has become even more pressing because the downturn showed that the country's technological and economic competitiveness still lags well behind world standards. The only way to maintain and sustain robust economic growth rates and be

[50]Jiang Luming *et al.*, 'Military–Civilian Integrated Development of Weapons and Equipment: Problems and Solutions.'

resilient against external shocks is through indigenous innovation.[51] To carry out this acceleration in technological development, the authorities have pointed out that the guiding hand of the state needs to become even more prominent. The State Council announced in June 2010 that 'the state-led mechanism for technological innovations' would be further strengthened, referring to the MLP and in particular government support for the development of the 16 high-priority large-scale projects at the heart of the plan.[52]

Establishing a New State Regulatory Model of Management

The establishment of a strong and transparent regulatory system of governance is a key dimension of the structural overhaul of the defense economy. But the numerous twists and turns this reform path has taken over the past 15 years suggests that there are contested views about the nature of this regulatory model, rooted in divergent bureaucratic and political interests.

The remaking of the defense industrial regulatory regime is part of a broader effort to create a new regulatory state model for the management of the Chinese political economy that dates back to the early 1990s. The Chinese authorities have sought to move away from the traditional fragmented authoritarian model of rule that was characterized by compartmentalization and stratification.[53] However, as Margaret Pearson has argued, the Chinese authorities are torn between the adoption of an 'East Asian State Development' regulatory model and an 'Independent Regulator System' model that is the standard in developed market economies, especially in Western Europe and North America. The East Asia development model is based on Japan's post-World War II regulatory model and is tolerant of state intervention to manage markets, favors well-connected firms, supports the creation of national champions, discourages excessive competition, and has little public accountability or transparency.[54] In contrast, the independent regulatory system emphasizes the importance of political independence, impartiality, and transparency.

[51]Li Xueyong, 'Beefing Up Efforts to Speed Up Indigenous Innovation, Focusing Attention on Accomplishing Transition of Economic Development Model', *Qiushi*, 1 June 2010.
[52]Yan Hao, 'China Bets on State-Led Scientific Research System to Shift Economy', *Xinhua News Service*, 3 June 2010.
[53]See Kenneth Lieberthal and Michel Oksenberg, *Policy Making in China: Leaders, Structures, and Processes* (Princeton UP 1988), 135–68.
[54]Margaret Pearson, 'The Business of Governing Business in China: Institutions and Norms of the Emerging Regulatory State', *World Politics* (Jan. 2005), 296–322.

While the independent regulator model has become the accepted international standard, Chinese authorities have been attracted to the developmental model because it embodies many of the views held by Chinese policymakers and regulators. As a consequence, Pearson argues that the emerging Chinese regulatory state model is a hybrid model that features select elements of the independent regulator and development frameworks, although with a bias towards the latter model. This includes nurturing the building of national champions, protecting favoured state firms, and allowing only limited competition. Moreover, new regulatory bodies that are established essentially inherit the norms, biases, and institutional interests of their predecessors as they are staffed by the same personnel.

The reform of the defense industrial regulatory system resembles the pattern described by Pearson. The principles of the new regulatory framework embrace many of the ideals of the developmental model, especially the willingness to support national champions, tight controls on market competition within the industry, and a lack of transparency. One issue that has yet to be resolved is what institutional norms and interests this new regulatory regime will adopt. This will depend to a large extent on how the dust settles in the bureaucratic contest for authority and power that has been taking place since the latest overhaul of the defense industrial regulatory system in 2008, when COSTIND was stripped of its status as a state commission and merged into a new super-ministry, the Ministry of Industry and Information Technology.[55]

Despite its downgrading, the renamed SASTIND emerged with only a limited reduction of its power and prestige. While it is a subordinate organization within the Ministry of Industry and Information Technology, SASTIND appears to have retained much of its autonomy and responsibilities. Among its key duties include leading the drafting of the 12th 5-Year defense development program. SASTIND was, however, stripped of its authority to oversee nuclear energy management and lost its role to the Ministry of Industry and Information Technology as the direct government counterparty to GAD.[56]

Although the restructuring of the defense industrial regulatory regime is still in progress and more changes to its framework can be expected, the general outlines of its operating principles and institutional norms are becoming more clearly defined. There will be

[55]'Xinhua Publishes Details of PRC State Council Institutional Reform Plan', *Xinhua Domestic Service*, 15 March 2008.

[56]Regulations on weapons-related issues are now issued jointly by the Ministry of Industry and Information Technology and GAD. For example, rules that were passed on armaments research and production licensing in April 2010 came from these two entities.

considerable similarities with the developmental regulatory model, including few inhibitions to direct intervention in the management of the industry; proactive efforts to nurture national champions, especially at the international level; ensuring the protection of the major conglomerates; tightly regulating competition; and limited transparency and public accountability. The impact on innovation capability is mixed. The downside is the lack of competition and transparency, but those firms that will be favored and selected as national champions are likely to benefit considerably under this regulatory framework.

Changing Industrial Culture and Governance Norms and Standards

One of the biggest challenges in nurturing the innovative spirit of the defense economy is to overturn an insular and conservative institutional mindset shaped by decades of central planning. This has meant a strong aversion to risk, a lack of competitive instincts, poor motivation, and weak disciplinary practices. To complement the reforms being undertaken to overhaul the defense economy's structure, organization, leadership, and other institutional problems, COSTIND launched an ideological campaign in the late 1990s known as the 'Four Mechanisms' to specifically address governance deficits.

The first issue was how to promote the idea and practice of competition, as this was a key aspect in the opening up and modernization of the defense economy. The second mechanism was evaluation. The lack of detailed, independent, and robust evaluations of the financial costs and technical and engineering specifications of major weapons projects has been a serious weakness of the Chinese defense economy. The consequences were rampant cost overruns for many projects and the failure of numerous programs. A more robust evaluation system has been established over the past decade through the recruitment and training of financial audit personnel and technical specialists.

Supervision is the third component. Monitoring the activities of defense economy personnel has been stepped up to counter the spread of corruption and other economic malpractices that have soared in the reform era. While this issue has been shrouded in secrecy, the lucrative opportunities available in the booming defense economy are likely to have led to growing abuses. One of the rare cases made public was the arrest of Kang Rixin, the general manager of China National Nuclear Corporation in 2009.[57] The authorities and enterprises have sought to address this problem through administrative and organizational initiatives, including the establishment of numerous organizations to prevent and investigate abuses.

[57] 'China Nuclear Chief Latest Hit in Graft Crackdown', *AFP*, 5 Aug. 2009.

The fostering of a committed and motivated workforce is the focus behind the concept of encouragement that is the final element in the four mechanisms. The goal is to develop techniques and incentives that will encourage the grooming of more innovative and hard-working employees. This includes the use of traditional Communist practices such as ideological and propaganda campaigns, improving labor and human relations management, and the adoption of more modern market-based concepts such as financial incentives, performance-related mechanisms, and intellectual property protection.[58]

The Chinese government and the defense economy began to pay serious attention to intellectual property protection from the mid-1990s, which in particular has led to the development of a robust patent regime since the beginning of the twenty-first century. Special attention in particular has been paid to enhancing the protection of scientists involved in both civilian and defense-related R&D. This has led to a virtual explosion in defense patent applications since 2000, which has been mirrored in the civilian arena. In 2008, the defense industry filed nearly 11,000 patent applications, compared to just 313 a decade earlier. More than 40,000 patents were filed between 1985, when the first application was made, and 2008, of which 58 percent were for invention patents. The pace of filings, which has been growing at an annual rate of 40 percent since 2000, is likely to continue to increase as the PLA and defense economy established a long-term national defense intellectual property-rights strategy implementation plan in 2009.

Another fundamental requirement of a modern and innovative defense economy is a comprehensive and coherent institutional framework of regulations and technical standards to guide technological development. Without clear standards, rules, and practices, the diffusion of technical know-how, sharing of information, and undertaking of advanced and complex manufacturing activities is seriously compromised. The Chinese defense economy did not begin to seriously construct such a system until the end of the 1990s.

When the GAD was established in 1998, one of its first priorities in conjunction with COSTIND was to strengthen and expand this regulatory and standards regime. The first regulations were issued in 2000 and there has been a steady flow of new rules and regulations on defense technological and weapons-related matters since then. The first national military standards were issued in 1983 and more than 23,200

[58]Sun Guangyun, *Zhongguo Guofang Keji Gongyede Gaigehe Fazhan Wenti* [The Problems of the Reform and Development of the Chinese Defense Technology Industry] (Beijing: Hangkong Gongye Chubanshe [Aviation Industry Press] 2003), 134–8.

had been established by 2007, which was approaching the US Department of Defense's active list of 26,000 specifications and standards.

A major difficulty encountered by the authorities has been the implementation of these standards. Military units and defense enterprises had previously enjoyed wide-ranging freedom in their activities and were unencumbered by the need to adhere to laws and regulations. Consequently, the enforcement of this new, more tightly managed regulatory regime has been problematic.

From Technology Push to End-User Pull: The Ascendant Role of the General Armament Department

The emergence of the PLA as the dominant actor in guiding defense S&T research and production activities since the late 1990s has been an important factor in raising the performance of the defense economy. Under the watchful eye of the GAD, the defense economy has had to shift from pursuing technology-push strategies to focus increasingly on demand-pull requirements from PLA end-users.

A useful way to understand the shifting relationship between the military and the defense economy is through principal-agent theory. The agent, which is the defense economy, acts on behalf of the principal, the military, to develop and produce weapons. The problem before the late 1990s was that the interests between the principal and agent, who during this period were represented by COSTIND, were severely misaligned. In addition, the PLA suffered from a serious moral hazard problem as the defense economy enjoyed superior information over the management of weapons programs and used this advantage to secure its own interests at the expense of the military. The interests between COSTIND and the PLA diverged to such an extent that their relationship had essentially broken down by the late 1990s. The military lacked the effective means to compel the defense economy to follow its instructions.

The 1998 restructuring allowed the PLA to address many of these principal-agent problems and re-establish a relationship that would allow it to be in the driving seat. The creation of the GAD allowed the PLA to put in place a proxy principal that had the expertise and resources to address the information asymmetry and thereby curtail the defense economy's ability to shirk its responsibilities or exploit any moral hazard advantages that it enjoyed. Moreover, the PLA was able to marginalize the once-powerful role of COSTIND and forge principal-agent relationships directly with the defense conglomerates.

To ensure that these defense companies were in compliance with its requirements, the GAD created a series of incentive structures and monitoring mechanisms. First, through the implementation of the 'four mechanisms' system, it has imposed tougher competitive and evaluation procedures in the development and procurement of weapons systems. In theory, defense enterprises have been required to improve their performance to meet these more stringent demands or face losing work. In practice though, the still highly regulated nature of the Chinese weapons market has impeded the effective application of these procedures. As only 'limited competition' is permitted within the defense sector, enterprises have not had to face the rigors of fully-fledged market competition.

Second, one of the main ways that the GAD has been able to implement demand-pull mechanisms has been through the procurement process, by withholding or postponing orders for equipment that do not meet its requirements. The military had no option but to accept the output of the defense economy during the Maoist era, but it was able to become more selective in the reform period. As the quality of indigenous equipment steadily declined, the PLA became increasingly reluctant to procure these arms and began to look overseas in the 1990s for weapons that met its needs. Although military chiefs continued to reaffirm the importance of self-reliance, the new realities of this demand-pull pressure forced the defense economy to re-examine how it could improve its performance or risk losing valuable contracts that could lead to further contractions in the defense manufacturing base.

Third, considerable efforts have been made to link military strategy and doctrinal planning with weapons and technology development. The separation between the military and defense industrial bureaucracies during the central planning era had also led to a gap in joint planning over their long-term development strategies. While consultation and coordination did take place regularly between the two establishments, this was primarily concentrated on annual, three-, and five-year economic and administrative plans. Little attention was paid to long-range strategic planning efforts that often played a crucial role in shaping the evolution of force doctrines and weapons requirements.

Fourth, the GAD has established a proactive and intrusive monitoring system through the strengthening of its military representative office apparatus. These offices are located throughout the entire defense economy, especially in major defense research institutes, production enterprises, and key centers of defense industrial activity.

Conclusions

The Chinese defense economy is making visible strides in building up its hard innovation capabilities and addressing shortcomings in its soft capabilities. The most impressive progress has occurred in the opening up of the defense economy to the capital markets, the promotion of civil–military integration, the strengthening of the GAD's role in managing weapons development, and the reform of the big defense conglomerates.

Results have been mixed in the revamping of the research and development apparatus, nurturing of a new talent pool of skilled scientists and engineers, and the building of a new regulatory and standards-based regime. Access to external sources of military and dual-use technologies and knowledge appear to be improving, especially with the resumption of more cooperative engagement between China and Russia and the deepening integration of China's civilian technology sectors with global innovation networks.

This progress in the development of the defense economy's innovation capabilities will continue on an upward trajectory and could even accelerate, as long as China's central leadership is committed to the goal of building a world-class military industrial complex, funding remains plentiful, and end-user demand continues to be strong. This is likely to be the case even as a new generation of leaders takes over the reins of power, since they also subscribe to the view defined in the country's MLP that having a world-class indigenous innovation capacity is critical to China's long-term national security and economic competitiveness. This means that the defense economy will likely transition from its current status as a hybrid imitator-innovator and become a fully-fledged innovation power by the mid to latter half of the 2010s. However, this indigenous innovation will likely occur at the lower rungs of the innovation ladder focusing primarily on incremental and architectural types of innovation.

The ability to successfully conduct component innovation activities on a sustained basis is still beyond the reach of the Chinese defense economy until towards the latter half of this decade, although there may be occasional breakthroughs in select pockets of excellence such as in the space, aviation, and nuclear sectors. Radical innovation leading to major technological breakthroughs remains an even more distant challenge stretching well into the 2020s. However, China showed with its success in developing nuclear weapons and strategic missiles in the 1960s and 1970s that it can pursue this type of innovation if the survival of the regime were considered to be at risk. It was able to overcome serious drawbacks to its defense innovation system through concentrated mobilization of resources, organizational flexibility, and top-level leadership support.

If China's leaders were to see its national security once again as seriously threatened as during the Maoist era, there could be another concerted drive to attain breakthroughs in critical defense technological capabilities. This seems to be happening in the area of asymmetric capabilities with the development of long-range precision ballistic missiles and kinetic anti-satellite systems. China's present approach appears to be the selective targeting of a few critical areas for accelerated development while the rest of the defense science, technology, and innovation system pursues a more moderate pace of transformation. But as the country grows more prosperous, more technologically capable, and its security interests become more global and complex, this targeted strategy is likely to be broadened.

Note on Contributor

Tai Ming Cheung is an associate research scientist at the University of California Institute on Global Conflict and Cooperation. He is in charge of the Institute's Minerva project, 'The Evolving Relationship Between Technology and National Security in China: Innovation, Defense Transformation, and China's Place in the Global Technology Order,' and serves as an associate adjunct professor at the School of International Relations and Pacific Studies at UC San Diego. His latest book is *Fortifying China: The Struggle to Build a Modern Defense Economy* (Cornell UP 2009).

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