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A Comprehensive Survey of China's Dynamic Shipbuilding Industry

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Michael C. Grubb
U.S. Navy

中海

U.S. NAVAL WAR COLLEGE

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Number 1

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Commercial Development and Strategic Implications

Gabriel Collins and Lieutenant Commander
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Foreword

I am pleased to introduce this first in an ongoing series of China Maritime Studies. These studies, which we hope to publish on a quarterly basis, form a major research product of the Naval War College's new China Maritime Studies Institute (CMSI).

Recognizing that China's rapid growth is a key factor in understanding the emerging twenty-first-century global order, Navy leadership directed that CMSI be created at the Naval War College (NWC) in October 2006. The objective was not to create another China institute—of which many fine examples exist in academia—but rather to create a China *maritime* studies institute. The intention was to give this new institute the focus required to succeed and thereby fill an emerging gap. It is important to note that CMSI is a scholarly research organization and CMSI scholars routinely share their work with Chinese colleagues, military and civilian. In many respects China and the United States are strategic partners as well as competitors, so this practice is quite appropriate. While prudence dictates gaining a good understanding of Beijing's maritime and naval capabilities, there is a clear incentive and potential for generating trust and cooperation with China in the domain of maritime security and development. Indeed, the concept of maritime partnership between Washington and Beijing was precisely the theme of our third annual CMSI conference back in December 2007.

CMSI draws upon the deep regional expertise of twelve faculty members with skills in Mandarin Chinese. Being located within NWC, CMSI has continuous access to a range of Navy, joint, and international operational experts, including the College's students. The institute's activities include an annual conference, a monthly speaker series, and support for faculty research in China. CMSI also provides support for Navy and joint commands. The quality of CMSI research is proven. For example, a book by CMSI scholars entitled *China's Future Nuclear Submarine Force* (Naval Institute Press, 2007) was described in the January 2008 edition of *Jane's Navy International* as "the benchmark unclassified study on the development of the PLAN's [People's Liberation Army Navy's] sub-surface combat capability."

In developing the new institute's research agenda, we recognize that Chinese naval development is following in the wake of China's clear emergence as a commercial maritime power. Indeed, the close connection between military and commercial maritime power was highlighted by Alfred Thayer Mahan when he taught at the Naval War College more than a century ago. Therefore, it is appropriate to launch this series—an

ongoing intellectual exploration into the origins, goals, and means of Chinese maritime development—with a comprehensive survey of the dynamic Chinese shipbuilding sector and its commercial and strategic implications.

In closing, I wish to congratulate the two authors, one of whom performed this research as a student at NWC, on their outstanding work. Indeed, this study has already had an impact on important deliberations in Washington, D.C. We will be grateful for your feedback on this and the studies that follow in this unique series.

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The opinions expressed in this paper are those of the authors and do not reflect the official assessments of the U.S. Navy or any other entity of the U.S. government.

A Comprehensive Survey of China's Dynamic Shipbuilding Industry

Commercial Development and Strategic Implications

Executive Summary

China's dynamic shipbuilding sector now has the attention of key decision makers in Washington. During testimony before the Armed Services Committee of the House of Representatives on 13 December 2007, Chief of Naval Operations (CNO) Admiral Gary Roughead observed, "The fact that our shipbuilding capacity and industry is not as competitive as other builders around the world is cause for concern." Pointing directly to Beijing's new prowess in this area, he concluded, "[China is] very competitive on the world market. There is no question that their shipbuilding capability is increasing rapidly."[1] The present study aims to present a truly comprehensive survey of this key sector of the growing Chinese economy. In doing so, it will provide decision makers and analysts with the clearest possible picture of the extraordinary pace of activity now under way in China's ports, as well as the commercial and strategic implications flowing from this development.

China's rapidly growing shipbuilding industry has focused primarily on commercial vessels. However, the People's Republic of China (PRC) government classifies shipbuilding as a strategic sector and has limited foreign shareholdings in Chinese shipyards and marine diesel and crankshaft factories to 49 percent. Viewed through a commercial lens, these actions raise World Trade Organization (WTO) compliance questions. Strategically, this affirms that Beijing sees a strong shipbuilding industry, upon which it is able to exert considerable influence, as a central pillar in China's maritime development.

China's shipbuilding industry benefited greatly from Deng Xiaoping's defense conversion program. Compared to other defense-related enterprises, such as aerospace, the Chinese shipbuilding industry has enjoyed a much smoother transition to international competitiveness. This stems from timing and structural advantages. The Sixth Ministry of Machine Building was "corporatized" into the China State Shipbuilding Corporation in 1982, giving the sector nearly twenty-five years to grow into the force that it is today. Shipbuilders have also enjoyed a relatively high degree of bureaucratic

freedom, a broad shift toward commercial shipbuilding, an increasing wave of opinion that China must become a maritime power, early experience in the international ship market (first delivery in 1982), substantial domestic ship demand (which served as a jumping-off point into the intensely competitive international marketplace), and access to a huge and low-cost labor pool.

China's two state-owned shipbuilders (the China State Shipbuilding Corporation [CSSC] and the China Shipbuilding Industry Corporation [CSIC]) report to the State Council via the State Owned Assets Supervision and Administration Commission (SASAC). Both companies are working to reform their business and management structures and are also raising capital, as well as their international profiles, by selling stock to the public. Ongoing changes include increased emphasis on hull-block construction, investment in major new "greenfield" shipyards, and bolstering of Chinese firms' ability to produce marine diesels and gas turbines—all of which have military implications. Other areas of technological focus include enhancing systems integration abilities and fostering the growth of China's currently weak ship-subcomponents industry, lest China become merely a "world-class hull builder."

The Chinese shipbuilding industry is also increasingly focused on human capital. Chinese universities and maritime academies now produce nearly 1,500 marine engineers and naval architects per year, roughly seven times the number of such graduates from U.S. institutions. The large Chinese yards are also gradually emphasizing sound HSE (health, safety, and environment) practices, an important priority for many foreign ship buyers. Chinese yards are additionally realizing that the ability to hire and fire workers freely is an important tool that will allow them to build more productive workforces; Chinese yards' per-worker production ($9,000) is an order of magnitude lower than Japanese ($550,000) and South Korean ($480,000) yards' figures. Finally, the large and growing number of Chinese involved with and exposed to the maritime industry creates a "strategic reserve" of knowledge and experience upon which the country can draw if sustained international tension ever creates the need to expand military ship production rapidly.

Chinese yards' have thus far primarily produced low-complexity ships, such as smaller tankers and bulk carriers (see figure 1). That said, the industry is now pushing to increase production of "high value" ships, including very large crude carriers (VLCCs), large container ships, cruise ships, floating production, storage, and off-loading units (FPSOs), and liquefied natural gas (LNG) carriers. Some sources note that China hopes to have thirty VLCC-capable building docks by 2015. China's official goal by 2015 is twenty-four million tons* of production capacity (35 percent of global capacity), which would make the PRC the world's number-one shipbuilder.

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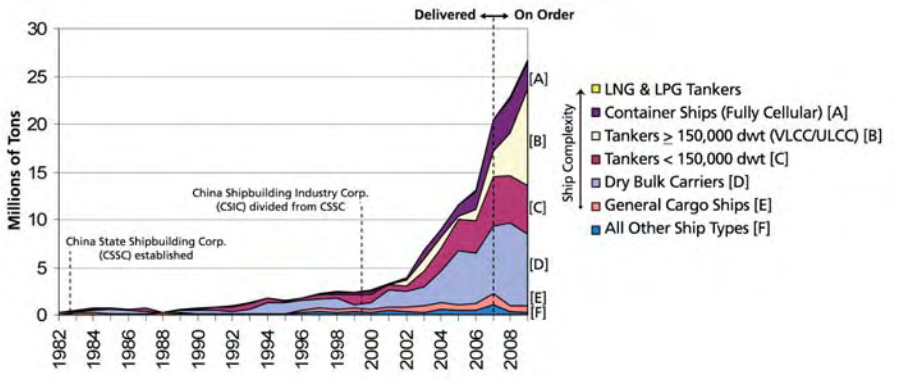
* Metric units are used throughout this paper unless otherwise noted (1 metric ton = 1,000 kg = 0.98 imperial long tons = 2,204.6 lbs).

Figure 1. *Chinese Ship Type Breakdown*



While CSSC and CSIC garner the lion's share of international attention, smaller "beach" and provincial yards are grabbing an increasing share of ship orders from Greek and other buyers seeking the lowest possible costs and trying to secure berths that may not be open at state yards. The quality of ships built at smaller yards varies widely; several hundred such yards were closed down or otherwise punished during a 2005 "campaign against low-quality ships."

Commercial priorities are likely to dominate China's shipbuilding industry for the time being. China's growth could lead to a bifurcated global ship market, wherein China dominates low-complexity ship construction and South Korea dominates the high-complexity end (LNG carriers, cruise ships, etc.). Under such a scenario, Japanese and European yards could lose badly.

If the global shipping sector suffers a significant slowdown, China's rapid and massive capacity buildup could leave Chinese builders in a serious financial bind that government orders probably could not fully offset.

The activities of the massive new Longxue (Guangdong), Haixiwan (Qingdao), and Changxing Island (Shanghai) shipyards will be key indicators of China's future intent with respect to balancing military and commercial shipbuilding. Each yard is more than 1,200 acres in size and if one were devoted to military shipbuilding, capacity would rise substantially from the current level. Alternatively, commercial operations at today's Jiangnan shipyard (Shanghai) could all be moved to Changxing Island and Jiangnan dedicated to military ship production, which would allow the yard to be optimized for series production of selected warships. Thus far, Guangdong Longxue appears to be dedicated to commercial ship production; the yard was set to specialize in building 230,000-dwt ore carriers, 308,000-dwt VLCCs, 82,000-dwt bulk carriers, and

76,000-dwt crude/product tankers, as well as drilling rigs and other offshore energy equipment when it opened in March 2008.[2]

In addition, during wartime merchant ships might be adapted to serve as auxiliaries, amphibious assault ships, and minelayers. Accordingly, the growing Chinese-flag merchant fleet represents a degree of latent military potential. Indeed, Chinese analysts have closely examined Britain's rapid conversion of forty-nine merchant vessels to military roles during the 1982 Falklands War. It should also be noted that the Chinese government maintains a vessel tracking system known as China Ship Reporting System, or "CHISREP," to which all Chinese-flag merchantmen must ostensibly report, no matter their location. Knowledge of where these vessels are at all times across the globe could have military utility during a time of conflict.

Other barometers of future Chinese strategic naval intent include

- Construction of covered building facilities for submarines and warships (particularly if used to build SSNs)
- Construction of the auxiliaries required by a blue-water navy (long-range oilers and resupply ships), and increased at-sea replenishment exercises
- Mass production of amphibious assault vessels that could be used in an invasion of Taiwan
- Acquisition of ship tenders for long-range repairs or acquisition of overseas port rights, particularly in the Indian Ocean region.

A fundamental conclusion of this study is that China's ambitious drive for new and world-premier shipbuilding capabilities is *not* at present primarily driven by military factors but rather by commercial incentives. As determined by conventional economic theory, Beijing has a strong comparative advantage in shipbuilding, and its emergence in this sector is therefore natural, to a large extent. Nevertheless, strategists around the Asia-Pacific, as well as in Washington, need to be aware of the concern highlighted by the CNO in his December 2007 testimony on Capitol Hill. China's dynamic commercial development in shipbuilding is presently adding very extensive latent maritime capacity that Beijing could draw upon in a future maritime rivalry or conflict. Such an outcome is not inevitable, especially given the many promising signs in China's "new diplomacy." Still, the risks that accompany present economic tendencies need to be noted, fully analyzed, and debated by experts.

Introduction

The staggering growth in PRC commercial shipbuilding output and advances in indigenous naval construction underscore shipbuilding's growing role as a key driver in China's economic and military development, and they are indicative of a rising maritime culture within China. Chinese yards now account for roughly 20 percent of the global shipbuilding market, with an estimated 80 percent of their gross output slated for export customers.[3] Chinese seaborne trade is expected to reach one trillion dollars annually by 2020, much of which will be carried on Chinese-built, -owned, and -operated merchant vessels.[4] Building a foundation for this comprehensive maritime growth, the PRC central government recently affirmed shipbuilding as a "strategic industry" in need of "special oversight and support," reinforcing the central role that shipbuilding will play in future Chinese maritime development.[5] Over the next five to ten years, Chinese analysts see their nation's shipbuilding industry as one that will become a world leader, rectifying its present weaknesses in innovation, subcomponent manufacture, systems integration, and yard management.[6]

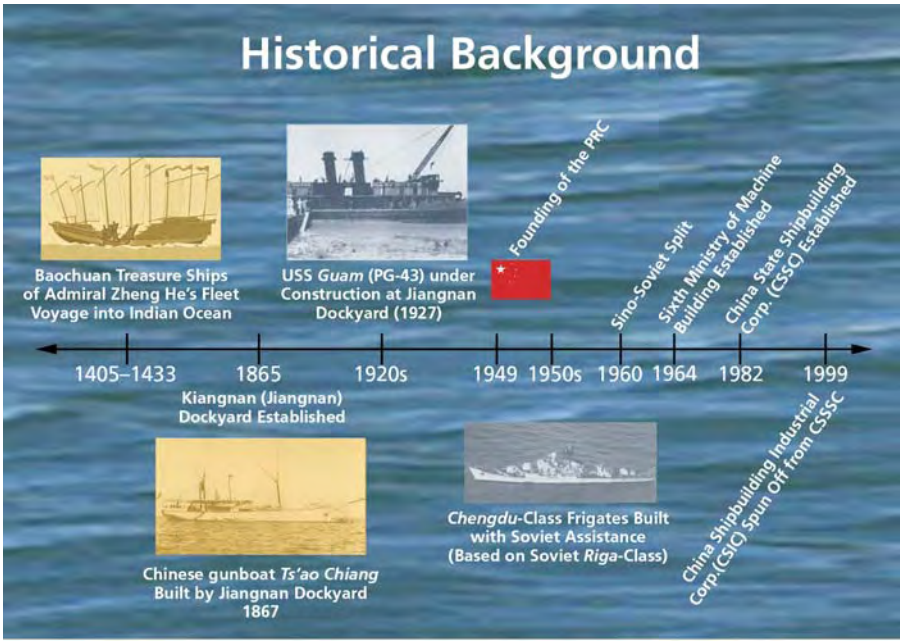
Considering these developments, this study will briefly trace the history of shipbuilding in China, focusing on how the industry transformed itself from a defense-focused, socialist monolith into a thriving commercial enterprise. The current structure and output of the PRC shipbuilding industry will be reviewed, highlighting the increasingly complex mix of control and influence among the PRC State Council, the Central Military Commission, local authorities, private entities, and international corporations within the Chinese shipbuilding industry. The second half of the study will present a more detailed examination of how China's impressive commercial shipbuilding growth may, or may not, translate into similarly significant improvements in Chinese naval development. Finally, the strategic aspects of PRC shipbuilding development will be discussed, and indicators and implications of a possible commercial-to-military shift in PRC shipbuilding priorities will be offered.

Historical Evolution

In May 1982 the Fifth National Congress eliminated the Sixth Ministry of Machine Building and established the China State Shipbuilding Corporation (CSSC) in its place. More than a bureaucratic name change, this decision "corporatized" all state shipbuilding activities under the CSSC and authorized a degree of market-based economic autonomy unprecedented under the communist economic system. CSSC's mandate included direct control of 153 organizations that ranged from shipyards to technical research and design universities; authority over virtually all military and commercial shipbuilding and repair; power to conduct joint ventures with foreign companies; and

ability to negotiate export sales, through the newly established China Shipbuilding Trading Company (CSTC).[7]

Figure 2. *A Historical Review of Chinese Shipbuilding*



Viewed broadly, the shipbuilding development strategy chosen by CSSC during this early period was similar to that which had propelled Japan to remarkable shipbuilding successes in the 1950s–60s and South Korea in the late 1970s–90s. China targeted shipbuilding as a pillar industry for national economic development and growth in other heavy industrial sectors (such as steel); it leveraged labor cost advantages, imported critical technology and manufacturing best practices from world shipbuilding leaders, and targeted export sales as a means of obtaining hard currency to fuel further economic development.[8] Despite these general similarities, however, parallels with a Japanese or Korean development model begin to break down when viewed more closely. The economic structures of the Japanese *keiretsu* and Korean *chaebol* business networks differ from each other, and were both dissimilar to the Chinese *jituan*-style business conglomerate that took shape in CSSC. Furthermore, Japanese and Korean shipbuilders were fundamentally capital-accumulating corporations, operating in regulated market economies, from the very start of their development. Conversely, CSSC remained answerable to the central government and operated as a rare "corporate" entity within a communist planned economy struggling to transform itself.[9]

Regardless of the degree to which foreign development models were used, the ability of the Chinese shipbuilding industry to negotiate the process of defense conversion is noteworthy. This is especially so considering the relative lack of success that Chinese aerospace and other formerly defense-focused industries have shown in attempting to enter commercial markets. There are several key reasons for the effective transformation of Chinese shipbuilding. First, economic liberalization and bureaucratic freedom of movement were afforded to CSSC well before they were to other industrial sectors. While CSSC was formed in July 1982, the Ministry of Aerospace Industry was not "corporatized" into the China Aviation Industry Corporation (AVIC) until 1993.[10] By that time CSSC had largely completed its shift to a commercial focus, with 80 percent of its output dedicated to the civil sector in 1992 and many subsidiaries out of military production altogether.[11]

Second, the shift from a military to commercial focus for Chinese shipbuilding was aided by the relatively small technological hurdles involved. The Luda-class destroyers, Jianghu-class frigates, and Ming-class submarines built in the early 1980s were only modest improvements on Soviet designs dating back to the 1950s, technologically closer to commercial vessels than to military ships by Western standards of the day. Furthermore, most shipyards engaged in military construction already had at least some experience in building commercial ships.

Third, CSSC's early commitment to the international market provided critical exposure to commercial business practices and experience in dealing with foreign companies. CSSC moved quickly to obtain foreign assistance in modernizing its shipyards for commercial production, signing partnerships with Mitsubishi Heavy Industries and British Shipbuilders to upgrade the Jiangnan and Dalian shipyards. These technical assistance agreements built upon successful license production deals signed with major Western marine diesel engine manufacturers in the 1970s, and they were accompanied by cooperative agreements with British and Hong Kong–based companies to help market Chinese-built ships on the international market. Western ship-classification societies were allowed to inspect and provide technical certifications for Chinese-built ships for the first time, and in 1983 the China Ship Inspection Bureau formally adopted technical standards approved by Lloyd's Register—a vital quality-control credential for attracting buyers on the international market.[12]

The fourth key factor in shipbuilding's successful defense conversion was a healthy balance of domestic and export demand. Export sales were explicitly targeted as a means of generating the hard currency required to purchase higher-technology subcomponents from abroad and to sustain long-term growth, but latent demand in China's domestic merchant fleet also played a vital role in facilitating the conversion of the PRC's shipbuilding industry. That industry had received little attention in previous decades; only

18 percent of China's merchant fleet was domestically built as of 1986, and the vast majority of the nation's international trade was carried in chartered or foreign-flag ships.[13] The opening of the Chinese economy increased the demand for maritime trade, and the PRC merchant marine expanded from 955 ships totaling 6.8 million gross tons in 1980 to 1,948 ships totaling 13.9 million gross tons in 1990.[14] Chinese shipyards were still too immature in capacity and capability to provide many of the large tankers and containerships needed in the national fleet, but the steady domestic demand for small-to-mid-sized shipping provided China's shipyards with a vital source of orders while the industry gradually overcame the challenges of breaking into the international market.[15]

Fifth, geography played a notable facilitating role in the successful conversion and growth of China's shipbuilding industry. The shipbuilding industry paid a heavy price for the ill-conceived "Third Front" initiative of the 1960s, but the obvious geographic restraints in building deep-draft ships somewhat minimized the effects of the inland industrialization movement (especially when compared to other defense sectors). The largest and most productive of China's shipyards remained along the coast, near the business centers of Shanghai, Dalian, Guangzhou, and Hong Kong, which have fueled much of China's economic rise over the past two decades.[16]

Finally, the competitive price advantage gained from plentiful cheap labor cannot be overlooked as a significant factor in the transformation of PRC shipbuilding. The seemingly endless supply of inexpensive labor helped Chinese shipbuilders enter the competitive international shipbuilding market twenty-five years ago, and it remains a significant marketing advantage today. As of 2002, the average wage for a shipyard worker in the PRC was estimated to be $325 per month, as compared to $1,400, $1,800, and $2,400 per month in South Korea, Japan, and Western Europe, respectively.[17] Although a sizable portion of this labor cost advantage is offset by production inefficiencies (to be discussed further in later sections), the ready availability of inexpensive labor has played a significant role in China's shipbuilding development and is likely to continue to do so for the foreseeable future. Having successfully maneuvered through the minefields of defense conversion, the PRC shipbuilding industry was well positioned as the global shipbuilding market emerged from its deep recession of the late 1980s. PRC shipyard commercial output crossed the one-million-tons-per-year mark in 1993 (with roughly 50 percent of tonnage built for export), propelling China to third position in global commercial shipbuilding, behind Japan and South Korea, by 1995. As the twentieth century drew to a close, China had emerged as a new commercial shipbuilding force and was poised for yet more unprecedented growth in the new century.

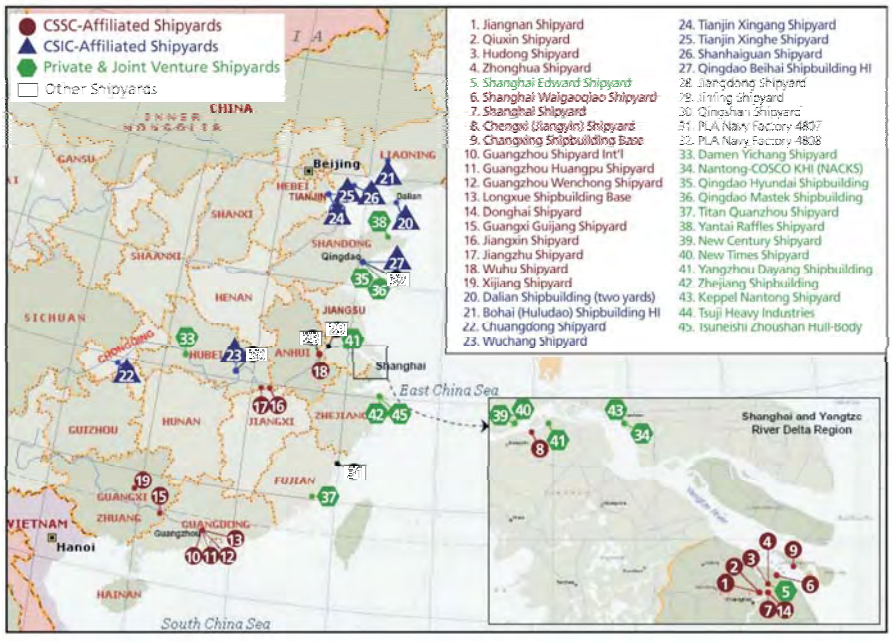
The Chinese Shipbuilding Industry Today

Two Massive State-Owned Conglomerates

The China State Shipbuilding Corporation (CSSC) remained the principal shipbuilding organization in China until July 1999, when it was divided into two separate entities. CSSC remained in control of most shipyards and related subsidiaries in Shanghai and south of the Yangtze, while the China Shipbuilding Industry Corporation (CSIC) was established and given control of shipbuilding operations in the northern half of the country. Currently, both serve as umbrella organizations for a wide range of shipyards, marine subcomponent manufacturing companies, research and design institutes, and a limited number of non-shipbuilding-related businesses.[18] CSSC and CSIC are considered major state-owned enterprises, and both report to the PRC State Council through the State Owned Assets Supervision and Administration Commission (SASAC).[19]

The partition of CSSC was part of a larger antimonopoly initiative by the PRC leadership. State-owned monopolies like CSSC were broken up and a limited amount of free-market competition introduced to help promote reform and innovation within each defense industrial sector. CSSC and CSIC both hold a significant degree of investment and capital-management autonomy from the state, and the two corporations are

Figure 3. *Locations and Affiliations of China's Major Shipyards*



allowed to compete directly for domestic government contracts as well as on the international market.[20] Competition is facilitated by similar industrial capabilities within each conglomerate, as well as similar commercial and military product lines. CSSC and CSIC both actively seek foreign and domestic contracts for such highly competitive ship types as containerships and very large crude oil carriers (VLCCs), and yards within each organization produce submarines and advanced surface combatants. Considering the high degree of product specialization and the overall noncompetitive nature of the PRC aerospace industry, the presence of healthy competition between state-owned shipbuilders is remarkable and noteworthy within China's defense industrial establishment.[21]

Additionally, incentives for self-improvement and technical innovation reside within the business structures of CSSC and CSIC themselves. As listed in table 1, major shipyards under CSSC and CSIC are further subdivided into several large shipyard group companies. These companies, such as the Hudong-Zhonghua Group under CSSC and the Dalian Shipbuilding Industry Group under CSIC, each manage subsidiary shipyards and largely function as independent corporate entities. Day-to-day operations and most contract bids are handled directly by the shipyards, with the CSSC and CSIC front offices dealing in more macrolevel resource management and large-scale (or high-profile) business issues.

As part of efforts to become more globally competitive, CSSC and CSIC have accelerated efforts to become publicly traded corporations. Many subsidiary shipyard companies within CSSC and CSIC are listed on stock exchanges in Shanghai and Hong Kong (shares of Guangzhou Shipyard International have been publicly traded since 1993), and CSSC has launched a comprehensive three-phase plan to increase public offerings across its entire organization. CSSC's diesel engine builder Hudong Heavy Machinery (HHM) recently went public with four hundred million shares valued at over twelve billion RMB (1.5 billion USD), which one CSSC executive characterized as "just a first step" in the process of incorporating CSSC's core business units.[22] (See tables 2 and 3.)

The business structure changes and incorporation initiatives by CSSC and CSIC are aimed at improving competitive and management practices within China's state-owned shipyards, but in true capitalist fashion, they are also intended to help finance China's long-term plan for growth in shipbuilding. The Party Central Committee and State Council identified shipbuilding as a key industry for development in 2000, and in May 2002 the Chinese premier, Zhu Rongji, challenged the country's shipbuilders "to propel the country to world No. 1 status." Following this direction, the State Commission of Science, Technology, and Industry for National Defense set a target of 2015 for China to become the world's leading shipbuilder.[23] This is a lofty goal, considering that China accounted for only 13.8 percent of gross tonnage built globally in 2005, substantially

Table 1. *PRC Commercial Shipbuilding since CSSC/CSIC Division (July 1999–December 2006)*

Sources: All shipbuilding statistics based on data extracted from Lloyd's Register–Fairplay Ltd., *Register of Ships,* Sea-web online database, www.sea-web.com. Shipyard affiliations based on Barbara Matthews, ed., *World Shipping Directory 2006–2007* (Surrey, U.K.: Lloyd's Register–Fairplay, 2006), pp. 1-1024 through 1-1048; "Sinopacific Heavy Industries Group: Private Enterprise Shipbuilding Group with Focus on International Customers," *Toplaterne,* no. 80 (January 2006), p. 16, available at www.mak-global.com/news/pdf/toplaterne80e.pdf; and review of shipbuilder company websites: *China State Shipbuilding Corporation,* www.cssc.net.cn; *China Shipbuilding Industry Corporation,* www.csic.com.cn; *China Ocean Shipping Co. (COSCO),* www.cosco.com; *Nantong-COSCO-Kawasaki Heavy Industries (NACKS) Engineering Co.,* www.nacks.com.cn; *Yantai Raffles Shipyard,* www.yantai-raffles.com; *Qingdao Hyundai Shipbuilding,* www.qingdaohyundai.com.

Notes:

1. Shipyards are sorted by their current affiliations. In some cases, ships were produced at the listed yards prior to mergers, privatization, and the establishment of joint ventures. Shipyards with no new-construction during the given time period are omitted.

2. The number of provincial/local shipyards is approximate. Some smaller yards have changed names, merged, and/or closed. Provinces, direct-controlled municipalities, and semiautonomous regions with no new-construction shipbuilding are omitted.

Enterprise Type	Shipyard[1]	No. of Yards	Ships Built		Deadweight		Gross Tonnage	
			No.	%	Tons	%	GT	%
State Council–Controlled Enterprises	**China State Shipbuilding Corp. (CSSC)**							
	Jiangnan Shipbuilding (Group) Co.							
	Jiangnan Shipyard		69	3.1	3,123,150	6.5	1,917,576	6.2
	Qiuxin Shipyard		17	0.8	241,611	0.5	169,087	0.5
	Hudong-Zhonghua Shipbuilding (Group) Co.							
	Hudong Shipyard		89	4.0	5,729,622	11.9	3,579,860	11.6
	Zhonghua Shipyard		25	1.1	240,179	0.5	203,819	0.7
	Shanghai Edward SB *(tabulated as joint venture)*							
	Shanghai Waigaoqiao Shipbuilding Co.		41	1.8	6,619,240	13.8	3,426,843	11.1
	Shanghai-Chengxi Shipbuilding Co.							
	Shanghai Shipyard		38	1.7	1,406,766	2.9	995,767	3.2
	Chengxi Shipyard		4	0.2	46,209	0.1	34,564	0.1
	Chengxi (Jiangyin) Shipyard		11	0.5	556,900	1.2	340,608	1.1
	Guangzhou Shipbuilding (Group) Co.							
	Guangzhou Shipyard International		65	2.9	2,110,314	4.4	1,451,287	4.7
	Guangzhou Huangpu Shipyard		15	0.7	12,769	0.0	27,513	0.1
	Guangzhou Wenchong Shipyard		44	2.0	874,133	1.8	665,103	2.2
	Other CSSC Shipyards							
	Donghai Shipyard		11	0.5	6,629	0.0	17,652	0.1
	Guangxi Guijiang Shipyard		9	0.4	5,845	0.0	6,617	0.0
	Jiangxin Shipyard		2	0.1	5,600	0.0	4,091	0.0
	Jiangzhu Shipyard		9	0.4	97,130	0.2	73,691	0.2
	Wuhu Shipyard		18	0.8	217,680	0.5	158,385	0.5
	Xijiang Shipyard		1	0.0	2,178	0.0	1,432	0.0
	Subtotal:	**17**	**468**	**21.1**	**21,295,955**	**44.3**	**13,073,895**	**42.5**
	China Shipbuilding Industry Corp. (CSIC)							
	Dalian Shipbuilding Industry (Group) Co.							
	No. 1 Yard (Ex–Dalian Shipyard)		74	3.3	2,899,949	6.0	1,877,225	6.1
	No. 2 Yard (Ex–Dalian New Shipbuilding HI)		62	2.8	6,699,555	13.9	4,050,260	13.2
	Bohai Shipbuilding Heavy Industries		26	1.2	1,902,769	4.0	1,074,001	3.5
	Chuandong Shipyard		3	0.1	10,746	0.0	8,481	0.0
	Wuchang Shipyard		22	1.0	35,087	0.1	46,416	0.2
	Tianjin Xingang Shipyard		32	1.4	610,870	1.3	439,699	1.4
	Tianjin Xinghe Shipyard		13	0.6	43,485	0.1	32,969	0.1
	Shanhaiguan Shipyard		4	0.2	37,634	0.1	76,456	0.2
	Qingdao Beihai Shipbuilding Heavy Industry		2	0.1	11,100	0.0	7,058	0.0
	Subtotal:	**9**	**238**	**10.7**	**12,251,195**	**25.5**	**7,612,565**	**24.7**
	Shipping Conglomerate Shipyards							
	China Ocean Shipping Co. (COSCO)							
	Nantong-COSCO KHI *(tabulated as joint venture)*							
	China Changjiang National Shipping Group							
	Jiangdong Shipyard		22	1.0	223,752	0.5	168,569	0.5
	Jinling Shipyard		75	3.4	923,438	1.9	758,461	2.5
	Qingshan Shipyard		31	1.4	301,368	0.6	229,806	0.7
	Damen Yichang Shipyard *(tabulated as joint venture)*							
	Subtotal:	**3**	**128**	**5.8**	**1,448,558**	**3.0**	**1,156,836**	**3.8**
	Other Shipyards by Area[2]							
	Anhui Province	3	16	0.7	4,939	0.0	6,284	0.0
	Chongqing Municipality	2	23	1.0	52,295	0.1	37,420	0.1
	Fujian Province	16	125	5.6	840,008	1.7	765,853	2.5
	Guandong Province	17	180	8.1	160,607	0.3	164,260	0.5
	Guangxi-Zhuang Autonomous Region	2	13	0.6	19,712	0.0	13,575	0.0
	Hubei Province	2	11	0.5	10,879	0.0	10,473	0.0
	Jiangsu Province	45	284	12.8	2,191,201	4.6	1,694,030	5.5
	Jiangxi Province	4	7	0.3	33,421	0.1	21,546	0.1
	Liaoning Province	3	26	1.2	8,302	0.0	8,291	0.0
	Qinghai Province	1	1	0.0	500	0.0	396	0.0
	Shandong Province	18	159	7.2	368,245	0.8	300,166	1.0
	Shanghai Municipality	6	19	0.9	9,238	0.0	16,359	0.1
	Tianjin Municipality	2	6	0.3	10,806	0.0	11,164	0.0
	Zhejiang Province	57	244	11.0	1,240,908	2.6	882,864	2.9
	Shipbuilder/Location Unknown		54	2.4	185,418	0.4	140,832	0.5
	Subtotal:	**178**	**1,168**	**52.6**	**5,136,479**	**10.7**	**4,073,513**	**13.2**
CMC-Controlled Enterprises	**PLA Shipyards**							
	PLA Navy Factory 4807		5	0.2	63,000	0.1	42,471	0.1
	Subtotal:	**1**	**5**	**0.2**	**63,000**	**0.1**	**42,471**	**0.1**
Other Enterprises	**Joint Venture Shipyards**							
	Nantong-COSCO Kawasaki HI Ship Engineering Co. (NACKS)		44	2.0	3,713,277	7.7	2,202,982	7.2
	Qingdao Hyundai Shipbuilding Co.		9	0.4	37,856	0.1	28,597	0.1
	Shanghai Edward Shipbuilding Co.		20	0.9	286,265	0.6	210,111	0.7
	Yantai Raffles Shipyard Co.		33	1.5	231,776	0.5	190,398	0.6
	Damen Yichang Shipyard		16	0.7	27,926	0.1	22,760	0.1
	Subtotal:	**5**	**122**	**5.5**	**4,297,100**	**8.9**	**2,654,848**	**8.6**

Enterprise Type	Shipyard[1]	No. of Yards	Ships Built		Deadweight		Gross Tonnage	
			No.	%	Tons	%	GT	%
Other Enterprises	Private Enterprise Shipyards							
	New Century Shipbuilding Co.		51	2.3	2,716,894	5.6	1,608,163	5.2
	Sinopacific Heavy Industries Group							
	Yangzhou Dayang Shipbuilding		13	0.6	323,534	0.7	202,421	0.7
	Zhejiang Shipbuilding Co. Ltd.		26	1.2	576,750	1.2	371,935	1.2
	Subtotal:	3	90	4.1	3,617,178	7.5	2,182,519	7.1
	Grand Total:	216	2,219	100.0	48,109,465	100.0	30,796,647	100.0

short of the 35.0 percent and 37.7 percent shares held by Japan and South Korea.[24] Yet China is now hot on the heels of South Korea, having taken ship orders equivalent to 29.6 million compensated gross tons in 2007, as opposed to 32 million CGT of orders for South Korean yards.[25]

To provide the infrastructure capacity needed to support increased output and market share, a significant portion of CSSC and CSIC financial resources have been devoted to expanding China's shipbuilding industrial base. The funding for infrastructure expansion has come from a mix of state subsidies, tax exemptions, reinvested profits, and private-sector financing. Highlighting the shifting nature of the Chinese economy, the state-run *China Daily* reported that "the central government supports large shipbuilding companies to issue corporate bonds or go public for shipbuilding infrastructure construction," an idea seemingly unimaginable in the prereform era.[26]

Through these initiatives, CSIC has invested in expansions of its Dalian and Bohai Shipbuilding Heavy Industry facilities; also, its Qingdao Beihai Shipbuilding Heavy Industry shipyard recently started construction on two new 500,000-dwt building docks. Similarly, CSSC has multibillion-dollar projects under way to build massive new "shipbuilding bases" on Changxing Island in Shanghai and Longxue Island in Guangzhou.[27] These expansion projects are aimed at increasing China's capabilities for building more technically complex ships, especially in such high-value sectors as large containerships, VLCCs, ultralarge crude oil carriers (ULCCs), liquefied natural gas (LNG) tankers, and cruise ships. If all plans come to fruition, CSSC and CSIC will between them add roughly twelve million deadweight tons of production capacity, carrying China to its official goal of twenty-four million tons, or 35 percent of world total shipbuilding capacity, by 2015.[28]

Joint Venture and Private Enterprise Yards

The development of China's shipbuilding industry has not been limited to CSSC and CSIC. The twenty-six shipyards under CSSC and CSIC cognizance account for nearly 70 percent of China's commercial output by deadweight but represent only 12 percent of the total number of shipyards engaged in new construction since the CSSC/CSIC division in 1999 (table 1). This percentage falls even lower in light of the scores of additional Chinese shipyards that engage only in ship repair and therefore do not regularly appear in ship-construction statistics.

Table 2. *PRC Commercial Order Book as of January 2007*

Sources: All shipbuilding statistics based on data extracted from Lloyd's Register–Fairplay Ltd., *Register of Ships,* Sea-web online database, www.sea-web.com.

Notes:

1. Shipyards are sorted by their current affiliations. In some cases, ships were produced at the listed yards prior to mergers, privatization, and the establishment of joint ventures.

2. All future orders for the Zhonghua Shipyard are included under the Hudong Shipyard listing in Lloyd's Sea-web database. A portion of Hudong-Zhonghua Shipbuilding constructs military vessels.

3. The Jiangyin Shipyard of the CSSC Shanghai-Chengxi Shipbuilding (Group) Co. now incorporates the former Chengxi Shipyard. See builder profile for Chengxi Shipyard at www.sea-web.com.

4. The CSSC Guangzhou Longxue Shipbuilding Base shipyard is currently under construction. Its first delivery is scheduled for 2008. See *CSSC,* Corporate Profile, www.cssc.net.cn/enlish/gsjj.php.

5. The number of provincial/local shipyards is approximate. Some smaller yards have changed names, merged, and/or closed. Provinces, direct-controlled municipalities, and semiautonomous regions with no new-construction shipbuilding are omitted.

Enterprise Type	Shipyard[1]	No. of Yards	Ships on Order		Deadweight		Gross Tonnage	
			No.	%	Tons	%	GT	%
State Council–Controlled Enterprises	**China State Shipbuilding Corp. (CSSC)**							
	Jiangnan Shipbuilding (Group) Co.							
	Zhonghua Shipyard		49	2.6	6,671,700	7.7	3,924,904	7.6
	Qiuxin Shipyard		20	1.0	329,400	0.4	226,545	0.4
	Hudong-Zhonghua Shipbuilding (Group) Co.							
	Hudong Shipyard		62	3.2	4,118,160	4.8	2,907,162	5.6
	Zhonghua Shipyard[2]							
	Shanghai Edward SB *(tabulated as joint venture)*							
	Shanghai Waigaoqiao Shipbuilding Co.		75	3.9	12,366,052	14.3	6,356,250	12.3
	Shanghai-Chengxi Shipbuilding Co.							
	Shanghai Shipyard		22	1.2	1,024,000	1.2	852,194	1.6
	Jiangyin Shipyard[3]		25	1.3	1,298,470	1.5	795,096	1.5
	Guangzhou Shipbuilding (Group) Co.							
	Guangzhou Shipyard International		53	2.8	2,309,200	2.7	1,424,858	2.8
	Guangzhou Huangpu Shipyard		6	0.3	6,877	0.0	18,386	0.0
	Guangzhou Wenchong Shipyard		29	1.5	480,777	0.6	396,297	0.8
	Guangzhou Longxue[4]		4	0.2	1,232,000	1.4	624,000	1.2
	Other CSSC Shipyards							
	Donghai Shipyard							
	Guangxi Guijiang Shipyard		1	0.1	2,197	0.0	1,532	0.0
	Jiangxin Shipyard		9	0.5	11,340	0.0	8,393	0.0
	Jiangzhu Shipyard		11	0.6	144,966	0.2	91,333	0.2
	Wuhu Shipyard		5	0.3	150,000	0.2	100,000	0.2
	Xijiang Shipyard		2	0.1	2,520	0.0	2,106	0.0
	Subtotal:	**15**	**373**	**19.5**	**30,147,659**	**34.9**	**17,729,056**	**34.3**
	China Shipbuilding Industry Corp. (CSIC)							
	Dalian Shipbuilding Industry (Group) Co.							
	No. 1 Yard (Ex–Dalian Shipyard)		34	1.8	1,873,694	2.2	1,253,046	2.4
	No. 2 Yard (Ex–Dalian New Shipbuilding HI)		58	3.0	7,789,600	9.0	4,461,672	8.6
	Bohai Shipbuilding Heavy Industries		39	2.0	4,614,200	5.3	2,528,501	4.9
	Chuandong Shipyard		17	0.9	89,897	0.1	60,730	0.1
	Wuchang Shipyard		15	0.8	46,130	0.1	44,466	0.1
	Tianjin Xingang Shipyard		22	1.2	554,060	0.6	409,818	0.8
	Tianjin Xinghe Shipyard		12	0.6	54,800	0.1	42,404	0.1
	Shanhaiguan Shipyard		8	0.4	237,900	0.3	158,490	0.3
	Qingdao Beihai Shipbuilding Heavy Industry		6	0.3	873,700	1.0	396,000	0.8
	Subtotal:	**9**	**211**	**11.1**	**16,133,981**	**18.7**	**9,355,127**	**18.1**
	Shipping Conglomerate Shipyards							
	China Ocean Shipping Co. (COSCO)							
	Nantong-COSCO KHI *(tabulated as joint venture)*							
	China Changjiang National Shipping Group							
	Jiangdong Shipyard		7	0.4	91,448	0.1	67,976	0.1
	Jinling Shipyard		57	3.0	1,474,020	1.7	1,062,240	2.1
	Qingshan Shipyard		47	2.5	1,189,159	1.4	726,736	1.4
	Damen Yichang Shipyard *(tabulated as joint venture)*							
	Subtotal:	**3**	**111**	**5.8**	**2,754,627**	**3.2**	**1,856,952**	**3.6**
	Other Shipyards by Area[5]							
	Anhui Province	3	8	0.4	6,280	0.0	4,850	0.0
	Chongqing Municipality	2	10	0.5	50,800	0.1	52,794	0.1
	Fujian Province	7	96	5.0	1,078,162	1.2	943,526	1.8
	Guandong Province	12	70	3.7	352,515	0.4	250,537	0.5
	Hubei Province	1	1	0.1	600	0.0	1,137	0.0
	Jiangsu Province	25	315	16.5	11,904,490	13.8	7,116,623	13.8
	Jiangxi Province	1	4	0.2	58,400	0.1	40,537	0.1
	Liaoning Province	3	17	0.9	199,384	0.2	151,922	0.3
	Shandong Province	11	118	6.2	2,025,329	2.3	1,282,832	2.5
	Shanghai Municipality	3	12	0.6	29,400	0.0	14,188	0.0
	Zhejiang Province	24	143	7.5	1,942,208	2.2	1,305,380	2.5
	Shipbuilder/Location Unknown		68	3.6	1,427,799	1.7	961,495	1.9
	Subtotal:	**92**	**862**	**45.2**	**19,075,367**	**22.1**	**12,125,821**	**23.4**
CMC-Controlled Enterprises	**PLA Shipyards**							
	PLA Navy Factory 4807		13	0.7	194,000	0.2	125,520	0.2
	PLA Navy Factory 4808		6	0.3	42,000	0.0	24,000	0.0
	Subtotal:	**2**	**19**	**1.0**	**236,000**	**0.3**	**149,520**	**0.3**
Other Enterprises	**Joint Venture Shipyards**							
	Damen Yichang Shipyard		12	0.6	98,500	0.1	68,572	0.1
	Nantong-COSCO Kawasaki HI Ship Engineering Co. (NACKS)		34	1.8	6,579,400	7.6	3,602,000	7.0
	Qingdao Hyundai Shipbuilding Co.		32	1.7	193,021	0.2	133,601	0.3
	Qingdao Jimo Mastek Shipbuilding Co.		6	0.3	540,000	0.6	294,000	0.6
	Shanghai Edward Shipbuilding Co.		4	0.2	83,500	0.1	55,000	0.1
	Titan Quanzhou Shipyard Co. Ltd.		2	0.1	13,000	0.0	9,000	0.0
	Yantai Raffles Shipyard Co.		16	0.8	199,209	0.2	149,658	0.3
	Subtotal:	**7**	**106**	**5.6**	**7,706,630**	**8.9**	**4,311,831**	**8.3**

Enterprise Type	Shipyard[1]	No. of Yards	Ships on Order No.	%	Deadweight Tons	%	Gross Tonnage GT	%
Other Enterprises	Private Enterprise Shipyards							
	New Century Shipbuilding (Group) Co.							
	New Century Shipbuilding		29	1.5	2,214,790	2.6	1,325,432	2.6
	New Times Shipbuilding		34	1.8	3,610,000	4.2	1,924,000	3.7
	Sinopacific Heavy Industries Group							
	Yangzhou Dayang Shipbuilding		64	3.4	1,266,900	1.5	782,278	1.5
	Zhejiang Shipbuilding Co. Ltd.		46	2.4	1,421,783	1.6	1,071,314	2.1
	Subtotal:	**4**	**173**	**9.1**	**8,513,473**	**9.9**	**5,103,024**	**9.9**
	Foreign-Owned Shipyards							
	Keppel Nantong Shipyard Co. Ltd.		14	0.7	19,670	0.0	22,905	0.0
	Tsuji Heavy Industries (Jiangsu) Co.		24	1.3	720,000	0.8	480,000	0.9
	Tsuneishi Zhoushan Hull-Body		16	0.8	1,079,700	1.2	585,000	1.1
	Subtotal:	**3**	**54**	**2.8**	**1,819,370**	**2.1**	**1,087,905**	**2.1**
	Grand Total:	**135**	**1,909**	**100.0**	**86,387,107**	**100.0**	**51,719,236**	**100.0**

Beyond CSSC and CSIC, the PRC State Council has jurisdiction over a large number of smaller shipyards administered by provincial and local governments, as well as numerous yards run by China's national shipping conglomerates. The exact number of

Table 3. *PRC Military Shipbuilding since CSSC/CSIC Division (1999–2006)*[1]

Sources: Richard Saunders, ed., *Jane's Fighting Ships 2006–2007* (Surrey, U.K.: Jane's Information Group, 2006); Eric Wertheim, ed., *The Naval Institute Guide to Combat Fleets of the World 2005–2006* (Annapolis, Md.: Naval Institute Press, 2005); and *Chinese Defence Today,* www.sinodefence.com. Various earlier editions of *Jane's Fighting Ships,* and *Jane's* online database, www.janes.com, were also consulted.

Notes:

1. Includes ships known to be under construction. Data relating to the exact month of delivery/commissioning for military shipbuilding is generally less granular than in commercial shipbuilding; therefore all ships built from 1999 to 2006 are included. For Ming SSKs, Houkin PTGs, and Yuhai LSMs, the exact year of delivery is not certain for all units. The last four Ming hulls, last two Houkin hulls, and last seven Yuhai hulls are included based on estimated build rates and best available data. All other hulls of these classes are believed to have been built before 1999.

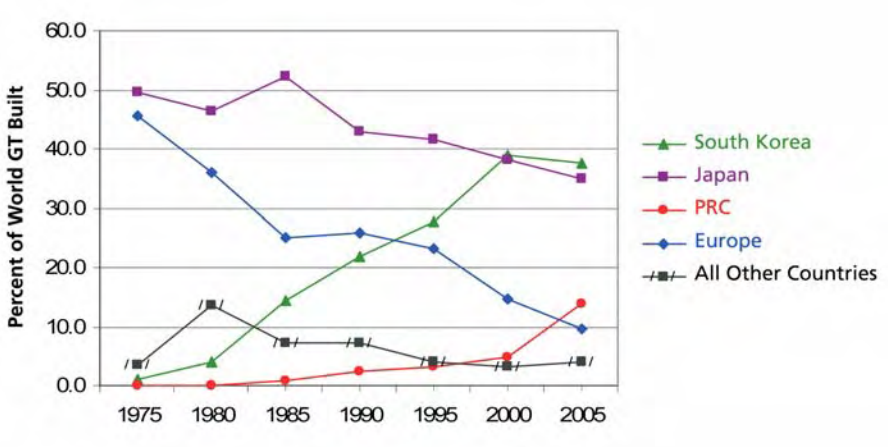
2. Shipyards are sorted by their current affiliations. In some cases, ships were produced at the listed yards prior to mergers. Shipyards with no new-construction during the given time period are omitted.

3. Provinces, direct-controlled municipalities, and semiautonomous regions with no new-construction shipbuilding are omitted.

4. List of ship types/classes produced is not all-inclusive. The primary and noteworthy ship types/classes produced at each yard are listed as space allows.

Enterprise Type	Shipyard[2]	No. of Yards	Ships Built No.	%	Displacement Tons	%	Primary Products[4]
State Council–Controlled Enterprises	China State Shipbuilding Corp. (CSSC)						
	Jiangnan Shipbuilding (Group) Co.						
	Jiangnan Shipyard		7	6.1	46,500	11.1	SONG SSKs, LUYANG DDGs
	Qiuxin Shipyard		8	7.0	8,411	2.0	HOUBEI PGGFs, HOUXIN PTGs
	Hudong-Zhonghua Shipbuilding (Group) Co.						
	Hudong Shipyard		9	7.9	56,050	13.4	JIANGKAI & JIANGWEI FFGs, Type 071 LPD
	Zhonghua Shipyard		7	6.1	33,600	8.1	YUTING LSTs
	Yard Unknown (built at either Hudong or Zhonghua)		3	2.6	5,550	1.3	YUNSHU LSMs
	Guangzhou Shipbuilding (Group) Co.						
	Guangzhou Shipyard International		1	0.9	23,000	5.5	FUCHI AOR
	Guangzhou Huangpu Shipyard		8	7.0	14,460	3.5	JIANGKAI & JIANGWEI FFGs, HOUJIAN PTGs
	Other CSSC Shipyards						
	Wuhu Shipyard		9	7.9	9,293	2.2	YUNSHU & YUNHAI LSMs
	Subtotal:	**8**	**52**	**45.6**	**196,864**	**47.2**	
	China Shipbuilding Industry Corp. (CSIC)						
	Dalian Shipbuilding Industry (Group) Co.						
	No. 1 Yard (Ex-Dalian Shipyard)		6	5.3	34,400	8.2	LUZHOU & LUHAI DDGs, YUTING LSTs
	Bohai Shipbuilding Heavy Industries		6	5.3	44,000	10.5	JIN SSBNs, SHANG SSNs
	Wuchang Shipyard		20	17.5	53,602	12.8	YUAN, SONG, & MING SSKs; YUTING LSTs
	Subtotal:	**3**	**32**	**28.1**	**132,002**	**31.6**	
	Other Shipyards[3]						
	Zhejiang Province						
	Zhanjiang Shipyard North		1	0.9	1,000	0.2	YUBEI LCU
	Shipbuilder/Location Unknown		5	4.4	12,820	3.1	YUBEI LCUs, YUTING LSTs, HOUBEI PGGFs
	Subtotal:	**1**	**6**	**5.3**	**13,820**	**3.3**	
CMC-Controlled Enterprises	PLA Shipyards						
	Dinghai Naval Dockyard		3	2.6	3,000	0.7	YUBEI LCUs
	Lushun Naval Shipyard		3	2.6	5,550	1.3	YUNSHU LSMs
	Qingdao Naval Dockyard		5	4.4	6,700	1.6	YUBEI LCUs, YUNSHU LSMs
	Subtotal:	**3**	**11**	**9.6**	**15,250**	**3.7**	
Other Enterprises	Foreign Shipyards						
	Russian Shipyards						
	Krasnoye Sormovo Zavod 199 (Nizhny Novograd)		1	0.9	3,076	0.7	KILO (Project 636) SSK
	Semashpredpriyatiye (Severodvinsk)		2	1.8	6,152	1.5	KILO (Project 636) SSKs
	Severnaya Verf 190 (St. Petersburg)		4	3.5	31,760	7.6	*SOVREMENNY* DDGs
	United Admiralty Shipyard (St. Petersburg)		6	5.3	18,456	4.4	KILO (Project 636) SSKs
	Subtotal:	**4**	**13**	**11.4**	**59,444**	**14.2**	
	Grand Total:	**19**	**114**	**100.0**	**417,380**	**100.0**	

Figure 4. *Market Share of World Gross Tonnage Produced, 1975–2005*



provincial and local shipyards is not known, as many new yards have opened and others have merged or changed names as free-market reforms reach the lower levels of the Chinese economy. Some are managed as highly organized group corporations that cater to international customers, while others are merely upstart "beach yards" with relatively little infrastructure or government oversight.[29] Illustrating this disparity, the highly reputable Fujian Mawei Shipbuilding is currently building a series of small containerships for German clients, whereas one Chinese analyst recently described lesser provincial yards as "heavily in debt, not organized, technologically backwards, and having weak risk management capacity."[30] Regardless of administrative structure and individual performance, however, provincial and local yards in the aggregate play an important and growing role in Chinese shipbuilding. They have produced 1,168 new ships, totaling over 5.1 million deadweight tons, since 1999 (10.7 percent of the PRC total), more than double the total provincial and local yard output from 1982 to 1999.[31] While "beach yards" would likely be unable to produce advanced surface combatants, the ability to bring this type of "grassroots" shipbuilding quickly on line could allow expanded production of simple landing craft and military auxiliary vessels within a relatively short time frame, if perceived national security needs require.

Unlike the variety at provincial and local levels, the shipyards controlled by China's shipping lines more closely resemble the shipyard group companies within CSSC and CSIC. Historically, shipping company yards focused on maintenance and repair of their own vessels, but in recent years they have increasingly moved into new construction to supply their own fleets, other domestic customers, and international buyers. The China Changjiang (Yangtze) National Shipping Group is the third-largest fully state-owned shipbuilder, behind CSSC and CSIC, producing 128 new ships, totaling 1.4 million dwt,

since 1999. It operates four new construction and numerous ship repair yards along the Yangtze River, mostly in the inland provinces of Hubei and Anhui.

China's other major national shipping conglomerates, the China Shipping (Group) Company and China Ocean Shipping Company (COSCO), also operate their own shipyards. China Shipping controls five shipyards in Shanghai and Guangzhou under its China Shipping Industry Company (CIC) subsidiary, all of them specializing in ship repair work.[32] COSCO operates major facilities in Dalian, Nantong, and Guangzhou that similarly focus on ship repair and conversion, but unlike CIC, COSCO also engages in construction. The Nantong-COSCO KHI Ship Engineering Company (NACKS) shipyard, one of China's leading commercial shipbuilders, is a fifty-fifty joint venture between COSCO and Kawasaki Heavy Industries (KHI) of Japan. It builds for the COSCO fleet as well as international customers, producing 3.7 million deadweight tons since 1999 (7.7 percent of China's total), delivering over 1.1 million tons in 2006 alone.[33]

The success of NACKS highlights a growing trend toward more joint venture and private enterprise companies in China's shipbuilding industry. Prior to 1999 there were only two joint venture shipyards operating in China: the Yantai Raffles Shipyard, a joint venture established in 1994 among the China National Petroleum Company, the Yantai City Mechanical Industrial Company, and the Brian Chang Group of Singapore; and Shanghai Edward Shipbuilding, a 1997 joint venture between CSSC and Hansa Shipbuilding of Germany.[34] In 1999 the Ninth People's Congress approved a constitutional amendment officially affirming the importance of the private sector to China's economy, and the government openly encouraged shipyards to pursue joint venture development following the bifurcation of CSSC.[35]

Initially, foreign investment in most joint ventures was limited to a 49 percent share, and agreements included mandatory provisions ensuring foreign technology transfer into Chinese shipyards as a result of any partnership. Foreign companies were limited to non-controlling interests in new ship construction and low-speed marine diesel engine production, but they were allowed to establish wholly owned marine equipment factories in China.[36] These restrictions were somewhat relaxed following China's admission to the World Trade Organization (WTO) in 2001, which required the gradual opening of the Chinese economy to foreign direct investment and foreign corporate ownership across all sectors.[37] That said, Beijing continues to view shipbuilding as a strategic sector and has forbidden foreign ownership of more than 49 percent in Chinese shipyards.[38] Certain wholly foreign-owned yards, such as Singaporean Brian Chang's Yantai Raffles yard, appear to have been "grandfathered" in, since they existed prior to the promulgation of this new rule in 2006.

Foreign shipbuilders have been quick to exploit the opening of the Chinese market and eager to reap the benefits of China's low-cost labor pool to offset the rising competition from Chinese shipbuilders. Virtually all Singaporean shipbuilding and repair companies have established joint ventures or wholly owned subsidiaries in China, and major shipbuilders from Japan and South Korea have likewise entered the Chinese market in force. Tsuji Heavy Industries and the Tsuneishi Group of Japan and Samsung Heavy Industries and Daewoo Shipbuilding of South Korea have established hull-block fabrication facilities in China and have had at least limited success obtaining authorization for full ship construction at their Chinese subsidiaries.[39] In total, eight joint-venture, private-enterprise, and foreign-owned shipyards have delivered ships by the end of 2006, and six additional non-state-owned yards have ships on order as of July 2007 (see tables 1 and 2).[40]

This is not to imply that the Chinese shipbuilding industry is heading toward a wave of multinational corporate ownership. To the contrary, the PRC government recently pulled in the reins on foreign investment in Chinese shipbuilding. Limitations on foreign shipbuilding investment were retightened in September 2006, again restricting foreign companies to 49 percent shares in Chinese shipyards, diesel engine, and crankshaft manufacturing enterprises. Additionally, foreign companies "must also transfer their expertise to local partners through the establishment of technology centers."[41] The state-run *Shanghai Daily* characterized these regulations instituted by the PRC Commission of Science, Technology, and Industry for National Defense (CSTIND) as a move "to both maintain control over the fledgling [shipbuilding] industry and tap overseas know how," noting further that "a 49 percent ceiling in foreign ownership means ship manufacturing falls into the central government's 'strategic' industry category and needs special oversight and support."[42] These restrictions clearly illustrate the limit to which the PRC government is willing to let Chinese shipbuilding move toward Western-style corporate business models and point to the strategic overtones of shipbuilding development in China. The rollback of foreign investment limits is also likely to stimulate questions by European and other shipbuilding competitors about Chinese compliance with WTO regulations, questions that are likely only to increase as China captures a growing share of the world shipbuilding market.[43]

Military Shipyards

The smallest, least significant, and least understood element of China's shipbuilding industrial structure is a group of shipyards directly controlled by the People's Liberation Army (PLA). Unlike China's other state-owned shipyards, which fall under the State Council, PLA shipyards answer to the General Armaments Department of the Central Military Commission (CMC). Little open-source data is available describing

Table 4. *Recent Foreign Investment in Chinese Shipbuilding*[1]

Sources: "STX Shipbuilding to Establish Two Subsidiaries in China," Yonhap News Agency, 15 September 2006; "Tsuji Heavy Is First Foreign Yard to Build Ships in China," *Lloyd's List,* 19 July 2006; "Daeyang Angles for Major Stake in China Shiprepair," *Lloyd's List,* 29 March 2006; and "Keppel Joins New Wave of China Shipbuilders," *Lloyd's List,* 2 June 2005.

Note: 1. Listed facilities are in addition to those included in tables 1 and 2.

Facility	Foreign Company	Primary Activity
Zhoushan IMC Yong Yue Shipyard	IMC Shipping (Singapore)	Ship Repair
Sembawang Shipyard (Tianjin) Co.	SembCorp Marine (Singapore)	Ship Repair
Keppel Nantong Shipyard	Keppel Singmarine (Singapore)	New Construction
Jaya Zhohai Shipyard	Jaya Holdings (Singapore)	New Construction
Dalian Daeyang Shipyard	Daeyang Shipping (South Korea)	Ship Repair
Hanjin-Qingdao Shunhe Shipyard	Hanjin Shipping (South Korea)	Ship Repair
STX Dalian Shipbuilding	STX Shipbuilding (South Korea)	New Construction
STX Dalian Hull-Block Factory	STX Shipbuilding (South Korea)	Hull-Block Fabrication
Daewoo Yantai Shipbuilding	Daewoo Shipbuilding (South Korea)	Hull-Block Fabrication
Samsung Hull-Block Factory	Samsung Heavy Ind. (South Korea)	Hull-Block Fabrication

the exact capabilities of the PLA shipyards or the full scope of their work. Maintenance and repair of PLA Navy vessels constitute a core competency, but at least five PLA yards have engaged in some degree of commercial shipbuilding at various times over the past twenty-five years. Currently, PLA Navy Factory 4807 in Fu'an and Navy Factory 4808 in Qingdao remain active in commercial new construction, both building small chemical- and oil-products tankers for Greek and Saudi buyers.[44]

China's Shipbuilding Geography

As one might expect, the vast majority of China's shipbuilding output comes from the country's coastal provinces.[45] China's eleven coastal provinces are home to 90.7 percent of the shipyards engaged in new construction since 1999, accounting for 91.9 percent of the total ships produced and 97.6 percent of the tonnage output by deadweight. Within the coastal areas, China's shipbuilding output is even further concentrated. Just three areas—Shanghai, Liaoning, and Jiangsu—have produced over 80 percent of China's total deadweight since 1999. Fourteen shipyards in Shanghai account for 36.7 percent and the shipyards of Liaoning and Jiangsu provinces for 23.9 and 21.8 percent, respectively. Of note, 83 percent of Liaoning's tonnage output came in that period from the two yards of the Dalian Shipbuilding Industry (Group) Company, China's largest shipbuilder by deadweight.

Concentration and Yet Also Dispersion

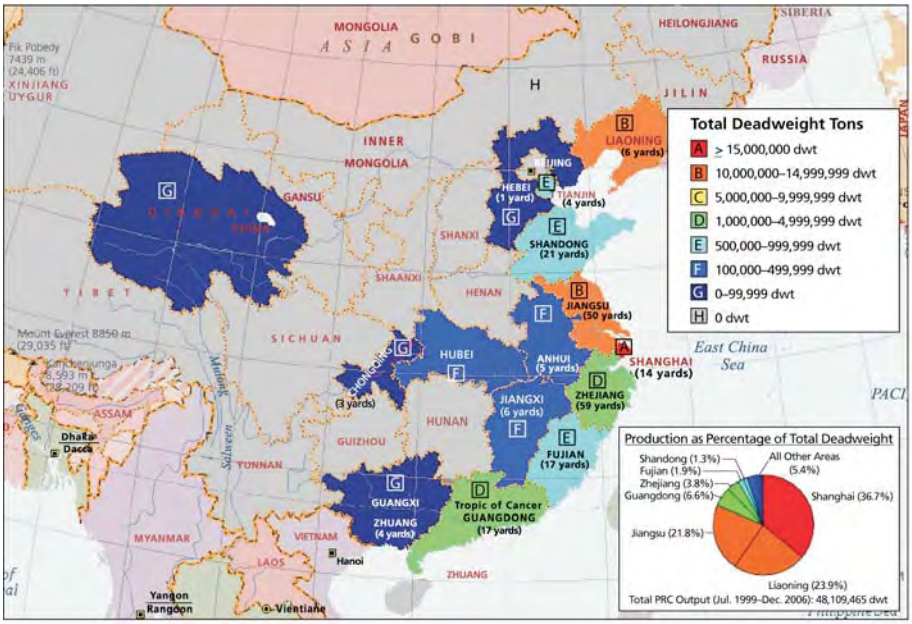
Despite the coastal concentration of tonnage output, the dispersion of China's shipbuilding infrastructure into several inland provinces is also noteworthy. Some of this dispersion is an artificial holdover from Mao Zedong's "Third Front" initiative of the

1960s, but most of China's shipyards along the Yangtze River continue to operate for legitimate economic reasons.

The Yangtze is navigable for oceangoing vessels as far as Wuhan in Hubei Province, some six hundred miles upriver from Shanghai. Smaller vessels use the river extensively for another thousand miles inland. Consequently, the Yangtze represents a commercial transportation link of importance similar to that of the Danube in Europe and the Mississippi in the United States; Vice Premier Huang Ju recently announced a fifteen-billion-RMB (1.85 billion USD) government initiative to develop further "shipbuilding standardization" and other shipping-related activities along this vital inland waterway.[46] Currently, the Yangtze's shipbuilding significance is highlighted by Song-class submarine construction at CSIC's Wuchang Shipyard in Wuhan and by China Changjiang National Shipping Groups' commercial construction work at four yards along the river. These include the Damen Yichang Shipyard in Hubei Province, a recently formed joint venture between Changjiang National and the Damen Shipbuilding Group of the Netherlands to build ships for export.[47]

The shipbuilding infrastructure along China's other rivers is not nearly as significant but does include numerous shipyards along the Yellow River in Shandong Province and the Pearl River in the south of China. Also, as China continues to promote access to the

Figure 5. *Shipbuilding Production by Province since 1999*
Source: Data compiled from Lloyd's Register–Fairplay Ltd., *Register of Ships,* Sea-web online database, www.sea-web.com.

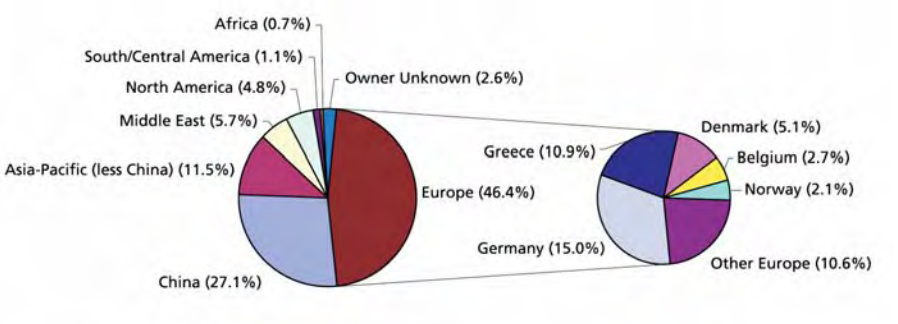


Mekong River for oceangoing ships, further development of inland shipbuilding/repair infrastructure is a future possibility.[48]

Customer Geography

Overall, Chinese commercial shipbuilding output is heavily weighted toward export sales, with roughly 80 percent of ships built in 2006 destined for export customers.[49] COSCO and other domestic customers have accounted for 553 ships, totaling thirteen million deadweight tons, built in China since 1999, but this represents only 27.1 percent of China's total deadweight output over the period. This is noteworthy considering that Chinese officials and media reports routinely stress strategic self-sufficiency in the building of a national merchant fleet as the overriding goal for shipbuilding capacity expansion.[50] Regardless of stated intentions, profit from international commercial sales appears to dominate, and the share of export tonnage is set to grow to nearly 80 percent, based on China's current commercial order book. The geographic distribution of buyers spans the globe but generally represents the overall ownership structure of the world merchant fleet.[51]

Figure 6. *Country of Origin for Buyers of Chinese-Built Ships, July 1999–December 2006*
Source: Data compiled from Lloyd's Register–Fairplay Ltd., *Register of Ships,* Sea-web database, www.sea-web.com. Figures depict country of ship group owner location, not country or flag of ship registry.

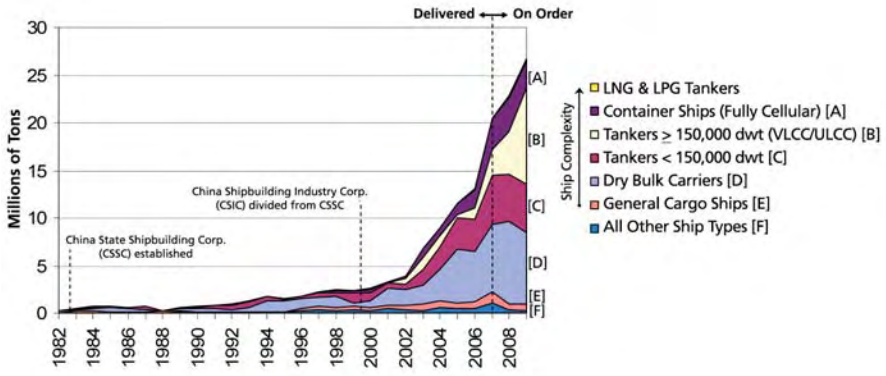


Shipbuilding Output by Ship Type

For many years after China's shipbuilding industry emerged in the 1980s, the types of ships built were of relatively low complexity. Commercially, the majority of China's shipbuilding output comprised dry bulk carriers, small tankers, and general cargo ships. On the naval side, shipbuilding through the 1980s was dominated by Luda-class destroyers, Jianghu I/II–class frigates, and Ming-class diesel submarines, all of which were obsolescent by Western standards at the time of their commissioning.

As shown in figure 7, the diversity and complexity of China's commercial shipbuilding output has steadily increased over the past twenty-five years. China has moved into the

Figure 7. *PRC Commercial Shipbuilding Output by DWT and Ship Type, 1982–2009*
Source: Data compiled from Lloyd's Register–Fairplay Ltd., *Register of Ships,* Sea-web database, www.sea-web.com.



lucrative international markets for large containerships and VLCCs/ULCCs, and CSSC's Hudong-Zhonghua Shipbuilding delivered the first Chinese-built LNG tanker in 2007, with at least three more LNG tankers in varying stages of construction at the Shanghai yard.[52] The ability of Chinese shipyards to build these larger, more complex ships can largely be attributed to a blending of growing domestic experience with a fair amount of foreign technology, but it is also a product of investments in expanded and modernized shipbuilding infrastructure. Photo 1, for example, shows the new Chinese-built LNG carrier *Dapeng Moon* at dockside in the heavily modernized Shanghai Hudong-Zhonghua shipyard.

Prior to 1995, China did not have a building dock large enough to construct VLCCs or other large types of commercial ships. A 300,000-dwt dock at Dalian Shipbuilding's No. 2 Yard (formerly "Dalian New Shipbuilding Heavy Industry") delivered the first Chinese-built VLCC in 2002, and since then eight additional VLCC-sized building docks have been added in China.[53] With current shipyard expansion projects, China's VLCC dock inventory is expected to reach thirty by 2015. This will dwarf the current nine in Japan and more than double the number in South Korea (the two countries that have heretofore dominated the global VLCC market).[54] As figure 5 illustrates, VLCCs will figure in China's output as more large building facilities come on line in coming years, and output will trend toward the mix of increasingly complex ships officially targeted in China's National Medium and Long-Term Plan of the Shipbuilding Industry:

- High-tech, high-function, and special ships, and large ships of 100,000 dwt and above

- Passenger ships, roll-on/roll-off (Ro-Ro) passenger ships, passenger-cargo ships, and train ferries
- LPG ships and LNG ships with a handling capacity of 5,000 cubic meters and above
- Containerships with a capacity of three thousand twenty-foot-equivalent units (TEU) and above
- Large deep-sea fishing boats, marine drill vessels, oil rigs, marine floating production, storage, and off-loading (FPSO) structures, and other offshore engineering equipment.[55]

China's move toward producing larger, more complex ships has not been limited to the commercial sector. When CSIC received China's first order for VLCCs in 1999, its general manager reportedly remarked that it was a dream come true, since Chinese shipbuilders "had long had two dreams—to build military aircraft carriers, and huge crude oil carriers."[56] Although China has yet to build an aircraft carrier, it now possesses building docks capable of doing so, and it has demonstrated significant progress in building more complex naval ships over the past decade.[57] Recent years have seen the Luyang II–class (Type 052C) air-defense destroyer emerge from Jiangnan Shipyard, Jiankai-class (Type 054) "stealth" frigates from the Hudong and Guangzhou Huangpu shipyards, and two new classes of nuclear-powered submarines from Bohai Shipbuilding Heavy Industries in Huludao. All of these classes represent notable advances in technology and complexity over previous Chinese warships, and each of these shipyards is engaged in both military and commercial construction.

Viewed holistically, the cumulative effects of China's improved commercial shipbuilding prowess have undoubtedly benefited China's naval development to some degree. As previously discussed, most of China's shipyards have undergone significant infrastructure improvements, and the large volume of foreign commercial sales has provided PRC shipyards (and the central government) with resources necessary to train and equip their workforces for naval construction. Beyond these generalizations, it becomes far more difficult to quantify the degree to which commercial success has benefited Chinese naval development. While some fundamental aspects of ship design and construction are inherent to any ship type, the unique design requirements and operational characteristics of warships often cause military shipbuilding to diverge sharply from the harsh economic demands that govern tankers and containerships built for an internationally competitive commercial market.[58]

Commercial-Military Synergies: Key Processes and Technologies

To provide a better understanding of the implications of China's commercial shipbuilding development on naval modernization, the second half of this study will focus

Photo 1. *Bulk carrier* Ecomar *(left) and LNG carrier* Dapeng Moon *(right) in Hudong-Zhonghua Shipyard*

on five key shipbuilding process and technology areas that have potential for significant civil-military overlap: advanced ship production methods, systems integration, hull construction and metallurgy, subcomponent technologies, and marine propulsion technologies. Examining China's indigenous capabilities in these key areas will offer a more refined look into China's commercial shipbuilding progress beyond the volumetric measurement of tonnage output and, more importantly, provide insight into how advances in these areas may (or may not) affect the pace of future Chinese naval development.

Advanced Ship Production Methods

The expansion and modernization of China's major shipbuilding facilities over the past decade have been accompanied by appreciable advances in shipbuilding processes and construction methods. For the most part, this trend has centered on the adoption of the hull-block construction method and associated zone-based production systems (i.e., on-block zone outfitting, painting, testing, etc.). The hull-block method can be traced back to the building of the U.S. emergency fleets during World Wars I and II; it essentially represents modular construction and group technology processes applied to shipbuilding. It has been perfected by Japanese and South Korean shipbuilders in recent decades by incorporating many of the quality-control and "just in time," "lean," manufacturing aspects of the renowned Toyoda Production System. Currently it is accepted as the gold standard of efficiency for virtually all forms of shipbuilding.[59]

The primary benefits of hull-block construction are shorter build times for individual ships and greater overall throughput capacity for a shipyard, translating into greater productivity and profit. In the centuries-old shipbuilding method of laying a keel and building an entire hull upon it piece by piece, a ship is typically not moved until it is launched into the water. In the hull-block method, modules are assembled in a quasi-assembly-line fashion, moving in logical work flows through various work stations and assembly points in the shipyard. Smaller modules are sequentially joined together to form ever-larger blocks; only the largest "grand blocks" are moved onto a building way or into a graving dock for final joining. This approach minimizes the amount of time

that each individual ship occupies the critical building-way/graving-dock bottleneck prior to launch. Furthermore, blocks are painted and outfitted with subsystems to an optimal extent throughout the process, thereby reducing the time required for fitting out after the hull is launched.

Although relatively simple in concept, full-scale adoption of the hull-block construction method is often challenging. It requires a paradigm shift, extending back to the ship-design process, and elaborate management control systems. Implementing hull-block construction methods can be equally challenging from a physical perspective, especially for older shipyards with infrastructure originally sized for sailing vessels, not today's mammoth supertankers. Moving large hull blocks (especially those made appreciably heavier by pre-outfitting) often requires investment in sophisticated transport equipment and high-capacity cranes; also, accurately joining grand blocks on traditional, inclined building ways is no trivial task. Consequently, many world-class commercial shipbuilders have achieved their leading positions by effectively starting from scratch, investing in new greenfield facilities. These new shipyards optimize their layout for efficient material flow; use modern high-capacity gantry cranes; and employ not inclined slipways but land-level building docks, ship lifts, or floating dry docks for ease of grand-block assembly and ship launching.[60]

In China, this "greenfield" trend is highlighted by the completely new CSSC Shanghai Waigaoqiao, Changxing Island, and Guangzhou Longxue shipyards, as well as by CSIC's Dalian Shipbuilding No. 2 and Qingdao Haixiwan yards. These new facilities incorporate hull-block construction and other modern building methods. Most major Chinese yards now have imported computer-aided design, modeling, and production equipment to aid further in implementing advanced production techniques.[61] As a result, China's improved shipbuilding infrastructure not only adds the additional capacity required to build today's large commercial ships but facilitates full implementation of modern shipbuilding techniques required to match the series-production rates of Japanese and South Korean shipbuilders. Recent Chinese writings indicate that block production and other efficiency improvements have allowed Waigaoqiao to shorten the time needed to build a 175,000-dwt Capesize bulk carrier from 369 days to, first, 109 days and now thirty-five days per vessel. Such advanced construction practices, together with other operational improvements, have allowed the yard's per-worker productivity to climb from 40,000 RMB/man-year to 127,000 RMB/man-year.[62]

In general, these more efficient production methods have the potential to yield similar beneficial effects on military shipbuilding: reduced build times, increased shipyard output, and lower individual unit cost. These potential benefits are certainly noteworthy and should not be discounted, but the inherent differences between military and commercial shipbuilding introduce a significant caveat—expected efficiency gains in

commercial shipbuilding cannot necessarily be translated in their entirety into Chinese naval development.

The efficiency gains realized through block construction and lean shipbuilding techniques are typically realized to their fullest extent only over the long term of series production. Military shipbuilding typically deals in much smaller production runs, and the inherent complexity of warships produce substantially more in-process design changes and technical problems that disrupt production flow than is the case in the commercial sector. Time and cost benefits can still be achieved in military shipbuilding as compared to traditional production methods, but it is exceptionally difficult to realize the full benefits of improved commercial production techniques when military and commercial production are attempted within the same facility. When coproduction is undertaken, delays in military production often negatively affect commercial efficiency (especially if delay ties up a critical production point, such as a building dock). Whereas a military client (i.e., the government) has little choice but to accept delays and disruptions in naval shipbuilding, an international shipowner, having other choices in building location, may be far less likely to accept delivery after the contracted dates.

Consequently, as China's shipbuilding industry continues to move toward a goal of efficiently building more complex and high-value commercial ships, it is likely to face many of the same coproduction and commercial-military prioritization challenges previously encountered by Western shipbuilders. Shipbuilders in the rest of the world (including the leading commercial builders in Japan and South Korea) have almost all responded by specialization. They have either isolated military production to a specific shipyard away from commercial activities or opted out of one or the other type of shipbuilding altogether. Furthermore, shipbuilders remaining active in both sectors have largely devoted their largest, most modern yards to commercial production, leaving smaller, older facilities to military shipbuilding, with its lower competitive pressures, smaller production runs, and generally smaller vessels.[63]

There are dangers in mirror-imaging the actions of private and publicly owned Western shipbuilders onto state-owned Chinese shipyards, but initial indicators show a similar trend developing in China. The older shipyards of CSSC and CSIC routinely engage in commercial and military shipbuilding within the same facility, often on adjacent building ways and even within the same building docks.[64] The same cannot be said of China's newest shipyards. At Dalian Shipbuilding, the new greenfield shipyard (Yard No. 2) has thus far produced only commercial ships, while Type 051 destroyers have been built on the inclined slipways of the old Dalian Shipyard (Yard No. 1). Likewise, CSSC's Shanghai Waigaoqiao land-level shipyard has focused on dry bulk carriers and large oil tankers since opening in 2003, while the PLAN's most advanced Type 052B/C

destroyers have slid down the ways a few miles away at the 142-year-old Jiangnan Shipyard.

This is not to say that highly advanced warships cannot be built at older shipyards. Bath Iron Works built *Arleigh Burke*–class Aegis destroyers on traditional slipways up through 2001 at its cramped 123-year-old facility in Maine.[65] Nonetheless, under normal peacetime conditions, the efficiency gains achieved through advanced production methods and shipyard facilities are more likely to help China achieve a larger share of the commercial shipbuilding market than to play a dominant role in PLAN modernization. Under more ominous strategic circumstances, though, PRC leadership could always forgo the commercial advantages of these new facilities for the sake of national security. Diverted toward military production, the advanced production capabilities of China's new shipbuilding infrastructure hold considerable strategic potential, as will be further discussed below.

Systems Integration

Advanced shipyards and production processes do not of themselves guarantee the ability to build complex ship types. Efficiently integrating numerous mechanical, electrical, cargo, and habitability systems within the confined space of a ship has always been a principal challenge for naval architects and shipbuilders, and it is often the greatest difficulty in warship construction. The space, weight, electrical load, and redundancy requirements for every major mechanical and electrical component must be accounted for in a ship's design, and a shipbuilder must successfully install, integrate, and test the miles of piping, cable, duct work, and computer software that link all of a ship's various subsystems together. These tasks become ever more demanding as the overall complexity of a ship increases, reaching a pinnacle in warship production due to the additional demands of weapons systems, increased redundancy, and large crews. Whereas a typical VLCC may have two hundred major pieces of mechanical and electrical equipment among its two dozen systems, a modern destroyer can have that level of complexity in its propulsion plant alone.[66]

Consequently, the ability of Chinese naval architects and shipbuilders to integrate successfully increasingly complex ship systems stands to have a significant impact on the pace of China's naval development. The dry bulk carriers and oil tankers that have thus far dominated Chinese commercial shipbuilding are relatively low in complexity and offer little or no potential for a carryover effect for improving systems integration in military shipbuilding. The same cannot be said of the considerably more complex 210,000-dwt FPSO vessels recently built by Dalian Shipbuilding or of the LNG tankers currently under construction at Hudong-Zhonghua Shipbuilding in Shanghai. The sophistication of the cargo processing and storage equipment on these vessels is at the

high end of the spectrum for commercial ships and exceeds that of most naval auxiliaries. Large cruise ships are more complex, in the sheer volume of systems that must be integrated to accommodate (and entertain) thousands of passengers, but the technological demands of building FPSOs and LNG carriers are by no means negligible.

The impression of progress in systems integration proficiency shown by Chinese shipbuilders on these projects is somewhat tempered by the level of foreign technical assistance required. In the case of the FPSO under construction at Dalian, the shipowner has required a team of technical representatives four times larger than for similar projects built in South Korea, and the most complex portions of the vessel's outfitting are scheduled to be installed in Singapore after it leaves Dalian.[67] Similarly, Chantiers de l'Atlantique of France is providing significant technical assistance for the LNG project at Hudong-Zhonghua Shipbuilding, reportedly maintaining a team of fifty technicians on site throughout the project.[68]

In the naval sector, the outward complexity of the Luyang II air-defense destroyer and other recent PLAN programs seems to indicate a growing trend of improving systems integration. The Luyang II class is equipped with the PLAN's first phased-array radar, the cornerstone of a combat system that also includes HQ-9 naval surface-to-air missiles and a forty-eight-cell vertical-launch system (VLS). The integration of these three subsystems into a comprehensive long-range, area-air-defense system is a notable achievement, and it may indicate a move toward improved PLAN blue-water capability.[69] While this may be the case, however, little is currently known as to the actual capabilities or operational effectiveness of the Luyang II's systems, and one cannot look past the purchase of advanced *Sovremenny*-class destroyers and Kilo-class submarines from Russia as indicators of continued limitations in indigenous capabilities for integrating the most complex warship systems.

As the FPSO and LNG projects illustrate, the systems integration capabilities of PRC shipyards will remain one of the primary challenges in PLAN modernization. The production of 300,000-dwt ULCCs demonstrates the ability of Chinese shipyards to build hulls of aircraft-carrier size and strength, but their ability to integrate the complex matrix of aircraft, catapults, arresting gear, weapons systems, and large propulsion plants required for an operational aircraft carrier remains in doubt.[70] Still, the steady progression in the complexity of both commercial and military shipbuilding in China makes systems integration capabilities an area worthy of future attention in tracking PLA naval modernization.

Hull Construction and Metallurgy

Notwithstanding its low systems complexity, a 300,000-dwt crude carrier is still a structurally imposing web of steelwork. International environmental safety concerns have

led to double hulls and increased subdivision in virtually all new crude carriers, and the large hatch openings and hull-fairing requirements of high-speed containerships have produced an equally demanding set of structural design and construction challenges.[71] In this regard, the volume of commercial production at Chinese shipyards has provided ample opportunity to refine and develop the steel fabrication and construction processes required for building today's large merchant vessels. These improvements have been facilitated by the increasing capacity, quality, and price advantage of China's steel industry, as well as by the importation of the latest automated welding and steel-panel-processing equipment from Europe, Japan, and South Korea.[72]

There are potential carryover effects for the military sector. While basic to ship production, steel quality and structural integrity have not always been a strong point for Chinese naval vessels. Luda-class destroyers and other earlier classes of Chinese surface combatants apparently lacked adequate watertight subdivision or damage-control capabilities. The four Type 053HT frigates built by Hudong-Zhonghua Shipbuilding for the Royal Thai Navy in the early 1990s were reportedly of such poor material quality that they required immediate dry-docking in Thailand after delivery to correct numerous serious deficiencies.[73]

Recent generations of PLAN combatants have undoubtedly benefited at some level from the hull construction experience gained from commercial production, and Chinese shipyards now possess more familiarity with the structural requirements of building larger, more complex ships, experience that could prove equally beneficial to future naval modernization efforts. Despite the opportunity for civil-to-military carryover, little is known, beyond superficial observation, of the actual structural quality of new PLAN vessels, and several shortcomings still exist in the commercial sector. One Chinese government official recently cited Chinese structural design abilities as lagging far behind top shipbuilders;[74] a Western technical representative interviewed specifically identified steel castings and welding quality as areas of continued concern when contracting work to Chinese shipyards.[75]

Further reflecting these concerns, a coalition of four PRC government agencies in April 2005 started a "national special campaign against construction of low quality ships" that included strengthened regulatory standards and inspections of Chinese-built ships and yards. These inspections reportedly forced suspension of operations at 303 Chinese shipyards and failed 586 ships of poor material quality (of which 202 were designated for scrapping).[76] Most of these shipyards were undoubtedly small local and provincial yards and the failed ships of early vintage, but the inspection results illustrate the wide disparity in basic quality that still exists across the Chinese shipbuilding industry.

There are also limits to the degree to which progress in commercial hull construction can directly benefit military shipbuilding. Whereas merchant ship hulls are typically made of mild-steel plates of consistent thickness for ease of construction and lower cost, stringent weight and strength concerns in naval vessels often force the use of more advanced steel types and a wide variety of plate thicknesses. These demands require sophisticated steel fabrication and welding techniques that are rarely found in commercial shipbuilding. Naval auxiliary vessels are often built to commercial hull standards, but the vast majority of combatant vessels are constructed with grades of steel, types and qualities of welds, and varieties of plate thicknesses that differ significantly from commercial practice. The use of stainless and high-nickel steels in LNG, LPG, and specialty chemical tankers provides some experience with more advanced fabrication and welding techniques, but the development of these skill sets will likely be driven more by military than by commercial ship production needs.

One notable exception in which commercial hull construction is leading military development is the use of aluminum in fast ferries. The extra cost and complexity of designing and building ships with this aluminum are made commercially viable by the speed benefits afforded through lighter weight. The lower structural strength and melting point of aluminum, however, have limited its use in mainstream warship construction.

Despite these strength and damage resiliency disadvantages, several navies have recently turned to aluminum as they look for high speed in specialized littoral warfare and transport vessels. In doing so, they have turned to leading commercial fast-ferry builders (such as Austal of Australia) for not only aluminum welding and fabrication techniques but complete aluminum hull designs. The trimaran variant of the U.S. Navy's new Littoral Combatant Ship (LCS) is being designed and built by Austal USA; in China, the aluminum catamaran hull of the new Type 022 Houbei-class fast attack craft is widely believed to be derived from Western fast-ferry designs.[77] Consequently, whereas traditional types of PLAN frigates and destroyers are likely to draw only general benefits in hull construction quality from commercial shipbuilding development, smaller fast-attack craft and other specialized types may benefit heavily from commercial advances in aluminum hull construction.

Subcomponent Technologies

Warships have always shared some degree of subcomponent commonality with commercial ships in basic habitability, deck equipment, and other non-combat-related mechanical systems. In recent years the level of commercial-military component commonality has increased, as naval vessels have incorporated more commercially available computer processors and networks, bridge control and navigation systems, and other commercial off-the-shelf (COTS) technology in an effort to control costs and facilitate

Photo 2. *Type 022 Fast Missile Boat*

more frequent technology upgrades. Consequently, the development of China's commercial marine equipment industry has significant relevance to further PLAN modernization.

The present state of the commercial marine equipment industry is one of notable concern for Chinese officials. Overall, only 40 percent of subcomponents on Chinese-built commercial ships are from indigenous suppliers. This average percentage falls precipitously for specific ship types of higher complexity (table 5) and is substantially lower than the 85 and 98 percent domestic-subcomponent-sourcing averages for South Korean and Japanese shipbuilders, respectively. Commenting on this foreign reliance, Zhang Xiangmu of CSTIND noted, "A lot of key components simply cannot be manufactured in China at the present time. The country's capacity to provide the products required for high-tech and high added-value ships is woefully insufficient."[78] Wang Rongsheng, the president of the China Association of the Shipbuilding Trade (CAST) echoed this assessment, commenting that the "low level of the ship components industry has become the bottleneck for the future development of China's shipbuilding industry."[79]

The impact of reliance upon foreign subcomponent technology goes beyond national self-reliance concerns. The cost of purchasing subcomponents abroad directly offsets hard-currency profits, raises the exposure of China's shipbuilders to monetary exchange-rate fluctuations, and diminishes the "pillar industry" effects of shipbuilding—that is, promotion of secondary industries in China. Moreover, delivery delays of outsourced components often interrupt shipyard production flows, further eating into profits through decreased efficiency. If not improved, one Chinese analyst has warned, this situation could make China a "hull builder" rather than a true shipbuilder.[80]

Table 5. *PRC-Sourced Subcomponents by Ship Type*
Source: *Ship Engineering* 27, no. 1 (2005) [in Chinese].

Ship Type	Percentage of PRC-Sourced Subcomponents
Capesize Dry Bulk Carrier (175,000 dwt)	59
Oil Products Tanker (46,000 dwt)	58
1200–1400 TEU Containership	41
Very Large Crude Oil Carrier (VLCC)	22
5668 TEU Containership	15
LPG Tanker	5

In response to these issues, the CSTIND has set a goal of producing 60 percent of all subcomponents on Chinese-built commercial ships by 2010, and 80 percent by 2015. The PRC's National Defense Science and Engineering Working Group has outlined a strategy for achieving these goals, and the latest National Medium and Long-Term Plan of the Shipbuilding Industry has cited spurring greater technical innovation in the marine equipment industry as a major goal. Achieving these goals will not necessarily require starting from scratch, as China already possesses a large array of marine equipment manufactures. The primary problem lies in the fragmented nature of the industry and low level of indigenous technological development. Consequently, organizing China's current disparate array of small equipment manufactures into a few internationally known "brand name" suppliers and using market-access-for-technology transfer agreements with foreign companies have become key aspects of China's overall marine subcomponent development strategy.[81]

In some areas, the Chinese subcomponent industry appears to be making progress, while in others it significantly lags international standards. This assessment is supported by myriad statements in Chinese and English sources, as well as by observation and interviews with shipbuilders and shipowners who operate in China. One of the authors attended the November 2007 MARINTEC marine exhibition in Shanghai and observed that Chinese firms making pumps, gears, propellers, and other machine-tooled parts were well represented but that European and Japanese firms dominated the displays of marine engines, complex electronics, and control and navigation equipment.

There is little doubt that the problems in China's marine equipment industry have affected PLAN modernization as they have the commercial shipbuilding sector. Indeed, Chinese shipbuilding industry trade publications readily note that innovation in pursuit of commercial and military objectives is a major concern for CSSC.[82] Such analyses point out that successful development of ship technologies for civilian use rapidly

shortens the time and cost associated with developing military variants; they also extol the benefits of military spin-offs for civilian shipbuilding. In particular, they cite military transport vessels and amphibious assault ships as types whose development may substantially benefit from the transfer of technology originally intended for civilian ships.

In general, China has long relied on foreign-made, licensed, or reverse-engineered technology for major weapons systems, and despite notable advances in indigenous combat systems in its latest classes, it still utilizes a high degree of imported combat systems equipment in most PLAN vessels (table 6).[83] This dependence upon foreign subcomponents, whether combat systems or less glamorous commercial dual-use items, drives up acquisition and life-cycle maintenance costs, increases system integration challenges, and places additional demands on crew training. The Chinese literature includes accounts of sailors tracing out systems by hand on new Kilo-class submarines due to a lack of technical documentation, as well as instances of flying in German technicians to repair imported MTU diesel engines on the Type 052 destroyer *Qingdao* (DDG 113) during the PLAN's first round-the-world cruise in 2002.[84] These examples illustrate the detrimental effect that imported technology can have on operational

Table 6. *Major Foreign-Built/Licensed Weapons Systems on PLAN Vessels*

Source: Bjorn Hagelin, Mark Bromley, and Siemon T. Wezeman, "Register of Transfers of Major Conventional Weapons, 2005," in *SIPRI Yearbook 2006: Armaments, Disarmament, and International Security* (Oxford: Oxford Univ. Press, 2006), pp. 494–96; and Stockholm International Peace Research Institute, "Trade in and Licensed Production of Major Conventional Weapons: China 1989–2005," www.sipri.org/contents/armstrad/access.html.

Note: 1. Numbers of weapons ordered are best estimates according to SIPRI data. Includes direct sales and production licenses. List does not include weapons systems sold as part of complete naval platforms (e.g., Kilo SSKs and *Sovremenny* DDGs).

Supplier Country	Weapon System (No. Ordered)[1]	Year(s) of Delivery	Platform Application
France	100 mm Naval Guns (2)	1989	1 Jianghu II FFG
	Castor-2 Fire Control Radars (14)	1994–2002	HQ-7 SAM system in 2x Luhu, 1x Luhai, 3x Luda I DDGs, and 8x Jiangwei II FFGs
	DRBV-15 Sea Tiger Radars (6)	1987–99	2x Luhu, 2x Luhai, 2x Luda I DDGs
	DUBV-23 Sonars (5)	1991–99	2x Luda, 1x Luhai, 2x Luhu DDGs
	DUBV-43 Sonars (2)	1994–96	2x Luhu DDGs
	R-440 Crotale SAMs (336)	1990–2002	2x Luhu, 1x Luhai, 3x Luda I DDGs, and 8x Jiangwei II FFGs
	AS-365/AS-585 Dauphin Helos (28)	1987–91	Various
Italy	RTN-20S Fire Control Radars (17)	1991–2001	2x Luhu, 1x Luda III, 1x Luhai DDGs, and 6 or 7 Houjian PTGs
Russia	Ka-27 PL (Helix-A) Helos (10)	1997–2000	Various
	Fregat/Top Plate Air Surv. Radars (4)	2004	2x Luzhou and 2x Luyang I DDGs
	MR-90/Front Dome FC Radars (8)	2004	2x Luzhou and 2x Luyang I DDGs
	48N6/SA-10 Grumble SAMs (144)	2002–?	2x Luzhou DDGs
	9M317/SA-17 Grizzly SAMs (264)	2005	2x Luyang I DDGs (also for *Sovremmeny* DDGs)

readiness, and they likewise highlight how China's ability to meet its goals of improving its domestic marine equipment industry stands to affect significantly both commercial and military shipbuilding development.

Marine Propulsion Technologies

Within the larger group of ship subcomponent technology, marine propulsion is worthy of particular note. It is an area in which Chinese industry has struggled to develop indigenous technology, but more significantly, marine propulsion is perhaps the dual-use technology most directly transferable between commercial and military shipbuilding. Commercial diesel engines are common in naval auxiliary vessels worldwide, but whereas U.S. Navy combatants are predominantly driven by high-performance gas turbine engines or nuclear reactors, Chinese surface combatants and submarines also rely heavily on diesels derived from the commercial sector. Medium-speed (300–1,000 rpm) diesels offer high power at a reasonable size and weight, and they typically have lower initial and fuel-consumption costs than higher-powered gas turbines.[85] Larger low-speed diesels offer high thermal efficiency and ideal fuel economy, but their mammoth size and weight make them ill suited for naval applications (with the exception of a few large auxiliary vessels). Medium-speed diesels are further attractive for many navies specifically because of their high commercial commonality; examples are the SEMT-Pielstick PA- and PC-series diesels on fifty-three Chinese-built commercial ships and seventy-two PLAN naval vessels (including forty-seven combatants).[86]

The Pielstick example demonstrates the civil-military overlap in diesel engine technology, but is also indicative of China's traditional high reliance on imported marine diesel technology. The earliest generations of PRC-built ships relied heavily on Soviet diesel engines, initially those directly imported from the Soviet Union, and gradually

Table 7. *Comparison of Major Marine Propulsion Types*
Sources: GE Aviation, "Model LM2500," www.geae.com/engines/marine/lm2500.html; and *MAN Diesel*, www.manbw.com.

Engine	Engine Max Power	Weight (tons)	RPM	Specific Fuel Rate (g/kw-hr)	Applicability	Comments
GE LM2500 Gas Turbine	25,055 kw (33,600 SHP)	5	3,600	227	Surface combatants, cruise ships, fast ferries	4x LM2500s on USN DDGs and CGs
MAN 18V488/60B Medium-Speed Diesel	21,600 kw (28,996 SHP)	259	514	176	All types of naval vessels, small/mid-sized comm. vessels	Largest medium-speed diesel marketed by MAN
MAN 7S80 MC6 Low-Speed Diesel	25,480 kw (34,169 SHP)	996	79	167	Mid-sized commercial vessels	Mid-sized low-speed diesel
MAN 14K98MC7 Low-Speed Diesel	87,220 kw (116,964 SHP)	2,446	97	171	Very large commercial vessels	Largest low-speed diesel marketed by MAN

engines built locally under license (often with technical assistance). Continued production of Soviet designs and reverse engineering of other foreign designs provided propulsion for roughly half of China's small commercial output in the 1960s and 1970s, with the remaining engines primarily coming from state-owned suppliers in East Germany, Czechoslovakia, Poland, and Yugoslavia. Similarly, Romeo-class submarines, Huangfeng patrol craft (PTGs), and T-43 minesweepers built in PRC shipyards during this period were propelled by Chinese copies of Zavod, Zvezda, and Kolomna diesel engines from the Soviet era. The quality of these Chinese engines was rather suspect; the engines of several Romeo-class submarines sold to Egypt reportedly required extensive refurbishment after their delivery voyages in 1983–84.[87]

The reforms under Deng Xiaoping opened China to a significant boost from European diesel technology. Sulzer Brothers of Switzerland signed a licensing agreement in 1978 to allow their world-class low-speed diesels to be manufactured in China, and Maschinenbau Augsberg-Nuernberg (MAN) of Germany and Burmeister & Wain (B&W) of Denmark followed with similar agreements in 1980.[88] Since then most other major international diesel manufacturers have likewise entered the lucrative Chinese market, either through licensing deals, joint ventures, or more recently, a limited number of wholly owned subsidiaries established in China (table 8). These companies represent the world leaders in diesel engine technology, and they have provided Chinese-built commercial ships with the propulsion reliability required to attract international customers.

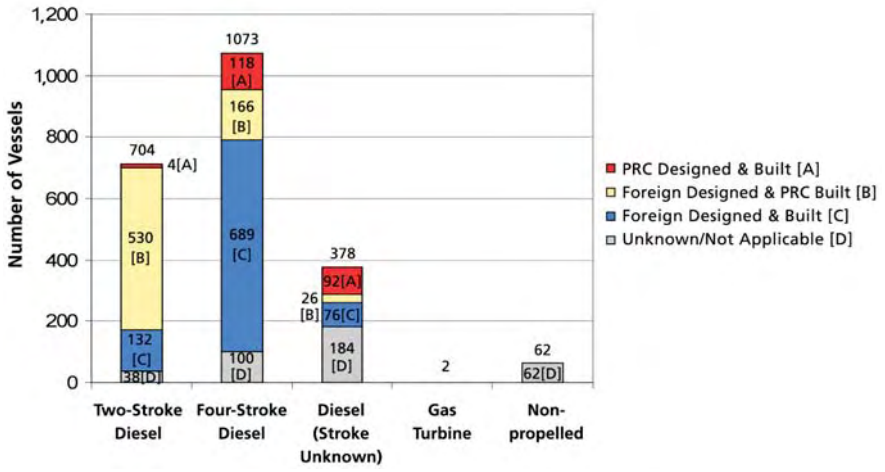
Table 8. *Foreign Diesel Manufactures in China*

Sources: Lloyd's Register–Fairplay Ltd., *Register of Ships,* Sea-web database, www.sea-web.com; and Wärtsilä Corp., *Wärtsilä Annual Report 2006* (Helsinki: Wärtsilä, 2006).

Low-Speed/Two-Stroke Diesels	
MAN B&W	Denmark
Wärtsilä Switzerland (Sulzer)	Switzerland
Mitsubishi Heavy Industries	Japan
Medium-Speed/Four-Stroke Diesels	
MAN	Germany
Motoren Werk Mannheim (MWM)	Germany
MTU Friedrichshafen	Germany
Wärtsilä	Finland
SEMT-Pielstick	France
Caterpillar-MaK	United States/ Germany
Cummins	United States
Daihatsu	Japan

Hudong Heavy Machinery, and the Shaanxi, Dalian, and Yichang Marine Diesel Engine Factories have become highly reputable manufacturers on the world commercial market through license production of foreign name brands, but as of yet no Chinese engine builder has broken through with a successful indigenous design. The vast majority of Chinese-built diesel engines remain licensed copies of foreign (principally European) designs. Chinese-designed engines account for only 11 percent of the known four-stroke/medium-speed diesel propulsion plants on Chinese-built ships since 1999 and less than 1 percent of the two-stroke/low-speed diesels prevalent on large commercial vessels. Chinese engine builders reportedly still

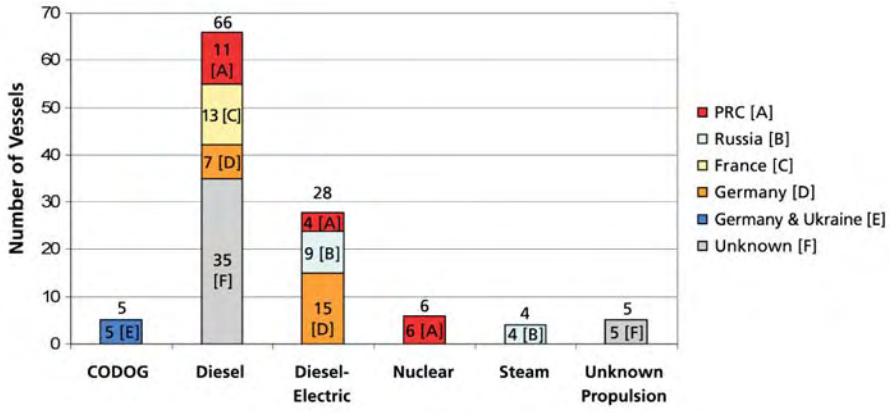
Figure 8. *Type and Origin of Propulsion Plants on PRC-Built Commercial Ships, 1999–2006*
Source: Data compiled from Lloyd's Register–Fairplay Ltd., *Register of Ships,* Sea-web database, www.sea-web.com.



experience difficulties manufacturing and mating engine blocks and crankshafts on large marine diesels; foreign licensing companies frequently provide close technical assistance and quality-control oversight for Chinese factories building their most advanced engine models.[89]

The proportion of Chinese indigenous technology is similarly low in naval propulsion. There is insufficient open-source data in the military sector to determine the ratio of imported engines and those built locally under license, but the design origin is known for most PLAN naval propulsion plants. Figure 9 illustrates the high proportion of

Figure 9. *Type and Design Origin of Propulsion Plants on New PLAN Ships, 1999–2006*
Sources: Richard Saunders, ed., *Jane's Fighting Ships 2006–2007* (Surrey, U.K.: Jane's Information Group, 2006); Eric Wertheim, ed., *The Naval Institute Guide to Combat Fleets of the World 2005–2006* (Annapolis, Md.: Naval Institute Press, 2005); and *Chinese Defence Today,* www.sinodefence.com. Various earlier editions of *Jane's Fighting Ships,* and *Jane's* online database, www.janes.com, were also consulted.
Includes foreign-built vessels (Kilo SSKs and *Sovremenny* DDGs), and units known to be under construction as of January 2007.



diesel propulsion in Chinese ships and submarines built since 1999, and the very small percentage of indigenous Chinese engines. MTU diesels from Germany are used on Song-class submarines, Luhai and Luyang I/II–class destroyers, and they may also be included in China's latest Type 071 (Yuzhao) amphibious ships.[90] Likewise, French SEMT-Pielstick diesels provide the main propulsion for Jiangkai-, Jiangnan-, and Jianghu-class frigates, Houjian-class PTGs, and eight additional classes of PLAN landing and auxiliary ships.[91]

Of note, licensed production of SEMT-Pielstick diesel engines for military application (Jianghu-class frigates) dates back to the mid–1970s, several years before production of licensed Sulzer, MAN, B&W, or Pielstick engines began for commercial use. Furthermore, the sale of Rolls-Royce Spey jet engines to China during this period raised international attention (and the direct involvement of presidents Richard Nixon and Gerald Ford, Henry Kissinger, and British prime minister Edward Heath), yet the transfer of naval propulsion technology went relatively unnoticed.[92] This applies to the Spey jet engines themselves, since a marine gas turbine derivative of the Spey has since been used for main propulsion in British warships.[93]

Marine gas turbines, like diesel design, have not been a bright spot in Chinese industry. Their development has been severely hindered by the slow place of indigenous jet engine development, which is symptomatic of larger issues within the Chinese aerospace industry as a whole. Progress in turbofan (vice older turbojet) technology has been particularly slow, thus affecting the high-performance aircraft and marine gas turbine applications that use these more modern and efficient engines.[94] Consequently, no indigenous marine gas turbine has been fielded to date, and the few PLAN units using gas turbine propulsion have thus far relied on imported engines. The lead unit of the Type 052 Luhu class of destroyers is equipped with two General Electric LM2500 gas turbines, but U.S. sanctions imposed following the Tiananmen Square incident forced all following Luhu, Luhai, and Luyang I units to use Zorya-Mashproekt DA-80 gas turbines imported from Ukraine. A technology transfer and license manufacturing agreement with Zorya-Mashproekt was signed in May 2001, but it is unclear whether the DA-80 turbines on the latest Luyang II destroyers were locally produced under license or imported fully built from Ukraine.[95]

The short-term likelihood that Chinese marine gas turbines will directly affect PLAN modernization is low, but there are indicators of possible improvements in the longer term. Jet engine development is a high priority within the PLA, and the recently introduced J-10 and J-11 fighters are expected to be powered by an indigenous W-10A turbofan engine. The original W-10 and other earlier Chinese turbofans were less than successful, but the W-10A reportedly benefits technologically from Lykulka-Saturn AL-31F turbofans imported from Russia to power Su-27, Su-30, and earlier J-10

aircraft. Furthermore, the Shenyang Engine Research Institute developed China's first indigenous aero-derivative gas turbine in 2002 (the QD-128, derived from the Kunlun jet engine), and Chinese companies are actively pursuing development of larger aero-derivative gas turbines for electrical power generation and other industrial applications.[96] Success with the W-10A turbofan and these aero-derivative initiatives could provide a significant boost to Chinese marine gas turbine development and help fill the persistent void in indigenous propulsion technology that has thus far hampered naval modernization in China.

Human Factors

The technical aspects of ship production methods, systems integration, steel hull construction, marine subcomponents, and marine propulsion certainly have tremendous bearing on the future course of shipbuilding development in China. However, the value of gains in these areas is diminished if they are not accompanied by similar growth of indigenous human capital able to harness new shipbuilding technology. This includes the engineering skills required to drive innovation in research and design, the craftsman-level technical skills required to build high-quality ships, and the business management acumen required to operate large manufacturing organizations efficiently. With the exception of a few specialty areas, these human skills are generally portable across shipbuilding sectors and therefore stand to impact directly both commercial and military shipbuilding development.

Thus far, deficiencies in these human elements have hindered the progress of Chinese shipbuilding development. Western and Chinese sources rate the overall productivity of Chinese shipyards as roughly one-sixth that of Japanese or South Korean yards, with some more detailed estimates placing PRC shipbuilders even farther behind world leaders. One Chinese analyst estimated the annual economic output of PRC shipyards at only nine thousand dollars per worker, far behind the $550,000 and $480,000 per capita outputs of Japanese and South Korean shipyard workers.[97] These statistics are also indicative of the disproportionately large workforce in the Chinese shipbuilding industry. The industry employs over 275,000 people across all shipbuilding sectors, with roughly 125,000 directly involved in construction of large oceangoing ships. By comparison, the more efficient, less labor-intensive shipbuilding industries in Japan and South Korea employ seventy-two and forty thousand people, respectively.[98]

To a certain degree the large size of the Chinese shipbuilding workforce is a matter of policy. Providing employment for China's massive population is a key role for state-owned shipbuilders, especially in major coastal cities, flooded with workers migrating from rural areas. Furthermore, many shipyards remain straddled with communist-style employment policies that severely limit or even prohibit the firing of workers. These

practices provide obvious disincentives for increasing productivity and efficiency, summarized by a Dalian Shipbuilding executive's observation that "it's difficult to control the workers if they get paid whether they work or not."[99]

While problems remain with regard to blue-collar workers, Chinese shipyards are actively recruiting new white-collar workers. The Nantong area in eastern China's Jiangsu Province is leading the way; shipbuilders and subcomponent makers/systems integrators there have, in conjunction with a number of technical universities and research institutes, formed the "Nantong Shipbuilding Industry Human Talent Alliance."[100] Alliance members strive to coordinate their work with Jiangsu provincial-level economic and shipbuilding industry development plans, focusing on attracting and retaining new engineers and technical experts graduating from universities. Retention tools include salary supplements of up to 500 RMB/month for new university graduates who join shipbuilding and subcomponent firms.[101]

Productivity issues are not limited to the worker level. Many Chinese shipyards still lack efficient human resource management and suffer from similar front-office deficiencies in material management, scheduling, systematic quality control, and industrial safety management. These shortcomings are reflected in continued quality and on-time delivery performance rated below Japanese, South Korean, and European shipbuilders and in serious concern displayed by some Western shipowners over a general disregard for worker safety at some Chinese shipyards. Western industry officials interviewed stressed the wide disparity in performance and business practices between small provincial and large state-owned Chinese shipyards, and they expressed doubts as to the ability of even well-established CSSC/CSIC yards to turn real profits in light of poor internal cost-control practices. This assessment is also evident in the remarks of a senior PRC government official, who recently stated that "the [shipyard] productivity gap offsets China's advantage in cheap labor."[102]

In a narrow view, it can be safely surmised that these same productivity and management issues will have similar negative effects on naval shipbuilding in China. The bloated workforce at Chinese shipyards does not help productivity. But in a wider perspective, the large number of shipyard workers may have a secondary strategic effect that actually benefits the PLA Navy. China's shipyards are exposing a growing number of Chinese workers to shipbuilding trades and are helping foster an awareness of the seas in a country long lacking a robust maritime tradition. Furthermore, China's sizable shipbuilding workforce includes a growing number of college graduates. Chinese universities produce approximately 1,200 naval architects per year; counting students studying overseas, China now matches (or surpasses) its competitors in the number of college graduates entering the workforce with shipbuilding-related technical degrees.[103] China's rapidly growing population of commercial seafarers provides the PLAN with a

strategic reserve in ship operational skills;[104] this growing mix of low- and high-end shipbuilding skills in commercial shipbuilding provides China with a ready pool of trained labor should a change in strategic circumstances ever require accelerated naval expansion. For as Alfred Thayer Mahan observed, "It is not only the grand total [of a country's population], but the number following the sea, or at least readily available for employment on ship-board and for the creation of naval material that must be counted" when considering a nation's sea power.[105]

Conclusions and Implications

China's Prospects in the Global Shipbuilding Market

In the short term, commercial priorities are likely to continue to dominate China's shipbuilding industry. The industry's recent corporate restructuring, facility expansion, and technological modernization efforts are primarily focused on supporting China's drive for global shipbuilding leadership by 2015, and they are likely to make this goal a reality. Commercial shipowners and shipbuilding analysts generally agree that lingering quality problems, delivery delays, and management issues at Chinese shipyards will continue to require extra "due diligence" on the part of potential buyers for the foreseeable future, but they also agree that the massive capacity and continued price advantage of Chinese shipbuilders will lead China to an ever-increasing commercial market share. This growth will result in significant ripple effects throughout the global shipbuilding industry. As Chinese shipbuilders capture more of the market for dry bulk carriers, tankers, and other commodity carriers at the low end of the commercial market, Japanese and South Korean shipbuilders will be forced to leverage their technology and productivity advantages by focusing more heavily on more complex ship types at the high end. Competitive pressures could push Japan, straddled by an aging and more costly workforce, out of the dry bulk and tanker markets altogether.

The steady technological maturation of China's shipbuilding industry will help Chinese shipyards increase their output of LNG tankers and other more complex ship types, but these high-end market segments are likely to be dominated by Japanese and South Korean shipbuilders for the foreseeable future. As with the current LNG project at CSSC's Hudong-Zhonghua Shipbuilding, China's initial entries into high-end market segments are likely to be politically motivated and government subsidized, with international ship buyers taking a "wait and see" approach until Chinese performance in these complex ship types is proven. Even if China's entry into high-end market segments is more gradual, ripple effects will still be felt worldwide. As Japanese and South Korean shipbuilders shift to higher-end market segments in response to Chinese dominance in the dry bulk and tanker markets, serious questions will arise as to the future

viability of European shipbuilders that currently survive only through specialization in cruise ships and other high-end niche markets. Many major shipowners are adjusting their long-term building strategies to account for these tectonic shifts in the world shipbuilding industry. One of them comments that building strong business relationships with Chinese shipbuilders now is a key consideration in preparing for the realities of the global shipbuilding industry of tomorrow.

Two major caveats accompany these predictions. First, China's remarkable shipbuilding growth has been partially fueled by an overall boom in the global shipping market. World seaborne trade grew by 3.6 percent in 2005 and is estimated to have done so again in 2006, building upon a 4.1 percent increase in 2004. This demand produced a 7.2 percent increase in world deadweight tonnage over 2005, the largest since 1989.[106] Shipping demand is expected to increase modestly over the short term, but any downturn in global economic conditions could result in significant shipbuilding overcapacity worldwide. China's current wave of shipyard expansion would only add to this excess capacity condition. Generous state financing of domestic shipbuilding contracts could artificially buoy PRC shipbuilders to some degree during a global shipping recession, but with over three-quarters of current Chinese commercial tonnage going to export, government contracts may not be able to offset completely a sizable drop in international commercial orders. Similarly, any shift from the quasi-fixed exchange ratio currently applied to Chinese currency in the international monetary system to a more market-based value would diminish the value of the foreign sales that currently inject significant foreign capital into the PRC shipbuilding industry.

The last major slump in world shipping (and thus shipbuilding) demand came following the "oil shocks" of the 1970s, and it extended through most of the 1980s. Any future collapse in commercial shipbuilding demand is likely to be caused by a similarly unexpected world crisis or shift in the global geostrategic environment. The possibility of such a crisis or geostrategic shift highlights the second major caveat on the initial commercial conclusions: China's focus on achieving world *commercial* shipbuilding dominance is contingent on the continuance of present world geopolitical conditions. Should strategic conditions change significantly, the PRC leadership might feel the need to abandon a policy of commercial shipbuilding development in favor of perceived national security needs. Devoted more fully to military purposes, China's shipbuilding industry could produce very different strategic results.

What If Military Shipbuilding Became a Top Priority in the PRC?

While the prospect of a total shift to military shipbuilding production in the PRC is unrealistic, even a more selective shift of shipbuilding priorities, at China's newest shipyards, could produce notable strategic results. Dedicated military production at

modern greenfield shipyards could support significant naval modernization if strategic resources were aligned accordingly. In the United States, this potential was exemplified by production at the Ingalls West Bank Shipyard in Pascagoula, Mississippi, during the late 1970s and 1980s.[107] That yard was built from scratch in the early 1970s, optimized for land-level mass production. It immediately commenced series production of *Spruance*- and *Kidd*-class destroyers, delivering thirty-one units between August 1975 and February 1983, eight in 1978 alone. The *Tarawa*-class amphibious assault ships were also built at the Ingalls West Bank facility during this same period, with all five of the forty-thousand-ton ships delivered between May 1976 and April 1980.[108] The 611-acre Ingalls West Bank Shipyard, however, is dwarfed by the new Guangzhou Longxue (over 1,400 acres) and Shanghai Changxing Island (more than 1,900 acres) greenfield facilities, which represent just a portion of China's new shipyard capacity.

Dedication of one of China's newest shipyards to military production would produce the most significant boost to PLAN modernization and expansion, but even a shift to strictly military shipbuilding at one or more of China's older shipyards could yield noteworthy effects. Dedicated military production would allow a yard's steel-plate fabrication and other production machinery to be optimized for series production of a selected warship class, generating mass-production efficiencies. Furthermore, the growing number of land-level facilities at Chinese shipyards could also benefit naval construction. Again looking to U.S. shipyards, the new Land Level Transfer Facility at Bath Iron Works illustrates the benefits of modernization at older shipyards. This new facility has improved production efficiency for the *Arleigh Burke*–class DDGs through greater use of block construction techniques and, perhaps more significantly, it now permits installation of the large SQS-53 bow sonar dome prior to launch. The size of the dome prevents installation prior to launch on traditional inclined shipways, requiring the ship to be towed to a separate facility for dry-docking specifically for the purpose, adding cost and delaying delivery. New land-level facilities at PRC shipyards can similarly reduce old-shipyard inefficiencies and facilitate inclusion of such advanced hull features as medium-frequency sonar domes that have thus far been absent from PLAN combatants.

Although naval combatants understandably receive considerable attention, the ability of PRC shipyards to increase significantly the production of amphibious ships and other naval auxiliary vessels must also be considered. The wide variety of infrastructure standards and technical capabilities at China's smaller provincial and local yards may limit the ability of these yards to produce the most advanced classes of surface combatants and submarines, but many of these yards can build less complex amphibious and auxiliary vessels. Any major expansion of PLAN surface combatant forces would require similar increases in oilers and other replenishment vessels; considering possible

Taiwan Strait scenarios, mass production of amphibious vessels could have significant strategic implications.

Lastly, the existing ability of Chinese shipyards to mass-produce and support commercial ships has the potential to support national security needs in a time of crisis. China's rapidly growing ship-repair and conversion infrastructure has obvious latent military capability, and the ability to convert merchant ships to military use cannot be discounted. Merchant tankers can be adapted for use in underway replenishment, roll-on/roll-off ships and commercial ferries have amphibious assault potential, and virtually any oceangoing vessel can be made a minelayer. Britain's rapid conversion of forty-nine commercial vessels taken up from trade for military use in the Falklands conflict of 1982 is often discussed in Chinese literature, and Chinese writings on the military use of merchant ships in wartime roles have been noted by Western analysts.[109] This level of Chinese interest illustrates a full-spectrum approach to the use of maritime resources in support of national security needs; the potential for PRC unconventional use of merchant shipping warrants further investigation in future studies.

Some Key Indicators to Watch

Considering these potential implications, there are several key events that, if they occur, could indicate a shift in PRC strategic shipbuilding priorities. The first important indicator would be the introduction of significant military production at any of China's newest greenfield shipyards. Military shipbuilding at CSSC's Shanghai Waigaoqiao, Shanghai Changxing Island, Guangzhou Longxue, or any other of China's most modern shipbuilding facilities would not only indicate a desire to tap into the massive building capacity and modern production technology these yards offer but, more significantly, would indicate a willingness to forgo the optimal commercial efficiencies of these new yards. Given the inherent inefficiencies of naval and commercial coproduction, these new facilities in such a scenario would lose some of their commercial advantage and slow the pace of China's current drive toward world commercial shipbuilding dominance.

The first test of this greenfield indicator will come by 2009, as CSSC's Jiangnan Shipyard completes its move to the new Changxing Island Shipbuilding Base in Shanghai. CSSC has thus far billed the new Changxing Island facility as a modern commercial facility "capable of building various high-tech ships, such as LNG ships, offshore engineering facilities and cruise ships";[110] the Jiangnan Shipyard, however, that it is replacing has also been an important builder of China's most advanced naval combatants. Jiangnan built (or is currently building) several classes of frigates and destroyers, two Song-class submarines, and, of particular note, the PLAN's Type 052C Luyang II air-defense destroyers. A shift of Jiangnan's share of military production to another of

China's older shipyards (vice Changxing Island) would be a strong reaffirmation of commercial shipbuilding's dominant position in the PRC's strategic priorities, while introducing naval construction at the Changxing Island greenfield facility would indicate a more mixed set of strategic priorities.

The second key indicator of a possible shift in PRC shipbuilding strategic priorities would be a segregation of military production to certain specific shipyards. Segregation would alleviate the commercial-military coproduction challenges previously discussed for both old and new shipyards, and it would allow certain yards to be specifically tooled and optimized for series production of a particular warship design. Dedication of one or more major CSSC or CSIC shipyards to military production would indicate a willingness to forfeit a degree of commercial capacity, and it might indicate PLAN readiness to move from the low-rate production of the latest Type 051B/C, Type 052, and Type 054 surface combatants to mass production of one or more selected classes.

Specialized military production facilities are of particular interest when considering nuclear submarine construction. Due to the unique technical and security considerations involved, nuclear submarine construction is performed in only a few select, specialized facilities worldwide. In China, all SSN and SSBN construction to date has been performed at a specific facility within the Bohai Shipbuilding Heavy Industry complex in Huludao. While nuclear facilities specialization is not a strategic indicator in itself, the number of these special nuclear-capable facilities is indicative of shipbuilding strategic intentions. The current facility at Huludao is capable of supporting the PRC's current small force of SSNs and SSBNs but could not be expected to support a major expansion of the PLAN nuclear submarine force on its own. Consequently, any major expansion of this facility or the establishment of a second specialized nuclear-capable shipbuilding facility would be a strong indicator of future PLAN force structure and PRC strategic shipbuilding priorities.

Finally, introduction of standardized "wartime use" technical design and construction requirements for Chinese-built, Chinese-owned merchant ships would be a subtle yet important indicator of how the PRC intends to use its shipbuilding infrastructure and oceangoing commercial fleet to support national defense. Building militarily useful merchant vessels with strengthened decks, extra communications equipment, increased electrical power and habitability capacities, and specified minimum speed and endurance could greatly ease the conversion of vessels from commercial to military use in time of crisis. Inclusion of extra design features such as these typically increases initial construction costs and somewhat diminishes the commercial capacity and profit potential of a vessel (thus likely requiring government subsidy), but as the British discovered in the Falklands conflict, the investment can prove invaluable if the vessels ever need to be requisitioned for military use. Inclusion of standardized "wartime use"

design and construction specifications in PRC merchant ships would indicate a more refined long-term national maritime strategy, including more integrated use of China's growing shipbuilding and shipping power for national security needs.

Strategic Benefits of Commercial Shipbuilding Prowess

In his study of Chinese defense conversion, Paul Humes Folta describes the logic of China's defense industry reforms as being a conversion "from swords to plowshares . . . and better swords."[111] Although it has taken nearly thirty years (and the development process is far from complete), the original goals of Deng Xiaoping's defense and economic reform efforts have largely been met in China's shipbuilding industry. The industry's conversion "from swords to plowshares" has placed it in the running to become the world's leading commercial shipbuilder, and the latest Type 052C Luyang II–class destroyers exemplify the "better swords" that are possible with a more mature national shipbuilding industrial base.

The civil-to-military benefits of PRC shipbuilding development are evident through both direct and indirect effects. Increased shipyard capacity for ship construction, repair, and conversion provides a direct benefit for military development, as does the continued development of Chinese indigenous marine subcomponent and propulsion technology sectors. Progress in the ability of local manufactures to design, produce, and service mechanical and electrical subcomponent systems of commercial ships will directly benefit PLA naval development through a wide array of dual-use component technologies, and the slow, but steady, development of indigenous medium-speed diesel engine production will provide direct relief to the PLAN's current reliance on imported propulsion technology.

While less tangible, the indirect effects of China's commercial shipbuilding development are perhaps just as significant to the modernization of the PLA Navy. The growth in cumulative experience within the PRC commercial shipbuilding industry provides a valuable technical foundation of human capital from which to draw in building more complex warships. Systems complexity, hull designs, and materials in warship design and construction often differ from those of the commercial shipbuilding market, but experience in modern commercial block construction techniques translate into military production efficiencies. Chinese naval architects, mechanical engineers, welders, and shipyard laborers gaining experience in commercial shipbuilding represent a strategic ready reserve of fundamental shipbuilding skills with portability to military production if ever needed.

In a strategic context, it can be argued that the long production times characteristic of shipbuilding make a strategic reserve of those skills largely irrelevant in an era when conflicts are apt to be brief, "come as you are" scenarios. A short-fused crisis in the

Taiwan Strait remains the most likely flash point in PRC international relations, and many have argued that the increasing trends of economic globalization and the balancing effects of nuclear weapons make a sustained conflict requiring World War II–style industrial mobilization a thing of the past. Writing over a century ago, Alfred Thayer Mahan addressed this very point: "The whole question of the value of a [strategic] reserve, developed or undeveloped is this: Have modern conditions of warfare made it probable that, of two nearly equal adversaries, one will be so prostrated in a single campaign that a decisive result will be reached in that time? Sea warfare has given no answer."[112]

Modern antiship cruise missiles, heavyweight torpedoes, and precision-guided munitions may provide a short and decisive answer to Mahan's question in the event of a future shooting war at sea, but the answer is not as clear with respect to a sustained crisis short of war. Continued questions surrounding the long-term trajectory and nature of China's rise as a global power and associated uncertainties in the future strategic balance in the Asia-Pacific region tell us that the possibility of sustained tensions triggering a buildup of naval forces cannot be discounted. In such an undesirable scenario, the latent potential of China's rapidly growing commercial shipbuilding industry would undoubtedly play a significant role in PLA naval expansion. Whether propelling China to commercial shipbuilding dominance, large-scale naval expansion, or more moderate advances in both directions, China's rapidly growing shipbuilding industry will increase the overall maritime power of the PRC and will remain an important strategic factor, one worthy of continued study in years to come.

Notes

1. "China Ship Building Challenges US, Top Admiral Says," Agence France-Presse, 14 December 2007.
2. "Unfinished Guangzhou Mega Yard Builds Up Head of Steam," *Lloyd's List,* 15 November 2007, available at Lexis-Nexis, www.lexisnexis.com/us/lnacademic/.
3. "Analysis of Economic Operation of China's Shipbuilding Industry in First Half Year," *World Ships & Boats,* no. 9 (September 2007), p. 9.
4. Xu Qi, "Maritime Geostrategy and the Development of the Chinese Navy in the Early Twenty-first Century," trans. Andrew Erickson and Lyle Goldstein, *Naval War College Review* 59, no. 4 (Autumn 2006), pp. 47–67.
5. Leo Zhang, "China to Limit Foreign Investment in Shipyards," *Shanghai Daily,* 19 September 2006, available at www.shanghaidaily.com.
6. "Pushing a Strategic Shift and Creating a Shipbuilding Power," *China Ship News,* no. 35, 7 September 2007 [in Chinese].
7. Irwin Millard Heine, *China's Rise to Commercial Maritime Power* (New York: Greenwood, 1989), pp. 37–39; and Evan S. Medeiros, "Revisiting Chinese Defense Conversion: Some Evidence from the PRC's Shipbuilding Industry," *Issues and Studies* 34, no. 5 (May 1998), pp. 79–101. The only shipyards left beyond the control of the CSSC were a few minor yards controlled by the PLA and primarily engaged in ship repair.
8. For more on shipbuilding development in Japan and South Korea, see Takafusa Nakamura, *The Post War Japanese Economy: Its Development and Structure,* trans. Jacqueline Kaminski (Tokyo: Univ. of Tokyo Press, 1981), pp. 71–75; and Daniel Todd, *The World Shipbuilding Industry* (New York: St. Martin's, 1985), esp. pp. 286–96 and 340–45, and *Industrial Dislocation: The Case of*

Global Shipbuilding, esp. pp. 136–50 and 183–99.

9. For a comparison of the Chinese business conglomerate to those in Japan and South Korea, see Richard J. Latham, "A Business Perspective," in *Mixed Motives, Uncertain Outcomes: Defense Conversion in China,* ed. Jorn Brommelhorster and John Frankenstein (Boulder, Colo.: Lynne Rienner, 1997), pp. 151–78, esp. pp. 158–61.
10. Evan S. Medeiros et al., *A New Direction for China's Defense Industry* (Santa Monica, Calif.: RAND, 2005), p. 157. For more on the defense conversion and modernization of China's aerospace industry, see Howard O. DeVore, *China's Aerospace and Defense Industry* (Surrey, U.K.: Jane's Information Group, 2000); and Kenneth W. Allen, Glenn Krumel, and Jonathan D. Pollack, *China's Air Force Enters the 21st Century* (Santa Monica, Calif.: RAND, 1995).
11. Medeiros, "Revisiting Chinese Defense Conversion," p. 90.
12. Todd, *Industrial Dislocation,* pp. 218–21; and Heine, *China's Rise to Commercial Maritime Power,* pp. 38 and 47–49. The now-dissolved British Shipbuilders was the umbrella organization formed following the nationalization of most of the United Kingdom's shipbuilding industry in the 1970s. The far-reaching deal between British Shipbuilders and CSSC was signed in November 1982, just four months after the formal establishment of CSSC. See also Heine, *China's Rise to Commercial Maritime Power,* pp. 108–109.
13. Heine, *China's Rise to Commercial Maritime Power,* pp. 18 and 37; and David G. Muller, Jr., *China as a Maritime Power* (Boulder, Colo.: Westview, 1983), pp. 58–61.
14. *Statistical Tables 1992* (London: Lloyd's Register of Shipping, 1992), p. 30. Statistics do not include ships under 100 gross tons; therefore, most "junks" are excluded.
15. Heine, *China's Rise to Commercial Maritime Power,* pp. 47–48; and Todd, *Industrial Dislocation,* p. 218.
16. See Medeiros, "Revisiting Chinese Defense Conversion," pp. 86 and 98.
17. *European Industries Shaken Up by Industrial Growth in China: What Regulations Are Required for a Sustainable Economy?* (Brussels: European Metalworkers' Federation, 2006), p. 57.
18. Non-shipbuilding-related business areas for both companies include fabrication of such large steel structures as bridges, port machinery, and cargo-handling equipment, but they also range as far as real estate holdings. For corporate profiles and complete lists of all business units under CSSC and CSIC, see *China State Shipbuilding Corp. (CSSC),* www.cssc.net.cn, and *China Shipbuilding Industry Corp. (CSIC),* www.csic.com.cn.
19. "Central Enterprises List," *State-Owned Assets Supervision and Administration Commission (SASAC),* www.sasac.gov.cn/zyqy/qyml/default.htm.
20. Medeiros et al., *New Direction for China's Defense Industry,* pp. 114–15.
21. The China Aviation Industry Corporation (AVIC) was also divided in 1999, forming AVIC I and AVIC II. There is little overlap in product lines between the two companies, and competition is very limited; AVIC I produces mainly combat aircraft, while AVIC II tends to specialize in helicopters. See Medeiros et al., *New Direction for China's Defense Industry,* p. 175.
22. "CSSC Aims to Be a Shipbuilding Leader Globally," *SinoCast China Transportation Watch,* 14 February 2007. Also see "Asset Injections Boost Listed SOEs," *Xinhua,* 15 February 2007; and "China State Shipbuilding to Incorporate Its Business," *SinoCast China Transportation Watch,* 19 October 2005.
23. "China's Drive toward World Dominance," Wärtsilä *Marine News* (March 2005), pp. 4–5; and Farah Song, "China Shipbuilding 'Juggernaut' Gains on Leaders Japan, Korea," Bloomberg.com, 22 March 2005.
24. By deadweight, through 2006 China accounted for 20 percent of world tonnage production, Japan 32 percent, and South Korea 35 percent. See "Shanghai Company Breaks into Shipbuilding Top 10," *China Daily,* 4 January 2007, available at www.china.org.cn.
25. "South Korea Stays Top Shipbuilding Nation," *World Maritime News,* 25 January 2008, http://www.worldmaritimenews.com.
26. "Getting Ship-Shape," *China Daily,* 31 December 2003, Hong Kong edition, available at www.chinadaily.com.cn.
27. Andrew Cutler, "World Leader by 2015? Shipbuilding in the PRC & the YRD," *Business Guide to Shanghai and the YRD,* October 2005, www.hfw.com/13/new/new13c075.html; and *China State Shipbuilding Corp.,* www.cssc.net.cn/english/jtcy1-jd.php.

28. "Getting Ship-Shape"; Cai Shun, "Full Steam Ahead," *Beijing Review* 48, no. 10 (10 March 2005), p. 36.
29. Cutler, "World Leader by 2015?" For an example of a high-end, provincially administered shipyard group, see *Fujian Shipbuilding Industry Group Co. (FSIGC),* www.fsigc.com.
30. Zhang Kai, "A Life and Death Test for Jiangsu's Shipbuilding Industry," *Mechanical and Electrical Equipment* 3 (2006), p. 16.
31. Lloyd's Register–Fairplay, *Sea-web: The Register of Ships Online,* www.sea-web.com. By Lloyd's data, provincial and local shipyards produced 1,939,441 dwt from 1982 to 1999. Statistical accuracy for output from these yards can be questionable in earlier years, but the relative magnitude of increased production from provincial and local shipyards is certainly significant.
32. *China Shipping Industry Co. (CIC),* www.csgcic.com/en/gsjj/index.htm; and Lloyd's Sea-web database.
33. Lloyd's Sea-web database. For a complete list of COSCO's shipyards, see Barbara Matthews, ed., *World Shipping Directory 2006–2007* (Surrey, U.K.: Lloyd's Register–Fairplay, 2006), pp. 1-1027 through 1-1030; and *COSCO Group,* www.cosco.com.
34. *Yantai Raffles Shipyard,* www.yantai-raffles.com; and Hansa Treuhand–Schiffsbeteiligungs AG & Co. KG, *Die Unternehmensgruppe* (Corporate Profile), 2004, available at www.hansatreuhand.de.
35. Chen Wen, "Fueling the Engine," *Beijing Review* 49, no. 11 (March 2006), pp. 28–32; and "Getting Ship-Shape."
36. "Getting Ship-Shape." NACKS Shipyard is a fifty-fifty joint venture, illustrating that the 49 percent investment limitation was not inflexible.
37. See "National Shipbuilding Group to Embrace More Opportunities and Challenges," *People's Daily,* 29 January 2002; and "WTO Boosts Ship Building," *People's Daily,* 15 October 2001, available at www.english.people.com.cn.
38. Leo Zhang, "China to Limit Foreign Investment in Shipyards."
39. "Tsuji Heavy Is First Foreign Yard to Build Ships in China," *Lloyd's List,* 19 July 2006; and the *Tsuneishi Corporation,* www.tsuneishi.co.jp.
40. The exact number of Chinese-owned private shipyards is not clear. Major private yards under Chinese ownership are included in tables 1 and 2. Additional privatization at smaller provincial-level yards is also known to be occurring. See *European Industries Shaken Up by Industrial Growth in China,* p. 35; "Shipbuilding as One of China's Key Industries," *Toplaterne,* no. 80 (January 2006), pp. 5–8; and "Private Enterprise Shipbuilding Group with Focus on International Customers," *Toplaterne,* no. 80 (January 2006), p. 16. Both *Toplaterne* articles available at www.mak-global.com/news/pdf/toplaterne80e.pdf.
41. Leo Zhang, "China to Limit Foreign Investment in Shipyards."
42. Ibid.
43. See *European Industries Shaken Up by Industrial Growth in China,* p. 41.
44. Lloyd's Sea-web database. The other PLA shipyards that have also previously built commercial ships are PLA Navy Factory 4803 in Shantou, 4806 in Zhoushan, and 4810 in Dalian.
45. The term "province" is used loosely to also include China's direct-controlled municipalities and semiautonomous regions (i.e., Shanghai, Tianjin, and Chongqing municipalities and the Guangxi-Zhuang Autonomous Region).
46. "Coordination Stressed in Developing the Yangtze River," *Xinhua,* 22 November 2006.
47. Matthew Flynn, "From Two Different Rivers Flow the Same Dreams," *Lloyd's List,* 31 January 2007.
48. See Marwaan Macan-Markar, "Sparks Fly as China Moves Oil Up Mekong," *Asia Times Online,* 9 January 2007, www.atimes.com/atimes.
49. "Analysis of Economic Operation of China's Shipbuilding Industry in First Half Year."
50. Wu Qiang, "China Maps Out Ambitious Goal for Shipbuilding Industry," *Xinhua,* 24 September 2006; and "Getting Ship-Shape."
51. For ownership, registry, and flag structure of the world merchant fleet, see United Nations, *Review of Maritime Transport 2006* (Geneva: United Nations Conference on Trade and Development [UNCTAD], 2006), pp. 26–36.
52. "China to Deliver First Liquefied Natural Gas Ship in September," *Xinhua,* 19 February 2007, OSC-CPP20070219968046, Open Source Center, www.opensource.gov.

53. Geoffrey Murray, "China's Largest Shipyard Formed by Merger in Shanghai," Kyodo News Service (Tokyo), 13 April 2001, OSC-JPP20010413000153, Open Source Center, www.opensource.gov; and Lloyd's Sea-web database.
54. "Chinese Shipmakers Threaten Korea's High-Value Builders," *Chosun Iibo* (Seoul), 1 March 2007, OSC-KPP0301971163, Open Source Center, www.opensource.gov; and "Current Capacity, Future Outlook for Japanese, Chinese Shipbuilding Industries," *Tokyo Sekai no Kansen,* 9 March 2006, OSC-FEA2006030902654, Open Source Center, www.opensource.gov.
55. Wu, "China Maps Out Ambitious Goal for Shipbuilding Industry." Quoted list of ship types is paraphrased from a larger list of goals that also included marine power systems, electronics, and other subcomponent systems. These additional systems are discussed later in the paper.
56. Chen Xiaojin, as quoted by Murray, "China's Largest Shipyard Formed by Merger in Shanghai."
57. Regarding building docks, the No. 2 Yard at Dalian Shipbuilding includes a dry dock measuring 550 by eighty meters. This is smaller than the 658.4-by-141.7-meter Dry Dock 12 at Newport News Shipbuilding used for building 102,000-ton *Nimitz*-class carriers but significantly larger than the 310-by-42.1-meter (following expansion) Dry Dock 1 at Babcock Rosyth, currently scheduled to be used for final assembly of the United Kingdom's 65,000-ton-displacement *Queen Elizabeth*–class carriers. See Matthews, ed., *World Shipping Directory 2006–2007,* pp. 1-1031 and 1-1323; Richard Saunders, ed., *Jane's Fighting Ships 2006–2007* (Surrey, U.K.: Jane's Information Group, 2006), pp. 829 and 871; and Richard Beedall, "Future Aircraft Carrier (CVF)," pts. 19 and 21, *Navy Matters,* navy-matters.beedall.com/cvf1-09.htm.
58. For a complete discussion, see John Birkler et al., *Differences between Military and Commercial Shipbuilding: Implications for the United Kingdom's Ministry of Defence* (Santa Monica, Calif.: RAND, 2005).
59. For full discussion, see Jeffrey K. Liker and Thomas Lamb, *Lean Manufacturing Principles Guide: A Guide to Lean Shipbuilding,* version 0.5 (Ann Arbor: Univ. of Michigan, 2000); and Richard Lee Storch et al., *Ship Production,* 2nd ed. (Centreville, Md.: Cornell Maritime, 1995), esp. pp. 60–104.
60. For the evolution of shipyard design, see Storch et al., *Ship Production,* pp. 161–94. The term "greenfield" simply refers to building on a previously undeveloped site—that is, on a fresh, "green field."
61. Medeiros et al., *New Direction for China's Defense Industry,* pp. 130–31.
62. "Freer Thought and Strengthened Innovation Will Allow China's Shipbuilding Industry to Develop Better and More Quickly," *China Ships,* no. 42.
63. Birkler et al., *Differences between Military and Commercial Shipbuilding,* pp. 85–92. This chapter provides a full discussion of specialization versus integration of commercial and military shipbuilding.
64. In December 2006 CSSC's Hudong-Zhonghua Shipbuilding launched a Type 054 frigate and Type 071 LPD from the same building dock as an LNG tanker.
65. Bath Iron Works, "Corporate History," *Bath Iron Works: A General Dynamics Company,* www.gdbiw.com/company_overview/history/default.htm. In 2001 BIW opened its new Land Level Transfer Facility adjacent to the original yard, and it now uses a floating dry dock for ship launchings. Of note, the only true "greenfield" shipyard built in the United States since World War II is the West Bank Facility of Northrup Grumman's Ingalls Shipbuilding in Pascagoula, Mississippi (see Storch et al., *Ship Production,* pp. 165 and 168). The new Aker Philadelphia Shipyard comes close, in that it was built from the ground up after completely leveling a portion of the former Philadelphia Naval Shipyard. Only the navy yard's large graving dock was incorporated into the new facility.
66. Based on review of blueprints and machinery list for a 209,000-dwt National Steel and Shipbuilding Co. (NASSCO) *Alaska*-class tanker, and the General Electric Company, *Propulsion Plant Manual for Spruance Class* (El Monte, Calif.: General Electric, 1976), pp. 1-15 through 1-19. The *Spruance* class is now decommissioned from U.S. Navy service, but its GE LM2500 propulsion plant is still widely used in U.S. ships as well as in the PLAN Type 052 destroyer *Harbin*. For a similar list of major machinery and subsystems on a smaller commercial ship (42,000-dwt product tanker), see Roy L. Harrington, ed., *Marine Engineering* (Jersey City, N.J.: Society of Naval Architects and Marine Engineers, 1992), pp. 8–9.

67. Based on an interview with an industry official familiar with the FPSO project at Dalian Shipbuilding.
68. *European Industries Shaken Up by Industrial Growth in China,* p. 55.
69. See Dominic DeScisciolo, "Red Aegis," U.S. Naval Institute *Proceedings* 130, no. 7 (July 2004), pp. 56–58.
70. Many other issues beyond technical capability continue to influence China's possible aircraft carrier development. For a full discussion, see Andrew S. Erickson and Andrew R. Wilson, "China's Aircraft Carrier Dilemma," *Naval War College Review* 59, no. 4 (Autumn 2006), pp. 13–45.
71. For full discussion of tanker and containership structures, see D. A. Taylor, *Merchant Ship Construction* (London: Marine Management [Holdings], 1992), pp. 177–202.
72. Of note, several major Chinese steelmakers have acquired financial interests in Chinese shipyards as part of mutually beneficial alliances to ensure steady supplies and demand for steel. Similarly, South Korean shipbuilder Hyundai Heavy Industries recently purchased a share of a Chinese steelmaker in order to increase its access to cheap Chinese steel. See "Chinese Steelmakers Go into Shipping for Cost Reduction," *SinoCast China Transportation Watch,* 8 February 2007; and "Rising Steel Price Pushes South Korea to Import More from China," *Steel Times International* 30, no. 8 (November 2006), p. 6.
73. Saunders, ed., *Jane's Fighting Ships 2006–2007,* p. 764; and Eric Wertheim, ed., *The Naval Institute Guide to Combat Fleets of the World 2005–2006* (Annapolis, Md.: Naval Institute Press, 2005), p. 798. Also see Medeiros et al., *New Direction for China's Defense Industry,* pp. 143–44.
74. Zhang Xiangmu, Commission of Science, Technology, and Industry for National Defense (CSTIND), as quoted by Wu, "China Maps Out Ambitious Goal for Shipbuilding Industry."
75. Interview with a technical representative for a shipowner currently building in China.
76. Wang Haichao, "Good Periodic Results Gained in the National Special Control Campaign against Low Quality Ships," *China Maritime Safety* 8 (2006). The four PRC agencies involved were the Ministry of Transportation, Ministry of Agriculture, National Security Supervisory Commission, and CSTIND.
77. "*Houbei* class (Fast Attack Missile Craft) (PGGF)," entry in *Jane's Fighting Ships,* 29 January 2007, from *Jane's Online,* www.janes.com.
78. Zhang Xiangmu, as quoted by Wu, "China Maps Out Ambitious Goal for Shipbuilding Industry."
79. Wang Rongsheng, as quoted by Cai Shun, "Full Steam Ahead," pp. 36–37.
80. Zhang Chengyu and Zhao Dali, "Status Quo and Development Way Forward for Marine Equipment Sector in China," *Ship Engineering* 27, no. 1 (2005), pp. 1–5. Also see Fan Yuzhong, "Ship Equipment Service Networks Must Globalize," *China Water Transport* 11(2006), pp. 38–39; and Zhang, "Life and Death Test for Jiangsu's Shipbuilding Industry," p. 16.
81. Zhang and Zhao, "Status Quo and Development Way Forward for Marine Equipment Sector in China," pp. 1–5; and Wu, "China Maps Out Ambitious Goal for Shipbuilding Industry."
82. "Domestic Innovation Will Be the Basic Force Helping China Become a Global Shipbuilding Power," *China Ships,* no. 41 (19 October 2007), p. 1.
83. See James C. Bussert, "China Builds Destroyers around Imported Technology," *Signal* 58, no. 12 (August 2004), pp. 67–69.
84. "China's Naval Engineers: Helping the Navy Sail Fast and Far," *Modern Navy* (August 2005), pp. 17–20.
85. There are no universally accepted rpm break points between low-, medium-, and high-speed diesels, but 300 and 1,000 rpm are most typically used. See Alan L. Rowen, "Diesel Engines," in *Marine Engineering,* ed. Harrington, pp. 91–145, esp. p. 94.
86. Includes both foreign-built engines and those built in China under license. All commercial statistics for this section are derived from Lloyd's Sea-web database, and military statistics from Saunders, ed., *Jane's Fighting Ships 2006–2007,* pp. 119–54; Wertheim, ed., *Naval Institute Guide to Combat Fleets of the World 2005–2006,* pp. 101–28; SinoDefense.com; and various earlier editions of *Jane's Fighting Ships*—unless otherwise stated.
87. John Jordan, "The People's Liberation Army Navy (PLAN)," *Jane's Intelligence Review* 6, no. 6 (June 1994), pp. 275–82.

88. Todd, *Industrial Dislocation,* p. 218; and "MAN Diesel Renews Low-Speed Cooperations, Engages New Partner," *MAN Diesel,* www.manbw.com. Of note, MAN and B&W merged in 1980 to become MAN B&W; the combined company is now known as MAN Diesel. Likewise, the diesel engine division of Sulzer Brothers was spun off into a separate company named New Sulzer Diesel (NSD) in 1990, was acquired by the Wärtsilä diesel conglomerate of Finland in 1997, and is now known as Wärtsilä Switzerland Ltd.

89. Zhang and Zhao, "Status Quo and Development Way Forward for Marine Equipment Sector in China," pp. 1–5; and Patrik Wägar, "Wärtsilä Enters New Era in Chinese Engine Building and Ship Design," Wärtsilä *Marine News* (March 2005), pp. 14–16.

90. An unconfirmed report places two MTU 20V956TB92 diesels and two Zorya-Mashproekt gas turbines on the Type 071. See Prasun K. Sengupta, "China," *India Force Magazine* (October 2006), available at www.forceindia.net/industry.asp.

91. Licensed use of SEMT-Pielstick designs is certainly not limited to the PRC. SEMT-Pielstick engines are license produced in six countries, including in the United States by the Fairbanks Morse Engine Company under the Colt-Pielstick brand name. Pielstick engines are used on the U.S. Navy's *Whidbey Island* and *Harpers Ferry*–class LSDs, *San Antonio*–class LPDs, *Henry J. Kaiser*–class AOs, and *Bob Hope*–class AKRs, and they are to be used on the new LCS.

92. See James Mann, *About Face: A History of America's Curious Relationship with China, from Nixon to Clinton* (1998; repr. New York: Vintage Books, 2000), pp. 74–75. Of note, the transfer of marine propulsion technology to Communist-bloc countries occurred regularly throughout the Cold War. MAN, B&W, and other Western-designed/built diesels were used on many Soviet and COMECON merchant ships. The most famous examples are the Soviet freighters *Poltava* and *Omsk,* with B&W diesel engines, which carried SS-4 and SS-5 missiles to Cuba in 1962. See Norman Polmar and John D. Gresham, *DEFCON-2: Standing on the Brink of Nuclear War during the Cuban Missile Crisis* (Hoboken, N.J.: Wiley, 2006), pp. 66–68; and Ambrose Greenway, *Soviet Merchant Ships,* 3rd ed. (Hampshire, U.K.: Kenneth Mason, 1978), pp. 32–34.

93. The marine gas-turbine variant of the Spey was first introduced on HMS *Brave* (F94) in 1990 and was subsequently used on all Batch 3, Type 21 *Broadsword*-class FFGs, and Type 23 Duke-class FFGs.

94. For full discussion, see DeVore, *China's Aerospace and Defense Industry,* pp. 67–71; and Medeiros et al., *New Direction for China's Defense Industry,* pp. 170–74.

95. See *Zorya-Mashproekt State Enterprise Gas Turbine Research & Production Complex,* www.zmturbines.com; Wertheim, ed., *Naval Institute Guide to Combat Fleets of the World 2005–2006,* pp. 109; and SinoDefense.com.

96. Yan Chengzhong, "QD-128: A Light Industrial Gas Turbine Derived from an Aeroengine," *Aircraft Propulsion* [Hangkong Fadongji] 4 (2005), pp. 4–8. See also "The Cradle of China's Midsize Aeroengine Development: The Shenyang Propulsion Research and Design Institute," in *Mixed Motives, Uncertain Outcomes,* ed. Brommelhorster and Frankenstein, p. 1; and Yao Erchang, "Development Prospects of the Large Capacity Gas Turbine Manufacturing Trade in China," *Electrical Generation Equipment,* no. 4 (2004), pp. 181–85 [in Chinese].

97. Zhang, "Life and Death Test for Jiangsu's Shipbuilding Industry," p. 16.

98. *European Industries Shaken Up by Industrial Growth in China,* p. 31; and "Current Capacity, Future Outlook for Japanese, Chinese Shipbuilding Industries."

99. Paul Sun Bo, as quoted by Stewart Brewer, "China: Building for the Future," *Det Norske Veritas,* Forum, 19 July 2006, www.dnv.com/publications. For a full discussion of employment practices at Chinese shipyards (including case studies), see *European Industries Shaken Up by Industrial Growth in China,* esp. pp. 38–40 and 72–74.

100. "Staying in Touch with Talent: Academe and Industry Combine Resources," *China Ship News,* no. 38, 28 September 2007, p. 9.

101. Ibid.

102. Zhang Xiangmu, as quoted by Wu, "China Maps Out Ambitious Goal for Shipbuilding Industry." For a shipowner/ship broker perspective on business management issues in China's shipbuilding industry, see *Purchasing Newbuildings in China: A Practical Guide to the Key Commercial and Legal Considerations* (Neuilly-sur-Seine, France, and Uxbridge, U.K.: Barry Rogliano Salles

Shipbrokers and Curtis Davis Garrard LLP, March 2006).

103. Statistics based on correspondence with a Western naval architecture firm's representative operating in China, and the Society of Naval Architects and Marine Engineers (SNAME); they include four-year bachelor degrees in naval architecture, ocean engineering, and shipbuilding technology.

104. The PRC had 122,208 seafarers in international commercial maritime trade as of 2005, or 9.96 percent of the world total (number-one ranking). By comparison, the United States contributed 20,560, or 1.68 percent of the world total. See International Labor Organization, *Seafarers' Wages and Hours of Work and the Manning of Ships Recommendation, 1996 (No. 187): Updating of the Minimum Basic Wage of Able Seamen* (Geneva: Joint Maritime Commission, 2006), p. 15.

105. Alfred Thayer Mahan, *The Influence of Sea Power upon History, 1660–1783,* 5th ed. (1890; repr. Boston: Little, Brown, 1894), p. 45.

106. UNCTAD, *Review of Maritime Transport 2006,* p. x.

107. Ingalls is now part of Northrup Grumman Ship Systems.

108. All Ingalls production statistics from *Northrup Grumman Ship Systems, Ingalls Operations,* www.ss.northropgrumman.com/company/ingalls.html. *Tarawa*-class tonnage is full-load displacement in metric tons.

109. The authors thank Dr. Lyle Goldstein for directing them to Chinese sources, including Guo Zhao Dong "The Apocalypse of Transportation Support of the British Army in the Malvinas Islands War," *National Defense Transportation Engineering and Technology,* no. 3 (2004), pp. 1–4. Also see Medeiros et al., *New Direction for China's Defense Industry,* pp. 150–51. For more on British use of merchant vessels in the Falklands, see Roger Villar, *Merchant Ships at War: The Falklands Experience* (Annapolis, Md.: Naval Institute Press, 1984).

110. CSSC, "CSSC's Changxing Shipbuilding Base," www.cssc.net.cn/enlish/jtcy1-jd.php.

111. Paul Humes Folta, *From Swords to Plowshares? Defense Industry Reform in the PRC* (Boulder, Colo.: Westview, 1992), p. 1.

112. Mahan, *Influence of Sea Power upon History, 1660–1783,* p. 48.

Acronyms and Definitions

A	**AKR**	commercial cargo ship
	AO	auxiliary oiler
	AOR	auxiliary replenishment oiler
	AVIC	Aviation Industry Corporation
B	**B&W**	Burmeister & Wain
	BIW	Bath Iron Works
C	**Capesize vessels**	bulk cargo ships that are too large (usually 150,000 dwt or bigger) for either the Suez Canal or Panama Canal and therefore must round either the Cape of Good Hope or Cape Horn
	CAST	China Association of the Shipbuilding Trade
	CG	guided-missile cruiser
	CGT	compensated gross tons
	CHISREP	China Ship Reporting System
	CIC	China Shipping Industry Company
	CMC	Central Military Commission
	CNO	Chief of Naval Operations
	CODOG	combined diesel and gas turbine
	COSCO	China Ocean Shipping Company
	COTS	commercial off-the-shelf
	CSIC	China Shipbuilding Industrial Corporation (dominant from Shanghai northward)
	CSSC	China State Shipbuilding Corporation (dominant from Shanghai southward)
	CSTC	China Shipbuilding Trading Company

	CSTIND	Commission of Science, Technology, and Industry for National Defense
D	**DDG**	guided-missile destroyer
	dwt	deadweight tonnage (weight-carrying ability of a ship at its limiting draft. With the exception of deadweight tonnage, tonnage for merchant ships is a measure of volume rather than weight, and a "register ton" is equal to one hundred cubic feet, in English units. It is intended as a measure of the cargo capacity of a ship and thus is an index of the ship's earning capability. "Gross registered tonnage" is based on the total volume within the enclosed ship's structure. "Net registered tonnage" is the gross tonnage minus the volume for machinery, crew spaces, ship operations, etc., and is thus space available for cargo [including passengers]. Gross and net tonnage are often used as the basis for such charges as pilotage, wharfage, and harbor fees)
F	**FFG**	guided-missile frigate
	FPSO	floating production, storage, and off-loading unit (floating oil storage vessel for offshore projects where it is uneconomic to build pipelines to the shore. An FPSO can store up to two million barrels of oil and is able to off-load oil directly into a tanker)
G	**GT**	gross tonnage
H	**HI**	Heavy Industries
	HHM	Hudong Heavy Machinery
	HSE	health, safety, and environment
K	**KHI**	Kawasaki Heavy Industries
L	**LCS**	[U.S.] Littoral Combatant Ship
	LCU	landing craft utility
	LNG	liquefied natural gas

	LPD	landing platform dock
	LPG	liquefied petroleum gas
	LSD	landing ship dock
	LSM	landing ship medium
	LST	landing ship tank
M	**MAN**	Maschinenbau Augsberg-Nuernberg
	MWM	Motoren Werk Mannheim
N	**NACKS**	Nantong-COSCO KHI Ship Engineering Company
	NASSCO	National Steel and Shipbuilding Co.
	NSD	New Sulzer Diesel
P	**PGGF**	patrol gunboat
	PLA	People's Liberation Army
	PLAN	People's Liberation Army Navy
	PRC	People's Republic of China
	PTG	guided-missile patrol craft
R	**RMB**	renminbi (the Chinese currency unit)
	Ro-Ro	roll-on/roll-off
	rpm	revolutions per minute
S	**SAM**	surface-to-air missiles
	SASAC	State Owned Assets Supervision and Administration Commission
	SHP	shaft horsepower
	SSBN	nuclear-powered ballistic-missile submarine
	SSK	hunter-killer submarine
	SSN	nuclear-powered attack submarine

T

TEU	twenty-foot-equivalent units

U

ULCC	ultralarge crude oil carrier (of greater than two million barrel capacity)
USD	U.S. dollars
USN	U.S. Navy

V

VLCC	very large crude oil carrier (carrying up to about two million barrels of oil)
VLS	vertical-launch system

W

WTO	World Trade Organization

About the Authors

Mr. Collins served from 2006 to 2008 as a research fellow in the China Maritime Studies Institute, focusing on energy and shipbuilding. During his period at the Naval War College, Mr. Collins published a variety of studies in such forums as *Jane's Intelligence Review, Orbis, Naval War College Review,* U.S. Naval Institute *Proceedings,* and *Oil & Gas Journal.* In addition, he is coeditor of the book *China's Energy Strategy: The Impact on Beijing's Maritime Policies* (Naval Institute Press, 2008). He is a 2005 honors graduate of Princeton University (AB, politics) and is proficient in Mandarin and Russian.

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